Understanding health risk factor prevalence and enhancing health behaviours of airline pilots

A thesis

submitted in fulfilment

of the requirements for the degree

of

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by

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Thesis Abstract

Cardiometabolic non-communicable diseases (NCD) and their major risk factors are associated with adverse acute and chronic health outcomes and may pose risks to flight safety and economic burden. Restorative sleep, healthy nutrition, and sufficient physical activity are powerful lifestyle behaviours that are fundamental for human health and well-being, and each are independently associated with NCD risk reduction. Although occupational preventive medicine research is increasing, airline pilots are largely underrepresented in the literature. Through a series of seven studies, this PhD thesis aimed to enhance the understanding of modifiable health risk factor status for airline pilots and to investigate evidence-based strategies for promoting positive health, wellness, and NCD risk factor mitigation among airline pilots.

To identify priority health risks among airline pilots and to serve as a foundation for further studies within the thesis, Study One systematically explored the global literature pertaining to the prevalence of cardiometabolic health risk factors among airline pilots. Study Two investigated the prevalence and distribution of subjective and objective cardiometabolic health risk factors among New Zealand airline pilots and compared these with the general population. Study Three synthesized global literature and summarised evidence-based considerations regarding the health benefits of sleep hygiene, healthy eating, and physical activity for cardiometabolic health promotion in airline pilots and further discussed evidence-based considerations for enhancing health behaviours in this occupational group. Study Four evaluated the efficacy of a 17-week, three-component personalised sleep, healthy eating, and physical activity lifestyle intervention for enhancing self-report health parameters during the coronavirus disease 2019 (COVID-19) pandemic. Subsequently, Study Five performed a 12-month follow-up investigation of the longitudinal effects of the 17-week intervention on self-report health parameters in addition to body mass and blood pressure management. Study Six further evaluated the effects of the three-component lifestyle intervention with utilisation of a wider range of objective cardiometabolic health parameters. Finally, Study Seven evaluated the efficacy of a smartphone-based app delivery of the three-component lifestyle intervention as a potentially scalable strategy for enhancing health and fitness parameters in airline pilots.

In Study One, A total of 47 studies derived from 20 different countries among a total pooled sample of 36,454 airline pilots were reviewed. The systematic review revealed substantial prevalence of > 50% for overweight and obesity, insufficient physical activity, and elevated fatigue among airline pilots globally. Further, this study highlighted the heterogeneity in methodology and lacking quality and quantity among the current literature pertaining to airline pilots, identifying the need for further research to better understand health risk factors and risk factor mitigation strategies among airline pilots.

In Study Two, the cross-sectional comparison of health risk factor prevalence between airline pilots (n = 504) and the general population (n = 2,033) identified notable and similar health risk factor prevalence between groups, with elevated prevalence of short sleep, physical inactivity, 'at risk' for hypertension, and lower positive self-rated health among airline pilots. Accordingly, findings called for further research to examine targeted, cost-effective intervention methods for promoting healthy bodyweight, managing blood pressure, and enhancing health behaviours to mitigate the risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety.

In Study Three, the narrative review outlined occupational health risks in airline pilots, summarised the evidence on health benefits of sleep hygiene, healthy eating, and physical activity as preventive medicine, and discussed evidence-based considerations for promoting health behaviours in this occupational group.

In Study Four, 38 airline pilots completed an acute 17-week personalised sleep hygiene, healthy eating, and physical activity intervention which elicited significant improvements in sleep quality and quantity, fruit and vegetable intake, and moderate-to-vigorous physical activity compared to the control group and suggested that achieving health guidelines for these behaviours promoted positive mental and physical health.

Study Five, provides further support that the personalised three-component lifestyle intervention can elicit and sustain long-term improvements in body mass and blood pressure management, health behaviours, and perceived subjective health in overweight and obese airline pilots and may support quality of life during an unprecedented global pandemic.

In Study Six, further implementation of the personalised three-component lifestyle intervention among 67 overweight airline pilots elicited significant (p = < 0.001) positive change associated with *moderate* to *large* effects sizes for objective health measures (VO_{2max}, body mass, skinfolds, girths, blood pressure, resting heart rate, push-ups, plank isometric hold) and self-report health (weekly moderate-to-vigorous physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) at 4-months post-intervention, relative to the control group (n = 58).

Lastly, Study Seven utilised a randomised control trial design to deliver a smartphone-based app three-component lifestyle intervention among 94 airline pilots, which elicited positive changes associated with *trivial* to *large* effects sizes for objective health measures (Cooper's 12-minute exercise test, resting heart rate, push-ups, plank isometric hold) and self-report health (weekly moderate-to-vigorous physical activity, sleep quality and quantity, fruit and vegetable intake, self-rated health, and perceived stress and fatigue) at 4-months post-intervention, relative to the control group (n = 92).

In summary, the studies in this thesis provide a foundation for understanding cardiometabolic health risk factor prevalence among airline pilots. Furthermore, our series of controlled clinical trials provide preliminary evidence that a personalised three-component physical activity, healthy eating, and sleep hygiene intervention can elicit short-term improvements and may promote sustained long-term positive adaptations in objective and subjective health parameters in airline pilots.

These findings are important for health care professionals and researchers to provide insight regarding the efficacy of lifestyle interventions for promoting health, and to inform practices relating to disease prevention, health promotion, and public health policymaking. Furthermore, in relation to the limited literature base pertaining to health behaviour intervention research among airline pilots, our findings provide novel contributions to this field.

Acknowledgements

I would like to express my sincere gratitude to all those involved with supporting this PhD project, including my supervisory team and the airline pilots who participated in the research studies, without whom it would have not been possible.

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To Dr Paul Winwood, Dr Tracey Clissold, and Dr Logan Posthumus, thank you for inspiring me to initiate my PhD journey and for the inspiration you have provided to me throughout the years from your passion for research and education. I greatly appreciate your friendship, expertise, and your passion for our field. I would not have accomplished my PhD without you.

Thank you to Air New Zealand, University of Waikato, and Toi Ohomai Institute of Technology for the financial support. Without it, the thesis would not have been possible. To all the airline pilots who I have worked with during this project, I appreciate your time dedicated to participating in the research and I have thoroughly enjoyed working with each and every one of you and I appreciate the insights and knowledge I have gained throughout my experiences.

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Attestation of authorship

“I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of university or institution of higher learning.”

Daniel Wilson

August 2022

List of Abbreviations

Table 1: List of thesis abbreviations.

AIS	Athen’s Insomnia Scale	MCS-12	SHF-12v2 Mental Component Summary Scale
ACTRN	The Australian New Zealand Clinical Trials Registry	MET	Metabolic Equivalent
ANCOVA	Analysis of Covariance	mHealth	Mobile Health
ANOVA	Analysis of Variance	mmHg	Millimetres of Mercury
BCT	Behaviour Change Technique	MOH	Ministry of Health
BIA	Bioelectrical Impedance	MS	Metabolic Syndrome
BMI	Body Mass Index	MVPA	Moderate-to-Vigorous Physical Activity
BP	Blood Pressure	NCD	Non-Communicable Disease
BPM	Beats Per Minute	NZ	New Zealand
CBT-I	Cognitive Behavioural Therapy for Insomnia	NZHS	New Zealand Health Survey
CFS	Chronic Fatigue Scale	OR	Odds Ratio
CI	Confidence Intervals	OSA	Obstructive Sleep Apnoea
CIS	Checklist Individual Strength	PA	Physical Activity
COVID-19	Coronavirus	PAR-Q	Physical Activity Readiness Questionnaire for Everyone
CRF	Cardiorespiratory Fitness	PCS-12	SHF-12v2 Physical Component Summary Scale
CRP	C-Reactive Protein	PHQ-9	Patient Health Questionnaire-9
CV	Coefficient of Variation	PRAA	Programme Readiness Allocation Algorithm
CVD	Cardiovascular Disease	PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
DBP	Diastolic Blood Pressure	PSQI	Pittsburgh Sleep Quality Index

DNA	Deoxyribonucleic Acid
ES	Effect Size
ESS	Epworth Sleepiness Scale
F&V	Fruit and Vegetables
FITT	Frequency, Intensity, Time, Type
FITT-VP	Frequency, Intensity, Time, Type, Volume, Progression
FSS	Fatigue Severity Scale
FV	Fruit and Vegetables
GAD-7	Generalized Anxiety Disorder-7
GI	Glycaemic Index
HADS	Hospital Anxiety and Depression Scale
HbA1c	Glycated Haemoglobin
HDL	High-Density Lipoprotein Cholesterol
ICAO	International Civil Aviation Organization
ICC	Intraclass Correlation Coefficient
IPAQ	International Physical Activity Questionnaire
IPAQ-SF	International Physical Activity Questionnaire Short Form
ISAK	International Society for The Advancement of Kinanthropometry
JCQ	Job Content Questionnaire

PSS	Perceived Stress Scale
RCT	Randomised Control Trial
RHR	Resting Heart Rate
SBP	Systolic Blood Pressure
SCL90	Symptom Checklist 90
SD	Standard Deviation
SF	Skin Folds
SF-12V2	Short Form Health Survey 12-Item
SF-36	Short Form Health Survey 36-Item
SH	Short Haul
SLS	Satisfaction with Life Scale
SPF	Samn–Perelli Fatigue
SPSS	Statistical Package for The Social Sciences
SQFFQ	Semi-Quantitative Food Frequency Questionnaire
SRQ20	Self-Reporting Questionnaire-20
T2D	Type 2 Diabetes
TC	Total Cholesterol
UK	United Kingdom
USA	United States of America

JSS	Jenkins Sleep Scale
KSS	Karolinska Sleepiness Scale
LDL	Low-Density Lipoprotein Cholesterol
LH	Long Haul
MAP	Mean Arterial Pressure
VAFS	Visual Analog Fatigue Scale
Vo2max	Maximal Oxygen Consumption
WC	Waist Circumference
WHO	World Health Organization
WHOQOL-BREF	World Health Organization Quality of Life Brief Form

CHAPTER ONE

Thesis Outline

The main aim of this thesis was to investigate the prevalence of cardiometabolic health risk factors among airline pilots and to evaluate evidence-based strategies to enhance health behaviours in pursuit of promoting positive health and wellness, and mitigation of cardiometabolic NCD risk factors (see Figure 1). The thesis comprised of two literature reviews, one cross-sectional study, and four clinical trials.

The first review aimed to systematically evaluate the global literature pertaining to the prevalence of cardiometabolic health risk factors among airline pilots to identify priority health risk metrics for this occupational group (Chapter Two). The second review narratively synthesized global literature and summarised evidence on health benefits of sleep hygiene, healthy eating, and physical activity for cardiometabolic health risk reduction in airline pilots and further discussed evidence-based considerations for promoting health behaviours in this occupational group (Chapter Four).

The cross-sectional study investigated the prevalence and distribution of subjective and objective cardiometabolic health risk factors among New Zealand airline pilots and compared these with the general population (Chapter Three).

The clinical trials aimed to; assess the acute and chronic effects of a personalised face-to-face three-component lifestyle intervention for enhancing health behaviours and subjective health (Chapter Five and Six); evaluate the effects of the face-to-face three-component lifestyle intervention for enhancing objective health measures (VO_{2max}, body mass, skinfolds, girths, blood pressure, resting heart rate, push-ups, plank hold) and self-report health (weekly moderate-to-vigorous physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) (Chapter Seven); and evaluate the efficacy of a smartphone-based app delivery of the three-component lifestyle intervention as a potential scalable strategy for enhancing health and fitness parameters in airline pilots (Chapter Eight).

The series of studies within the thesis enhance the current understanding of modifiable health risk factor prevalence among airline pilots and the efficacy of multicomponent lifestyle health interventions for promoting health outcomes among this occupational group. These findings are important for health care professionals and researchers to provide insight regarding the efficacy of lifestyle interventions for promoting health, and to inform practices relating to disease prevention, health promotion, and public health policymaking. Furthermore, in relation to the limited literature base pertaining to health behaviour intervention research among airline pilots, our findings provide novel contributions to this field.

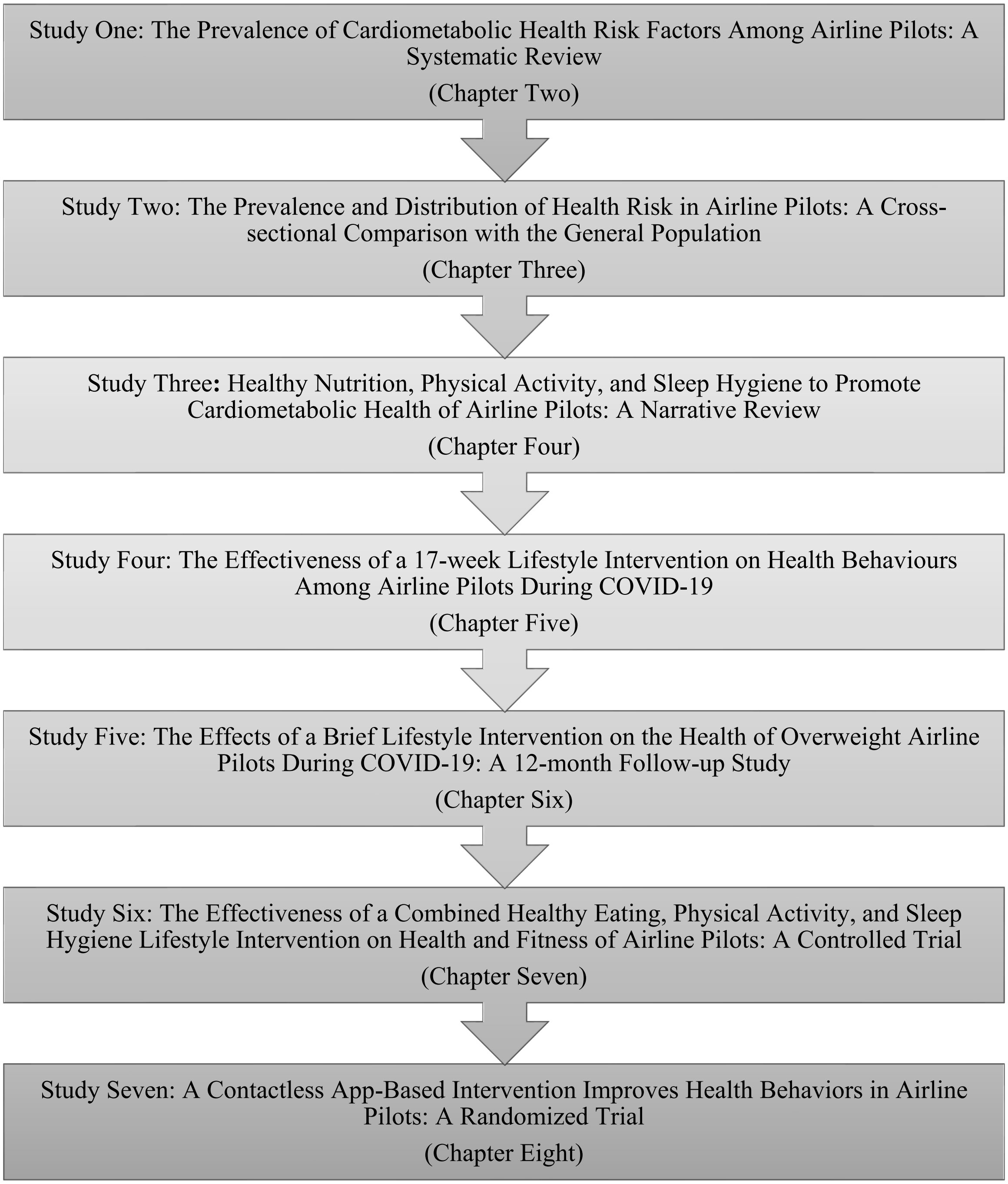

Figure 1: Schematic of the thesis structure.

Chapter Organisation

The thesis comprises of a total of nine chapters. Each of the chapters (Two – Eight) are composed as standalone chapters that are either published, accepted, and awaiting publication, or under review in journals and are congruent with standard scientific reported formatting (abstract, background/introduction, methodology, results, discussion, and conclusion).

Due to each chapter being a stand-alone research paper for peer reviewed publication, there is some repetition throughout the thesis. A unified single reference list of citations is included at the end of the thesis to support reading flow and consistency.

Research Outputs Arising from this Doctoral Thesis

Peer Reviewed Journal Publications

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2020). The Effectiveness of a 17-Week Lifestyle Intervention on Health Behaviours Among Airline Pilots During COVID-19. *Journal of Sport and Health Science.* 10(3) 333-340. https://doi.org/10.1016/j.jshs.2020.11.007 [Impact Factor: 13.077]

Wilson, D., Driller, M., Winwood, P., Johnston, B., & Gill, N. (2021). The Effects of a Brief Lifestyle Intervention on The Health of Overweight Airline Pilots During COVID-19: A 12-Month Follow-Up Study. *Nutrients*. 13(12) 4288. https://doi.org/10.3390/nu13124288 [Impact Factor: 6.706]

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2022). The Prevalence and Distribution of Health Risk Factors in Airline Pilots: A Cross-Sectional Comparison with the General Population. *Australian and New Zealand Journal of Public Health.* Advance online publication. https://doi.org/10.1111/1753-6405.13231 [Impact Factor: 3.755]

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2022). The Prevalence of Cardiometabolic Health Risk Factors Among Airline Pilots: A Systematic Review. *International Journal of Environmental Research and Public Health.* 19(8) 4848. https://doi.org/10.3390/ijerph19084848 [Impact Factor: 4.614]

Wilson, D., Driller, M., Winwood, P., Johnston, B., & Gill, N. (2022). The Effectiveness of a Combined Healthy Eating, Physical Activity, and Sleep Hygiene Lifestyle Intervention on Health and Fitness of Overweight Airline Pilots: A Controlled Trial. *Nutrients*. 14(9) 1988. https://doi.org/10.3390/nu14091988 [Impact Factor: 6.706]

Wilson, D., Driller, M., Johnston, B., & Gill, N. (Accepted). A contactless app-based intervention improves health behaviors in airline pilots: A randomized trial. *The American Journal of Preventive Medicine.* [Impact Factor: 6.604]

Wilson, D., Driller, M., Johnston, B., & Gill, N. (Under review). Healthy Nutrition, Physical Activity, and Sleep Hygiene as Preventive Medicine for Airline Pilots: A Narrative Review. *Journal of Lifestyle Medicine.*

Oral Presentations Arising for this Thesis

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2020, December). *The Effectiveness of A 17-Week Lifestyle Intervention on Health Behaviours Among Airline Pilots During COVID-19*. Conference session presented at Australasian Society of Lifestyle Medicine's Virtual International Conference 2020. (Poster Presentation).

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2021, March). *The Effectiveness of a Sleep, Diet and Exercise Intervention on Quality of Life Among Airline Pilots During COVID-19.* Scientific Meditech. The 2nd International Webinar on Physical Health, Nursing Care and COVID-19 Management. (Oral Keynote Presentation). Retrieved from https://physicaltherapy.scientificmeditech.com

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2021, July). *The Effects of a Brief Lifestyle Intervention on Health Behaviour and Weight Loss Maintenance in Airline Pilots During COVID-19.* Scientific Meditech. The 3rd International Webinar on Physical Health, Nursing Care and COVID-19 Management. (Oral Keynote Presentation). Retrieved from https://physicaltherapy.scientificmeditech.com

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2021, November). *The Effects of a Brief Lifestyle Intervention on Health Behaviour and Weight Loss Maintenance in Airline Pilots During COVID-19.* The 2021 National ITP Research Symposium. (Oral Presentation). Retrieved from https://www.openpolytechnic.ac.nz/2021-itp-symposium/

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2021, December). *The Effects of a Brief Lifestyle Intervention on Health Behaviour and Weight Loss Maintenance in Airline Pilots During COVID-19.* Nutrition Society of New Zealand Annual Scientific Conference 'Tūhono – Reconnecting'. (Poster Presentation). Retrieved from https://www.nutritionsociety.gecco.co.nz/2021-nsnz-annual-scientific-conference/

CHAPTER TWO

The Prevalence of Cardiometabolic Health Risk Factors Among Airline Pilots: A Systematic Review

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2022). The Prevalence of Cardiometabolic Health Risk Factors Among Airline Pilots: A Systematic Review. *International Journal of Environmental Research and Public Health.* 19(8) 4848. https://doi.org/10.3390/ijerph19084848 [Impact Factor: 4.614]

Prelude

Cardiometabolic non-communicable diseases and their associated health risk factors are a leading contributor to morbidity and mortality globally among the general population. However, the prevalence of cardiometabolic health risk factors among airline pilots are not well defined in the literature. Thus, this chapter systematically reviews the literature base to identify the prevalence of cardiometabolic health risk factors among airline pilots globally.

Abstract

The occupational demands of professional airline pilots such as shift work, work schedule irregularities, sleep disruption, fatigue, physical inactivity, and psychological stress may promote adverse outcomes to cardiometabolic health. This review investigates the prevalence of cardiometabolic health risk factors for airline pilots. An electronic search was conducted utilising PubMed, MEDLINE (via OvidSP), CINAHL, PsycINFO, SPORTDiscus, CENTRAL, and Web of Science for publications between 1990 and February 2022. The methodological quality of included studies was assessed using two quality assessment tools for cross-sectional and clinical trial studies. The prevalence of physiological, behavioural, and psychological risk factors was reported using descriptive analysis. A total of 48 studies derived from 20 different countries, reviewing a total pooled sample of 36,958 airline pilots. Compared with general population estimates, pilots had a similar prevalence for health risk factors, yet higher sleep duration, lower smoking and obesity rates, less physical activity, and a higher overall rate of body mass index > 25. The research reported substantial prevalence > 50% for overweight and obesity, insufficient physical activity, elevated fatigue, and regular alcohol intake among pilots. However, the heterogeneity in methodology and the lack of quality and quantity in the current literature limit the strength of conclusions that can be established. Enhanced monitoring and future research are essential to inform aviation health practices and policies (Systematic Review Registration**:** PROSPERO CRD42022308287).

Keywords: aviation medicine; occupational health; morbidity; noncommunicable disease risk; risk factors; modifiable risk

Introduction

Cardiometabolic noncommunicable diseases (NCDs) such as cardiovascular disease (CVD), stroke, type 2 diabetes (T2D), and their primary risk factors are a leading public health concern that produce significant and growing economic costs globally (Miranda et al., 2019). The leading cause of mortality worldwide is CVD (Townsend et al., 2016), which has been reported as the most frequent cause of permanent groundings among Korean airline pilots (Choi & Kim, 2013). Cardiovascular and cerebrovascular incidents have also been reported among the most prevalent causes of flight incapacitation in the United Kingdom (Evans & Radcliffe, 2012).

Airline pilots experience unique occupational demands which may promote adverse outcomes to cardiometabolic health, including shift work, work schedule irregularities, sleep disruption, fatigue, the sedentary nature of the job, and stress demands associated with flight safety (Choi & Kim, 2013; Coombes et al., 2020; International Civil Aviation Authority, 2012; Sykes et al., 2012; Wilson et al., 2021b). Cardiometabolic diseases are associated with numerous modifiable risk factors across physiological, behavioural, and psychological domains (Miranda et al., 2019). Central and systemic obesity, hypertension, dyslipidemia, hyperglycemia, insulin resistance, and adipose dysfunction are among prevalent physical risk factors associated with increased risk of CVD and T2D (Eckel et al., 2005; Miranda et al., 2019). Modifiable behavioural risk factors (Marmot & Bell, 2019) such as unhealthy diet, physical inactivity, excessive alcohol consumption, and tobacco smoking, along with psychological risk factors including high fatigue (Basu et al., 2016) and depression (Lasserre et al., 2017), are each independently established as risk factors for cardiometabolic diseases.

To date, no systematic reviews have been published pertaining to the evaluation of modifiable health risk factor prevalence among airline pilots. Estimations of health risk prevalence are important for monitoring of trends and to inform risk reduction interventions; hence, the aim of the current review was to critically analyze the global literature to quantify the prevalence of modifiable cardiometabolic health risk factors among commercial airline pilots. The findings from this review may be valuable to inform aviation health practices and policies for supporting pilot health, enhancing flight operation safety, and identifying deficiencies within the literature base to inform future research.

Materials and Methods

Protocol

This systematic review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) (Page et al., 2021). The protocol of this systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO, CRD42022308287).

Literature Search

An electronic search was conducted utilising PubMed, MEDLINE (via OvidSP), CINAHL, PsycINFO, SPORTDiscus, CENTRAL, and Web of Science. A broad search strategy was implemented to gather literature published between 1 January 1990 and 28 February 2022. Key terms incorporated in the search string were relating to airline pilots and cardiometabolic health risk prevalence (see Table 2). The search was limited to peer-reviewed publications in English. Eligible publications were extracted, and their reference lists were manually checked for potentially relevant studies. The reference lists of existing review articles pertaining to aviation medicine were also cross-checked for relevant articles.

Table 2: Search terms blocks were combined for text and word search in PubMed and adapted to the remaining databases: 1 and 2; 1 and 3; 1, 2, and 3.

1. Airline Pilots	**2. Cardiometabolic Risk Markers**	**3. MeSH**
Pilots OR “airline pilot*” OR “commercial pilot*” OR “professional pilot*” OR “civil pilot*” OR “civilian pilot*” OR “aviation pilot*” OR “commercial airline*”	“Health risk*” OR “risk factor*” OR cardiometabolic OR cardio-metabolic OR cardiovascular OR “cardiometabolic risk” OR “metabolic syndrome” OR “syndrome x” OR diabetes OR hypertension OR weight OR overweight OR obesity OR “body composition” OR adiposity OR “physical activity” OR exercise OR sleep OR circadian OR apnoea OR apnea OR nutrition OR diet OR eating OR fruit* OR vegetable* OR stress OR lipids OR cholesterol OR	MeSH terms: “risk factors” [mesh] OR “health risk behaviours” [mesh] OR “health status indicators” [mesh] OR “risk

OR aircrew OR “cockpit crew*” NOT military* NOT army NOT “pilot study” NOT piloted NOT “pilot project” NOT “pilot research”	glucose OR insulin OR “insulin resistance” OR “insulin sensitivity” OR “waist circumference” OR fat OR “blood pressure” OR hypertension OR “C-reactive protein” OR “inflammatory markers” OR inflammation OR “microvascular dysfunction” OR fatigue OR medical OR depression OR stress OR distress OR anxiety OR alcohol OR smok* OR microalbumin* OR “endothelial dysfunction”	assessment” [mesh]

Note: * indicates use of truncation.

Eligibility Criteria

Publications were identified for inclusion on the basis of population, literature type, publication date, and cardiometabolic health risk eligibility. The population criteria for inclusion were fixed-wing pilots (airline, commercial, civilian), and no restrictions were placed on fleet type (short-haul, long-haul, mixed-fleet). Articles were excluded if they included pilots with < 1 year experience of being a pilot, as well as those who worked part-time, were a helicopter pilot, or worked in noncivil aviation roles (Air Force, military, army, or private), and if they were published before 1990. Literature sources that met inclusion were peer-reviewed original articles (retrospective, prospective, cross-sectional, case–control, cohort, and experimental), and other sources were excluded, e.g., literature reviews, commentaries, and editorials. To be eligible for inclusion, publications had to report on at least one of the following cardiometabolic health risk markers: blood pressure (BP), body composition (body mass, body mass index [BMI], waist circumference, waist-to-hip ratio, body fat percentage, lean mass percentage, visceral adiposity), glycemic control (fasting or postprandial glucose, HbA1c), insulin (fasting, insulin sensitivity, or insulin resistance), inflammation (C-reactive protein, inflammatory markers), blood lipid panel (total cholesterol [TC], low-density lipoprotein [LDL] cholesterol, high-density lipoprotein [HDL] cholesterol, and triglycerides [TG]), microalbuminuria, endothelial or microvascular dysfunction, alcohol consumption, smoking, dietary behaviours (fruit and vegetable intake, high-energy-dense intake, high-saturated-fat intake, high sugar intake, or low-fiber), physical activity (sedentary behaviour, moderate-to-vigorous physical activity (MVPA), or daily steps), cardiorespiratory fitness (submaximal or maximal oxygen consumption [VO_2]), sleep (hours per night, sleep quality), psychosocial stress (stress, depression, anxiety, and fatigue), and self-rated health.

To avoid including studies involving work duty-induced inflation of cardiometabolic risk prevalence, studies pertaining to outcome measures recorded preceding (< 24 h), during, or acutely following (< 48 h) long-haul flights were excluded. Where available, nonflight duty baseline data from these studies were utilised. Studies reporting data exclusively on pilot subpopulations (e.g., diabetic or obese pilots) were excluded. A hand search of recent issues of prominent aviation journals was conducted to screen for any recently published articles that were not yet indexed and apparent on the systematic search.

Screening Process

The lead author conducted the initial literature search, and results were downloaded and imported into Endnote citation software (Endnote x9, Clarivate Analytics, Philadelphia, PA, USA) for collation and duplicate removal. Thereafter, articles were exported to Microsoft Excel (Microsoft® Excel version 16.54) for further removal of duplicates and subsequent eligibility screening. Initial title and abstract screening were conducted by one author and cross-checked by a second reviewer. Subsequently, potentially eligible articles from the initial screening progressed to full-text evaluation of eligibility for inclusion. Discrepancies in outcomes between the reviewers were resolved via discussion and consultation with a third reviewer.

Methodological Quality Assessment

The methodological quality of publications included for this review was independently assessed by two reviewers. The risk-of-bias quality assessment checklist (adapted from Hoy and colleagues (Hoy et al., 2012) was utilised for evaluation of cross-sectional studies, which consisted of four external validity items and six internal validity items. Clinical trials were evaluated utilising the risk-of-bias tool from Cochrane (Sterne et al., 2019). The summative quality assessment for each publication was expressed as being of low quality (high risk of bias), moderate quality (high risk of bias), or high quality (low risk of bias). Consistent with the Grades of Recommendation, Assessment, Development, and Evaluation and Cochrane approaches, total scores for the cross-sectional study assessment were grouped as the following thresholds: very high risk of bias (0–4 points), high risk of bias (5–6 points), or low risk of bias (7–10 points). Clinical trials were rated as ‘high’, ‘low’, or ‘unclear’ for seven items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and outcome-specific evaluations of risk of bias.

Data Extraction

The study country, aim, design, participant characteristics, outcomes of interest, and instruments for included publications were extracted (see Table 5). If necessary, additional publication information was sought from trial registries, article supplementary materials, or direct contact with article authors. Study data were independently extracted and coded by one reviewer, and a second reviewer independently extracted and coded 20% of the included studies for process cross-evaluation. Any discrepancies between reviewers were resolved via discussion and consultation with a third reviewer if necessary. For clinical trials included in our analysis, descriptive data were extracted from their reported baseline data, and post-intervention data were not included. For between-group studies that only reported subgroup descriptive statistics (e.g., interventional and control), we computed the combined population mean using Cochran’s formula (Cochran, 1954).

Analysis of Data

The prevalence of cardiometabolic health risks was reported using descriptive analysis. Available data were sought and extracted from included publications for descriptive analysis, including one or multiple of the following available statistical metrics: mean descriptive statistics, prevalence proportions, incidence rates, standardized incidence ratios, prevalence ratios, odds ratios, risk ratios, or scoring outcomes derived from relevant self-report instruments. The meta-analysis estimates for proportions and descriptive statistics for cardiometabolic health risk factors were calculated by weighing the studies according to their sample size within pooled samples. A 95% confidence interval was presented alongside pooled prevalence statistics. Meta-analyses were not conducted for some cardiometabolic risk factors due to a low number of studies reporting the parameter of interest ($n < 4$) or due to methodological heterogeneity. Data were entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into statistical software SPSS v28 for Windows (IBM, New York, NY, USA), where meta-analysis interpretation was performed.

Results

Study Selection

The search strategy produced 6,138 unique results, 107 of which were deemed potentially eligible at primary screening. After full-text reviews, 48 passed eligibility evaluation for inclusion. A PRISMA flowchart depicting stages of the selection process is illustrated in Figure 2.

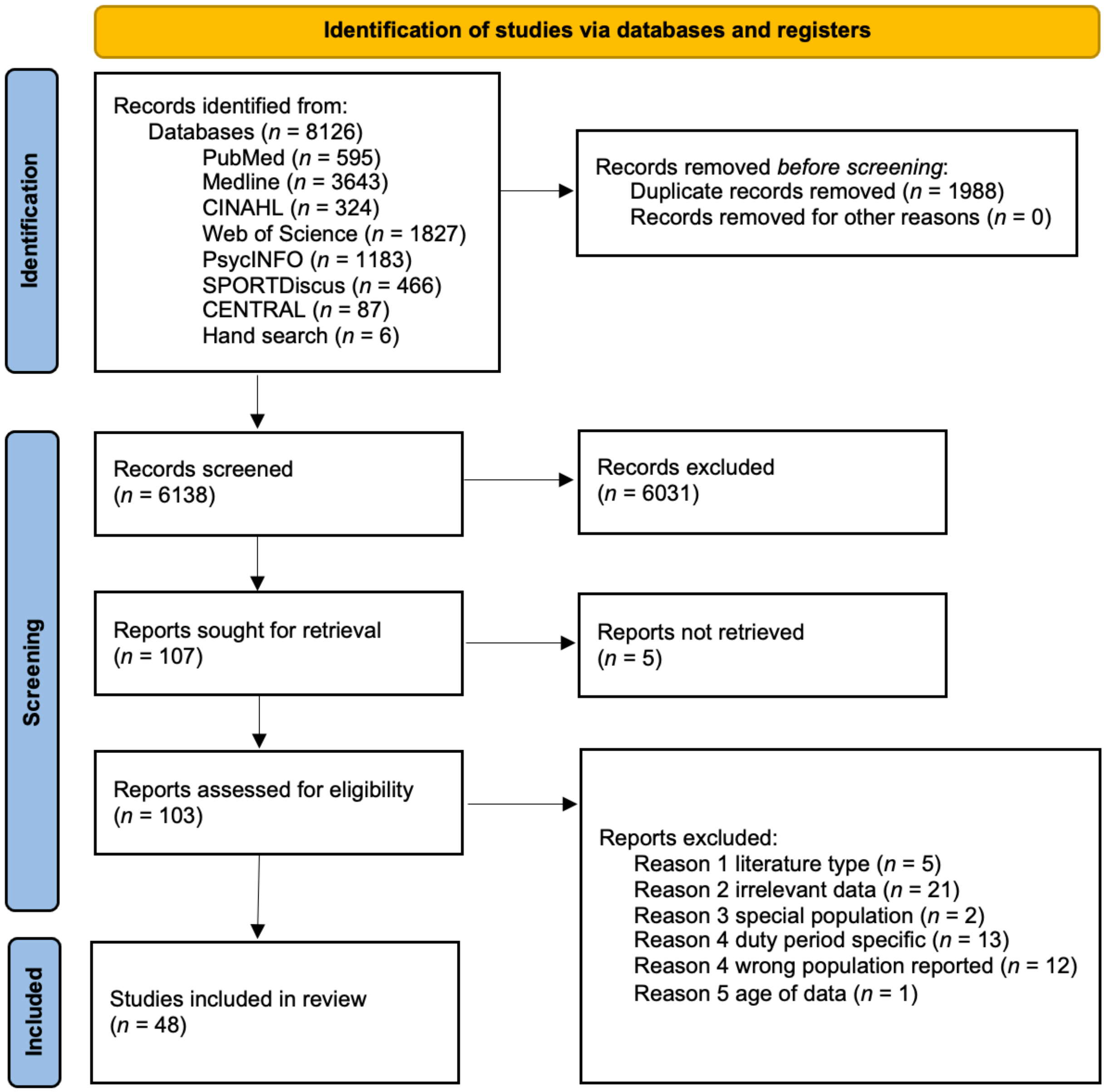

Figure 2: PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Study Characteristics

The 48 studies involved a total of 36,958 participants, included in 45 cross-sectional studies and three clinical trials (see Figure 3). The characteristics of the included studies are summarised in Table 5. Across all studies, males represented 96% of participants. The mean age of participants was 40 ± 11 years according to 35/48 studies which reported the mean age. The most prevalent age range reported in the remaining studies was 35–45 years. Twenty-five studies reported self-report subjective data, 14 utilised a combination of self-report subjective and objective data, and five reported only objective data. The included studies were conducted in 20 different countries or regions, including Brazil (five), China (five), New Zealand (four), Finland (three), Indonesia (three), Sweden (three), the United Kingdom (three), the United States (three), Korea (two), the Netherlands (two), Portugal (two), and one study each from Arab states, Australia, Europe, Germany, India, Oceania, Saudi Arabia, Spain, and Thailand. Four studies involved participants from numerous countries.

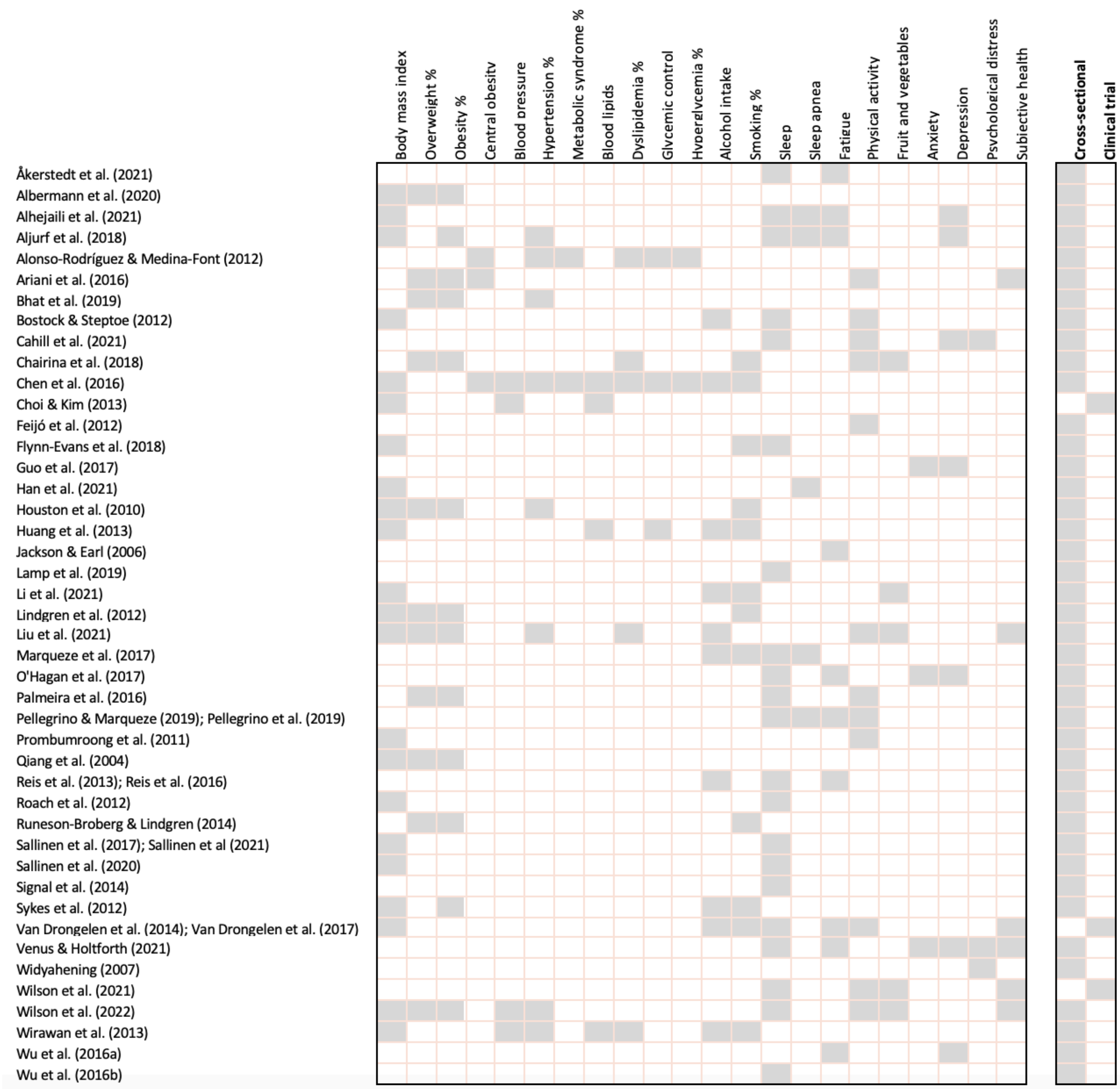

Figure 3: Cardiometabolic risk markers and airline pilot outcome summary for each study.

Quality of Reviewed Articles

The results of the risk-of-bias assessment are displayed in Tables 3 and 4. Of the 48 publications included in the review, four were considered of low methodological quality with a high risk of bias and 13 were considered of high methodological quality with a low risk of bias. Weak external validity was apparent for most cross-sectional studies, with a paucity of random sampling (n = 39) and high nonresponse bias (n = 33) as leading factors. Lacking reliability and validity of outcome measures (n = 17) and inappropriate observed prevalence period (n = 14) were prominent factors of poor internal validity among cross-sectional studies. The three clinical trials reviewed ranged from low to moderate quality, all exhibiting high risk of bias for allocation concealment and blinding of participants.

Table 3: Methodological quality scores of cross-sectional studies.

	External validity				**Internal validity**						
Author (year)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Quality**
Åkerstedt et al. (2021) (Akerstedt et al., 2021)	N	N	N	Y	Y	Y	Y	Y	Y	Y	(3) High
Albermann et al. (2020) (Albermann et al., 2020)	Y	Y	N	Y	Y	Y	N	Y	Y	Y	(2) High
Alhejaili et al. (2021) (Alhejaili et al., 2021)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Aljurf et al. (2018) (Aljurf et al., 2018)	Y	N	N	N	Y	Y	Y	Y	Y	Y	(3) High
Alonso-Rodríguez and Medina-Font (2012) (Alonso-Rodriguez & Medina-Font, 2012)	Y	Y	N	Y	Y	Y	Y	N	Y	Y	(2) High
Ariani et al. (2017) (Ariani, 2016)	N	N	N	N	N	Y	N	Y	Y	Y	(6) Med
Bhat et al. (2019) (Bhat et al., 2019)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High
Bostock and Steptoe (2012) (Bostock & Steptoe, 2013)	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Cahill et al. (2021) (Cahill et al., 2021)	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med

Chairina et al. (2018) (Chairina et al., 2018)	N	N	N	N	Y	N	N	N	Y	Y	(7) Low
Chen et al. (2016) (Chen et al., 2016)	Y	N	N	N	Y	Y	Y	Y	N	Y	(4) Med
Feijó et al. (2012) (Feijo et al., 2012)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High
Flynn-Evans et al. (2018) (Flynn-Evans et al., 2018)	N	N	N	Y	Y	Y	N	Y	Y	Y	(4) Med
Guo et al. (2017) (Guo et al., 2017)	Y	N	N	N	Y	Y	Y	Y	N	Y	(4) Med
Han et al. (2020) (Han et al., 2021)	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Houston et al. (2010) (Houston et al., 2010)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	(1) High
Huang et al. (2012) (Huang et al., 2013)	N	Y	N	Y	Y	Y	N	N	N	Y	(5) Med
Jackson and Earl (2006) (Jackson & Earl, 2006)	N	N	N	N	Y	Y	N	Y	N	Y	(6) Med
Lamp et al. (2019) (Lamp et al., 2019)	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Li et al. (2021) (Li et al., 2021)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Lindgren et al. (2012) (Lindgren et al., 2012)	Y	Y	N	N	Y	Y	N	Y	N	Y	(4) Med
Liu et al. (2021) (Liu et al., 2021)	N	Y	N	Y	Y	Y	N	Y	N	Y	(4) Med
Marqueze et al. (2017) (Marqueze et al., 2017)	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High
O'Hagen et al. (2016) (O'Hagan et al., 2017)	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Palmeira et al. (2016) (Palmeira & Marqueze, 2016)	Y	Y	Y	N	Y	Y	N	Y	Y	Y	(2) High
Pellegrino and Marqueze (2018) (Pellegrino	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med

& Marqueze, 2019)											
Pellegrino et al. (2018) (Pellegrino et al., 2019)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Prombumroong et al. (2011) (Prombumroong et al., 2011)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Qiang et al. (2004) (Qiang et al., 2005)	N	Y	N	Y	Y	Y	Y	Y	Y	Y	(2) High
Reis et al. (2013) (Reis et al., 2013); Reis et al. (2016) (Reis et al., 2016a)	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Roach et al. (2012) (Roach et al., 2012a)	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Runeson-Broberg and Lindgren (2013) (Runeson-Broberg et al., 2014)	Y	Y	N	N	Y	Y	N	Y	N	Y	(4) Med
Sallinen et al. (2017) (Sallinen et al., 2017)	Y	N	Y	Y	Y	N	Y	N	N	N	(5) Med
Sallinen et al. (2020) (Sallinen et al., 2020)	Y	N	N	Y	Y	N	Y	N	Y	N	(5) Med
Sallinen et al. (2021) (Sallinen et al., 2021)	N	N	N	N	Y	Y	N	Y	Y	Y	(5) Med
Signal et al. (2014) (Signal et al., 2014)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Sykes et al. (2012) (Sykes et al., 2012)	Y	Y	N	N	Y	Y	N	Y	Y	Y	(3) High
Venus and Holtforth (2021) (Venus, 2021)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Widyahening (2007) (Widyahening, 2007)	N	N	N	N	Y	N	N	Y	N	Y	(7) Low
Wilson et al. (2022) (Wilson et al., 2022a)	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	(1) High
Wirawan et al. (2013) (Wirawan et al., 2013)	Y	Y	N	N	Y	Y	N	N	N	Y	(5) Med
Wu et al. (2016a) (Wu et al., 2016a)	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med

Wu et al. (2016b) (Wu et al., 2016b)	Y	N	N	N	Y	Y	Y	Y	Y	Y	(3) High

Note: High = high quality (low risk of bias); Low = low quality (high risk of bias); Med = medium quality (moderate risk of bias); N, no; Y, yes; 1—Was the study's target population a close representation of the national population in relation to relevant variables, age, sex, and occupation? 2—Was the sampling frame a true or close representation of the target population? 3—Was some form of random selection used to select the sample OR was a census undertaken? 4—Was the likelihood of nonresponse bias minimal? 5—Were data collected directly from the subjects (as opposed to a proxy)? 6—Was an acceptable case definition used in the study? 7—Was the study instrument that measured the parameter of interest (e.g., prevalence of lower-back pain) shown to have reliability and validity (if necessary)? 8—Was the same mode of data collection used for all subjects? 9—Was the length of the shortest prevalence period for the parameter of interest appropriate? 10—Were the numerator(s) and denominator(s) for the parameter of interest appropriate?

Table 4: Risk-of-bias assessment of clinical trials.

Author (year)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Choi and Kim 2013 (Choi & Kim, 2013)	High	High	High	High	Unclear	Low	Low
Van Drongelen et al. 2014 (van Drongelen et al., 2014); Van Drongelen et al. 2016 (van Drongelen et al., 2017)	Low	High	High	High	Low	Low	High
Wilson et al. 2021 (Wilson et al., 2021a)	High	High	High	Low	Low	Low	Low

Note: 1 = random sequence; 2 = allocation concealment; 3 = blinding of participants; 4 = blinding of outcomes; 5 = incomplete outcome data; 6 = selective reporting; 7 = other; High = high risk of bias; Low = low risk of bias; Unclear = not possible to rate risk of bias.

Physiological Cardiometabolic Risk Factors among Pilots

Twenty-eight studies investigated physiological cardiometabolic risk factors. From the 22 studies reporting BMI, 12 were objectively measured and 10 were based on self-report data. The overall objectively measured BMI (n = 20,279) pooled mean was 26.1 ± 3.0 kg/m^2 and the overall subjective BMI (n = 3,710) pooled mean was 24.7 ± 3.1 kg/m^2. For females, one study (n = 661) reported an objectively measured BMI of 23.9 kg/m^2 (20.0–27.7), and another (n = 32) reported a subjective BMI as 22.7 kg/m^2.

Eleven studies investigated the prevalence of overweight and obesity; five (n = 19,171) were objectively measured and six (n = 3,309) were based on self-reporting from participants. The pooled mean for objective measures of overweight and obesity were 47.5% (47.4–47.5%) and 11.6% (11.6–11.7%), respectively. One study reported obesity only, revealing a prevalence of 20% (Sykes et al., 2012). The pooled mean for subjective measures of overweight and obesity was 43.6% (43.3–43.9%) and 12.4% (11.9–12.9%), respectively. The overall pooled prevalence of overweight plus obesity was 59.1% (59.0–59.2%) for objective measures and 56.0% (55.5–56.5%) for subjective measures. The combined pooled prevalence from subjective and objective measures for overweight, obesity, and overweight plus obesity was 46.8% (46.7–46.9), 11.7% (11.6–11.8%), and 58.6% (58.5–58.7%), respectively. One study (Houston et al., 2010) (n = 661) reported the prevalence of overweight and obesity for females as 28% and 6%, respectively. The prevalence of metabolic syndrome was reported by two studies, ranging from 15% (Alonso-Rodriguez & Medina-Font, 2012) to 38% (Chen et al., 2016). Furthermore, these studies reported objectively measured central obesity (> 102 cm) prevalence as 18% (Alonso-Rodriguez & Medina-Font, 2012) and 64% (Chen et al., 2016). Only one study investigated C-reactive protein levels, reporting a mean hs-CRP serum level of 1.68 ± 1.79 (mg/L) (Alonso-Rodriguez & Medina-Font, 2012).

Four studies (n = 16,327) reported the prevalence of hypertension (BP ≥ 140/90 mmHg) from objective measurement as 29% (Houston et al., 2010), 28% (Chen et al., 2016), 26% (Wilson et al., 2022a), and 11% (Bhat et al., 2019), with a pooled prevalence of 27.6% (27.5–27.7%). Furthermore, one study (n = 303) reported the prevalence of elevated BP (≥ 130/85 mmHg) as 38% (Alonso-Rodriguez & Medina-Font, 2012). Derived from four studies (Chen et al., 2016; Choi & Kim, 2013; Wilson et al., 2022a; Wirawan et al., 2013), the objectively measured pooled mean systolic blood pressure (SBP) was 126 ± 14 mmHg, and the objectively measured pooled mean diastolic blood pressure (DBP) was 79 ± 9 mmHg. The prevalence of self-reported known hypertension of participants in three studies was 13% (Aljurf et al., 2018), 7% (Liu et al., 2021), and 6% (Wirawan et al., 2013). One study reported the prevalence of objective hypertension for females as 14% (Houston et al., 2010).

HDL cholesterol and triglycerides were reported in four studies (Chen et al., 2016; Choi & Kim, 2013; Huang et al., 2013; Wirawan et al., 2013) (n = 1,640), revealing pooled means of 1.3 ± 0.9 mmol/L and 19 ± 1.6 mmol/L, respectively. Additionally, three studies reported the prevalence of low HDL as 8% (Alonso-Rodriguez & Medina-Font, 2012), 46% (Chen et al., 2016), and 57% (Chairina et al., 2018) and of elevated triglycerides as 24% (Alonso-Rodriguez & Medina-Font, 2012), 28% (Chen et al., 2016), and 29% (Chairina et al., 2018). The pooled mean of three studies (Choi & Kim, 2013; Huang et al., 2013; Wirawan et al., 2013) (n = 1,337) reporting TC was 5.3 ± 1.0 mmol/L, and an LDL cholesterol mean of 3.3 ± 0.9 mmol/L was derived from two studies (Choi & Kim, 2013; Huang et al., 2013) (n = 742). The prevalence of self-reported known dyslipidemia of participants in two studies was 10% (Wirawan et al., 2013) and 19% (Liu et al., 2021). Only two studies investigated hyperglycemia, reporting the prevalence as 31% (Alonso-Rodriguez & Medina-Font, 2012) (≥ 100mg/dL) and 30% (Chen et al., 2016) (≥ 5.6 mmol/L).

Behavioural Cardiometabolic Risk Factors among Pilots

Thirty-one studies included the evaluation of behavioural cardiometabolic risk factors. Alcohol intake was investigated in 10 samples of airline pilots (Bostock & Steptoe, 2013; Chen et al., 2016; Huang et al., 2013; Li et al., 2021; Liu et al., 2021; Marqueze et al., 2017; Reis et al., 2013; Reis et al., 2016a; Sykes et al., 2012; van Drongelen et al., 2014; van Drongelen et al., 2017; Wirawan et al., 2013); one study utilised a validated questionnaire (Li et al., 2021), and five studies (Chen et al., 2016; Huang et al., 2013; Li et al., 2021; Liu et al., 2021; Marqueze et al., 2017) (n = 2538) ascertained "regular alcohol intake" on the basis of a participant self-recall question, producing a pooled prevalence of 52% (51.3–53.1). Twelve studies (Chairina et al., 2018; Chen et al., 2016; Flynn-Evans et al., 2018; Houston et al., 2010; Huang et al., 2013; Li et al., 2021; Lindgren et al., 2012; Marqueze et al., 2017; Runeson-Broberg et al., 2014; Sykes et al., 2012; van Drongelen et al., 2014; Wirawan et al., 2013) (*n* = 19,116) reported smoking prevalence, yet no studies evaluated quantity or frequency of smoking. The pooled prevalence was 9.4% (9.3–9.5%). One study reported the prevalence of smoking for females as 6% (Houston et al., 2010).

From the 20 studies evaluating sleep, seven studies objectively measured sleep hours with actigraphy (*n* = 1,764) (Flynn-Evans et al., 2018; Lamp et al., 2019; Roach et al., 2012a; Sallinen et al., 2021; Sallinen et al., 2020; Sallinen et al., 2017; Signal et al., 2014; Wu et al., 2016b), and six used self-recall methods (*n* = 2,224) (Akerstedt et al., 2021; Bostock & Steptoe, 2013; Marqueze et al., 2017; Wilson et al., 2021a; Wilson et al., 2022a; Wu et al., 2016b). The pooled means for objective and self-recall sleep hours per night were 7.2 ± 1.1 and 7.0 ± 0.6, respectively. Three studies reported the prevalence of < 6 h of sleep per night as 23% [43], 20% (van Drongelen et al., 2017), and 22% (Aljurf et al., 2018). Furthermore, other studies reported that < 6 h of sleep per night was associated with obesity (Palmeira & Marqueze, 2016) and poor sleep quality (Pellegrino & Marqueze, 2019) within participants. The prevalence of excessive sleepiness assessed by the Epworth Sleepiness Scale (score ≥ 10) was reported by five studies (Alhejaili et al., 2021; Aljurf et al., 2018; Marqueze et al., 2017; Pellegrino & Marqueze, 2019; Reis et al., 2013), exhibiting a pooled prevalence of 44.5% (44.1—44.8%). Among four studies reporting high obstructive sleep apnea (OSA) risk ascertained from the Berlin Questionnaire, the prevalence was 5% (Alhejaili et al., 2021), 20% (Marqueze et al., 2017), 21% (Pellegrino & Marqueze, 2019), and 29% (Aljurf et al., 2018), providing a pooled mean of 21.4% (21.3–21.5%).

The prevalence of self-reported insufficient physical activity (< 150 min MVPA per week) was reported in five studies (*n* = 2233) providing a pooled prevalence of 51.5% (51.3–51.7%) (Ariani, 2016; Chairina et al., 2018; Pellegrino & Marqueze, 2019; Wilson et al., 2021a; Wilson et al., 2022a). Additionally, < 150 min MVPA per week was found to be associated with obesity in one study which reported a prevalence ratio of 1.08 (0.98–1.19) (Palmeira & Marqueze, 2016). One study reported the mean days per week of moderate physical activity and strenuous physical activity as 3.3 ± 1.9 and 2.0 ± 1.4, respectively. Another study reported the mean walking minutes and MVPA minutes per week as 110 ± 117 and 145 ± 72, respectively.

Three studies (*n* = 955) reported the prevalence of subjective insufficient daily fruit intake as 33% (< 200 g/day) (Liu et al., 2021), 60% (Wilson et al., 2022a), and 65% (< 2 servings/day) (Wilson et al., 2021a) and of insufficient daily vegetable intake as 19% (< 300 g/day) (Liu et al., 2021), 47% (Wilson et al., 2021a), and 48% (Wilson et al., 2022a) (< 3 servings/day). From these studies, two reported the prevalence of combined insufficient fruit and vegetable intake as 68% (Wilson et al., 2022a) and 84% (Wilson et al., 2021a). One study reported the mean number of snacks per duty as 4 ± 3 (van Drongelen et al., 2014).

Psychological Cardiometabolic Risk Factors among Pilots

Sixteen studies included an evaluation of psychological cardiometabolic risk factors. Among 10 studies investigating the prevalence of psychological fatigue, four studies (*n* = 2,987) utilised the Fatigue Severity Scale (FSS), two of which reported a psychological fatigue prevalence (FSS ≥ 4 mean score) of 77% (Venus, 2021) and 89% (Reis et al., 2013; Reis et al., 2016a). Another two studies reported the severe psychological fatigue prevalence (FSS ≥ 36 total score) as 33% (Alhejaili et al., 2021) and 68% (Aljurf et al., 2018). The prevalence of elevated psychological fatigue in the remaining studies (*n* = 2,719) was reported as 5% (Wu et al., 2016a), 27% (Pellegrino & Marqueze, 2019; Pellegrino et al., 2019), 30% (van Drongelen et al., 2014; van Drongelen et al., 2017), and 75% (Jackson & Earl, 2006), each produced with different methodology.

Seven studies subjectively measured the prevalence of depression, with a pooled mean of 21% (20.8–21.6) for mild depression derived from five studies (Alhejaili et al., 2021; Cahill et al., 2021; Guo et al., 2017; Venus, 2021; Wu et al., 2016a) (*n* = 3,411) utilising the Patient Health Questionnaire (PHQ-9; score ≥ 10). One study reported a depression prevalence of 35% (Aljurf et al., 2018) according to the Hospital Anxiety and Depression Scale (score > 8), whereas another study reported depression or anxiety within the last 12 months as 54.4% (O'Hagan et al., 2017). One study reported mild depression (PHQ-9 score ≥ 10) prevalence in females as 11% (Wu et al., 2016a). Two studies (*n* = 2,527) reported the prevalence of mild anxiety derived from the Generalized Anxiety Disorder-7 (GAD-7; score > 10) scale, noting 4% (Guo et al., 2017) and 7% (Venus, 2021). The prevalence of below-average or poor subjective self-rated health was reported in three studies (n = 1282) as 8% (Liu et al., 2021), 25% (Wilson et al., 2022a), and 39% (Ariani, 2016), each derived from different methodology.

Table 5: Summary of characteristics of studies that investigated cardiometabolic health risk parameters among airline pilots.

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Åkerstedt et al. (2021) (Akerstedt et al., 2021)	Investigate associations among schedule, fatigue, and sleep	Cross-sectional; subjective; Sweden	n = 89; 76%; 38 ± 9 years	Fatigue (KSS) = 4.2 ± 1.8; sleep = 6.8 ± 1.4 h; sleep, duty time, and early starts are important predictors of fatigue in the 24 h window and that the number of very early starts and short sleep have cumulative effects on fatigue across a 7-day work period	Karolinska Sleepiness Scale; sleep duration self-report
Albermann et al. (2020) (Albermann et al., 2020)	Evaluate the prevalence of lower-back pain compared with the general population	Cross-sectional; subjective; Germany	n = 698; 92%; 40 ± 9 years	BMI = 24.4 ± 2.7; overweight = 35% and obesity = 3.2%; chronic lower-back pain = 83%; time spent sitting during work = 90%	BMI (self-report); Oswestry Lower-Back Pain Disability Index
Alhejaili et al.	Evaluate the	Cross-	n = 39; 100%;	BMI = 24.5 ± 2.4;	BMI; Athen's

(2021) (Alhejaili et al., 2021)	presence of obstructive sleep apnea in pilots	sectional; subjective and objective; Saudi Arabia	43 ± 10 years	insomnia prevalence (AIS ≥ 6) = 31%; high risk of obstructive apnea = 5%; abnormal sleepiness = 23%; mild depression = 26%; moderate severity depression = 10%; suboptimal sleep quality = 39%; severe fatigue = 33%; VAFS abnormal fatigue = 23%	insomnia scale (AIS); Berlin Questionnaire; Epworth Sleepiness Scale (ESS); Pittsburgh Sleep Quality Index (PSQI); Fatigue Severity Scale (FSS); Visual Analog Fatigue Scale (VAFS); Patient Health Questionnaire (PHQ-9)
Aljurf et al. (2018) (Aljurf et al., 2018)	Evaluate the prevalence of fatigue, depression, sleepiness, and the risk of obstructive sleep apnea	Cross-sectional; subjective; Arab states	*n* = 328; 99%; 41 ± 10 years	BMI = 27.6 ± 5.0; BMI ≥ 30 = 24%; Sleep < 6 h = 22%; known hypertension = 13%; severe fatigue (FSS ≥ 36) = 68%; reported mistakes being made in the cockpit because of fatigue = 67%; ESS excessive sleepiness = 34%; high risk of OSA	Fatigue Severity Scale (FSS); Berlin Questionnaire; Epworth Sleepiness Scale (ESS); Hospital Anxiety and Depression Scale

				= 29%; depression (HADS ≥ 8) = 35%	(HADS)
Alonso-Rodríguez and Medina-Font (2012) (Alonso-Rodriguez & Medina-Font, 2012)	Evaluate C-reactive protein levels and the prevalence of metabolic syndrome	Cross-sectional; objective; Spain	*n* = 1009; 100%; 42 ± 11 years	elevated BP = 38%; hyperglycemia = 31%; elevated serum triglycerides = 24%; abdominal obesity = 18%; low HDL cholesterol = 8%; hs-CRP serum levels = 1.7 ± 1.8 mg/L; high hs-CRP incidence increased with age; metabolic syndrome (MS) prevalence = 15%; MS in pilots < 35 years old = 4%; MS in pilots 35–50 years old = 14%; MS in pilots > 50 years old = 29%; hs-CRP was significantly higher in pilots with MS than those without MS	Venous blood test; waist circumference; blood pressure; not all instruments specified
Ariani et al. (2016) (Ariani, 2016)	Evaluate physical exercise habits and associated factors	Cross-sectional; subjective; Indonesia	*n* = 332; 100%; 20-29 years = 39%, 30–39 years = 23%, 40–49 years = 21%, 50–65	< 150 MVPA min per week = 56%; overweight = 28% and obesity = 53%; central obesity = 46%; low or average SLS score (≤	BMI (self-report); Satisfaction with Life Scale (SLS); not all

			years = 16%	24) = 39%	instruments specified
Bhat et al. (2019) (Bhat et al., 2019)	Examine the prevalence of hypertension and obesity and their relationship	Cross-sectional; objective; India	*n* =1185; 89%; 35 ± 14 years	Overweight = 39% and obesity = 7%; hypertension = 11%	BMI; blood pressure
Bostock and Steptoe (2012) (Bostock & Steptoe, 2013)	Investigate work schedule influence on diurnal cortisol rhythm	Cross-sectional; subjective; the United Kingdom	*n* = 30; 100%; 20–29 years = 15%, 30–39 years = 41%, 40–49 years = 30%, 50–65 years = 15%	BMI = 25.6 ± 2.5; sleep = 8.2 ± 1 h; consumed alcohol on nonwork days = 52%; exercised > 10 min on nonwork days = 28%	BMI (self-report); not all instruments specified
Cahill et al. (2021) (Cahill et al., 2021)	Investigate the relationship among work-related stress, wellbeing, and coping mechanisms	Cross-sectional; subjective; international	*n* = 821; 88%; < 25 years = 5%, 25–35 years = 27%, 36–45 years = 31%, 46–55 years = 26%, 56–65 years = 12%	Mild depression = 40%; moderate-severity depression = 4%; severe depression = 2%; regular exercise (≥ 3 times per week) = 25%; perceived regular sleep difficulties = 81%; regular work stress digestive symptoms = 59%; regular work stress induced psychosocial distress = 37%	Patient Health Questionnaire -9 (PHQ-9); Oldenburg Burnout

Chairina et al. (2018) (Chairina et al., 2018)	Identify the risk factors associated with dyslipidemia	Cross-sectional; subjective and objective; Indonesia	*n* = 128; 100%; not reported	Overweight = 20% and obesity = 65%; < 150 MVPA min per week = 71%; inappropriate or excessive food intake = 66%; smoking = 45%; dyslipidemia = 62%; elevated TG = 29%; elevated LDL = 47%; low HDL = 57%	Instruments not specified
Chen et al. (2016) (Chen et al., 2016)	Evaluate metabolic syndrome and periodontal disease status	Cross-sectional; objective; China	*n* = 303; 100%; 35 ± 8 years	BMI = 23.6 ± 2.6; smoking = 33%; regular alcohol drinker = 20%; metabolic syndrome =3 8%; elevated waist circumference = 64%, 87.6 ± 8.5 (cm); low HDL levels = 46%, 1.2 ± 1.9 (mmol/L); elevated fasting plasma glucose = 30%, 5.4 ± 0.6 (mmol/L); high SBP = 28%, 124 ± 11 (mmHg); elevated TG levels = 28%, 1.5 ± 0.8 (mmol/L); high DBP = 17%, 79 ± 7 (mmHg)	Venous blood test; saliva test; periodontal examination; blood pressure; waist circumference; BMI; Community Periodontal Index
Choi and Kim (2013) (Choi &	Evaluate the effects of	Clinical trial;	*n* = 326; 100%; 30–39 years =	TC > 220 mg/dL = 18%; TC (mg/dL) =	BMI; venous blood test;

Kim, 2013)	physical examination and diet consultation on risk factors for CVD	subjective and objective; Korea	47%, 40–49 years = 33%, 50–59 years = 20%	236 ± 13; HDL (mg/dL) = 51 ± 11; LDL (mg/dL) = 155 ± 16; TG (mg/dL) = 154 ± 81; BMI = 24.5 ± 2.1; weight (kg) = 73 ± 8; SBP (mmHg) = 118 ± 12; DBP (mmHg) = 76 ± 9	blood pressure
Feijó et al. (2012) (Feijo et al., 2012)	Evaluate the prevalence of common mental disorders and related factors	Cross-sectional; subjective; Brazil	*n* = 807; 92%; 46 years	Regular physical activity practice = 61%; common mental disorders = 7%	Self-Reporting Questionnaire—20 items
Flynn-Evans et al. (2018) (Flynn-Evans et al., 2018)	Investigate work schedule effects on neurobehavioural performance and sleep	Cross-sectional; subjective and objective; USA	*n* = 44; 91%; 31 ± 7 years	BMI = 24.2 ± 2.6; sleep = 6.8 ± 0.9 h; sleep latency 18%; sleep efficiency = 83%; smoking habit = 5%	Sleep diary; Psychomotor Vigilance Task; Samn–Perelli fatigue scale; actigraphy
Guo et al. (2017) (Guo et al., 2017)	Investigate the effects of emotional intelligence on depression and anxiety	Cross-sectional; subjective; China	*n* = 319; 100%; 31 ± 6 years	Mild depression = 24%; moderate depression = 1%; mild anxiety = 4%; moderate anxiety = 0.3%	Trait Meta Mood Scale; Proactive Coping Scale; The Patient Health Questionnaire (PHQ-9);

					Generalized Anxiety Disorder-7 (GAD-7)
Han et al. (2021) (Han et al., 2021)	Investigate the occurrence of obstructive sleep apnea	Cross-sectional; subjective and objective; Korea	*n* = 103; 100%; 44 ± 8 years	BMI = 24.6 ± 2.1; neck circumference = 38 ± 2 (cm); OSA high risk = 32%	BMI; Epworth Sleepiness Scale (ESS); Berlin questionnaire; neck circumference; polysomnography; apnea–hypopnea index; oxygen desaturation index; respiratory disturbance index
Houston et al. (2010) (Houston et al., 2010)	Identify the 10-year absolute CVD risk of pilots using a cardiovascular disease risk prediction	Cross-sectional; subjective and objective; the United Kingdom	*n* = 14,379; 95%; not reported	BMI = 26.0 (male) and 23.9 (female); overweight = 47% (male) and 28% (female); obesity = 12% (male) and 6% (female); smoking = 8% (male) and 6%	BMI; blood pressure; not all instruments specified

	model			(female); hypertension = 29% (male) and 14% (female); population 10-year absolute CVD risk = 8% ± 7%; 10-year absolute CVD risk > 20% (high risk) was 9% for males and 0% for females	
Huang et al. (2013) (Huang et al., 2013)	Evaluate distribution of APOE gene polymorphism, dyslipidemia, and overweight	Cross-sectional; subjective and objective; China	*n* = 416; 100%; 39 ± 11 years	BMI = 24.2 ± 2.5; fasting glucose = 5.2 ± 0.6 (mmol/L); smoking = 54%; regular alcohol intake = 32%; total cholesterol = 4.6 ± 0.9 (mmol/L); LDL (mmol/L) = 2.8 ± 0.8; HDL = 1.3 ± 0.3 (mmol/L); TG = 1.6 ± 0.9 (mmol/L)	BMI; venous blood test; not all instruments specified
Jackson and Earl (2006) (Jackson & Earl, 2006)	Evaluate fatigue prevalence	Cross-sectional; subjective; the United Kingdom	*n* = 162; 94%; 38 ± 9 years, range 21–59 years	Global CFS fatigue score = 18 ± 5; severe fatigue on the CFS = 75%; "fatigue worse than 2 years ago" = 81%; "feel tired with impaired judgement while flying?" = 80%; "concerned with the level of fatigue you	Chronic Fatigue Scale (CFS)

				experience?" = 78%	
Lamp et al. (2019) (Lamp et al., 2019)	Evaluate sleep timing and duration	Cross-sectional; subjective and objective; USA	n = 92; 84%; 51 ± 9 years	Sleep = 8.2 ± 1.7h	Actigraphy
Li et al. (2021) (Li et al., 2021)	Investigate the prevalence of functional gastrointestinal disorders and associated triggers	Cross-sectional; subjective; China	n = 212; 100%; 34 ± 7 years	BMI = 23.8 ± 2.4, range 19–29; regular alcohol = 31%; smoking = 49%; functional gastrointestinal disorder prevalence = 39%	BMI (self-report); semi-quantitative food frequency questionnaire (SQFFQ)
Lindgren et al. (2012) (Lindgren et al., 2012)	Investigate associations among digestive symptoms and diet, insomnia, and lifestyle factors	Cross-sectional; subjective; Sweden	n = 354; 91%; 49 ± 6 years	Male BMI = 25.2; female BMI = 22.7; overall overweight = 41% and obesity = 4%; smoking = 5%	BMI (self-report); not all instruments specified
Liu et al. (2021) (Liu et al., 2021)	Investigate health-related quality of life and its related factors	Cross-sectional; subjective; China	n = 373; 100%; 35 ± 8 years	BMI = 23.8 ± 2.2; hypertension = 7%; dyslipidemia = 19%; overweight = 46% and obesity = 3%; smoking = 39%; regular alcohol intake = 38%; physical activity days per week	BMI (self-report); WHOQOL-BREF; not all instruments specified

				= 2 (range 1–3); vegetable intake ≤ 300 g per day = 19%; fruit intake ≤ 200 g per day = 33%; self-rated health (very poor or poor) = 13%; self-rated quality of life (very poor or poor) = 8%; self-rated energy and fatigue (very poor or poor) = 6%	
Marqueze et al. (2017) (Marqueze et al., 2017)	Evaluate factors associated with unintentional sleep at work of airline pilots	Cross-sectional; subjective; Brazil	*n* = 1234; 97%; 39 ± 10 years	Smoking = 7%; regular alcohol = 75%; moderate alcohol intake = 24%; harmful use of alcohol = 1%; sleep 6.9 ± 1.2 h; unintentional sleep while on duty = 58%; sleep quality "fairly or very bad" = 11%; OSA high risk = 20%; excessive sleepiness = 42%	Alcohol Use Disorders Identification Test; Karolinska Sleep Questionnaire; Berlin questionnaire; Epworth Sleepiness Scale; Work Ability Index
O'Hagan et al. (2017) (O'Hagan et al., 2017)	Investigate the differences in self-reported depression or	Cross-sectional; subjective; Europe	*n* = 701; 95%; not reported	Depression or anxiety in the past 12 months prevalence = 54%; working > 41 h per week, sleep disruption,	Internally validated questionnaire

	anxiety			elevated fatigue, and being female were factors associated with higher probability of reporting feeling depressed or anxious in the last 12 months	
Palmeira et al. (2016) (Palmeira & Marqueze, 2016)	Identify the prevalence and associated factors of overweight and obesity	Cross-sectional; subjective; Brazil	*n* = 1198; 100%; 39 ± 10 years, range 21–67 years	Overweight = 54% and obesity = 15%; factors associated with obesity included ≤ 150 min of weekly physical activity, ≤ 6 h of sleep during days off, sleepiness, and time of being a pilot were associated with obesity	BMI (self-report); Karolinska Sleep Questionnaire
Pellegrino and Marqueze (2019) (Pellegrino & Marqueze, 2019); Pellegrino et al. (2019) (Pellegrino et al., 2019)	Investigate the association of work organisation and sleep aspects with work ability	Cross-sectional; subjective; Brazil	*n* =1234; 97%; 39 ± 10 years	< 150 MVPA min per week = 50%; perceived insufficient sleep = 32%; excessive sleepiness = 43%; perceived of high fatigue = 27%; OSA high risk = 21%; poor sleep quality = 48%; poor sleep quality was associated with shift characteristics, being insufficiently	Karolinska Sleepiness Scale; Berlin questionnaire; Epworth Sleepiness Scale; Yoshitake questionnaire; Work Ability Index; Job Stress Scale; Need for

				physically active, and sleeping < 6 hours on days off.	Recovery Scale
Prombumroong et al. (2011) (Prombumroong et al., 2011)	Evaluate the prevalence of lower-back pain and associated factors	Cross-sectional; subjective; Thailand	*n* = 684; 100%; 40 ± 10 years	BMI = 24.3 ± 2.8; no regular exercise = 64%; lower-back pain in the last 12 months = 56%	BMI (self-report); Job Content Questionnaire Thai version (JCQ Thai version); Nordic questionnaire for lower-back pain
Qiang et al. (2004) (Qiang et al., 2005)	Evaluate the association of body mass index with cardiovascular disease	Cross-sectional and prospective; subjective and objective; USA	*n* =3019; 100%; range 45–54 years	BMI = 27.2 ± 3.4; overweight = 55% and obesity = 7%; pilots who were overweight and obese had 6% and 22% higher CVD risk, respectively	BMI; blood pressure
Reis et al. (2013) (Reis et al., 2013); Reis et al. (2016) (Reis et al., 2016a)	Evaluate the prevalence of fatigue and compare the differences among fatigue,	Cross-sectional; subjective; Portugal	*n* = 456; 97%; 39 ± 8 years	Total fatigue prevalence (FSS ≥ 4) = 89%; JSS ≥ 4 = 35.0%; excessive sleepiness = 59%; alcohol intake > 3 times per week = 1%	Internally validated questionnaire; Fatigue Severity Scale (FSS);

	sleep, and labor specificities				Epworth Sleepiness Scale (ESS); Jenkins Sleep Scale (JSS)
Roach et al. (2012) (Roach et al., 2012a)	Evaluate the impact of work schedule on the sleep and fatigue	Cross-sectional; subjective and objective; Australia	*n* = 19; 100%; 54 ± 2 years	BMI = 25.0 ± 2.4; sleep hours = 7.2 h	Samn–Perelli Fatigue Checklist; actigraphy; not all instruments specified
Runeson-Broberg and Lindgren (2014) (Runeson-Broberg et al., 2014)	Assess the prevalence of musculoskeletal symptoms	Cross-sectional; subjective; Sweden	*n* = 354; 91%; 31-40 years = 9%, 41–50 years = 61%, 51–60 years = 29%, 61+ years = 2%	Overweight = 41% and obesity = 4%; smokers = 5%	BMI (self-report); Nordic questionnaire for analyzing musculoskeletal symptoms
Sallinen et al. (2017) (Sallinen et al., 2017); Sallinen et al. (2021) (Sallinen et al., 2021)	Evaluate and compare sleep patterns, sleepiness, and management strategies	Cross-sectional; subjective and objective; Finland	*n* = 477; 100%; 43 ± 7 years	BMI = 25.1 ± 2.9; sleep = 7 h 27 min ± 51 min	Actigraphy; Karolinska Sleepiness Scale; BMI (self-report)
Sallinen et al. (2020) (Sallinen et al., 2020)	Compare sleepiness ratings of airline pilot and truck	Cross-sectional; subjective and	*n* = 33; 100%; 44 ± 7 years	Sleep = 7 h 48 min ± 56 min; BMI = 25.6 ± 3.6; KSS = 4.0	Actigraphy; Karolinska Sleepiness Scale; BMI

	drivers	objective; Finland			(self-report); not all instruments specified
Signal et al. (2014) (Signal et al., 2014)	Evaluate the uptake and effectiveness of fatigue mitigation guidance material	Cross-sectional; objective; New Zealand	*n* = 52; 100%; 55 years	Sleep hours = 7.0 ± 1.2 h; sleep efficiency = 88 ± 5%	Actigraphy
Sykes et al. (2012) (Sykes et al., 2012)	Compare the prevalence of medical conditions and risk factors with the general population	Cross-sectional; subjective and objective; New Zealand	*n* = 595; 97%; not reported	BMI = 27.1; obesity prevalence = 20%; smoking = 2%; alcoholic drink per week = 5.4	Instruments not specified
Van Drongelen et al. (2014) (van Drongelen et al., 2014); Van Drongelen et al. (2017) (van Drongelen et al., 2017)	Investigate the effects of an mHealth intervention to mitigate fatigue and determine risk factors for fatigue	Clinical trial; subjective; the Netherlands	*n* = 502; 93%; 41 ± 8 years	BMI = 24.1 ± 2.3; alcohol intake several days per week = 67%; smoking = 11.2%; CIS = 62 ± 22; moderate physical activity (days p/w) = 3.3 ± 1.9; strenuous physical activity (days p/w) = 2.0 ± 1.4; number of snacks per duty = 4.6 ±	BMI (self-report); Checklist Individual Strength (CIS); Need for Recovery scale; Dutch Questionnaire on the Experience

				3.6; sleep quality (1–20 scale) = 7.5 ± 3.9; sleep duration < 6 h = 20%; health perception (1–5 scale, higher value denotes better health) = 3.4 ± 0.8; CIS fatigue prevalence = 30%	and Evaluation of Work; Jenkins Sleep Scale; Pittsburgh Sleep Quality Index; Short Form 36-item (SF-36) Health Survey
Venus and Holtforth (2021) (Venus, 2021)	Evaluate work schedule effects on fatigue risks on flight duty, stress, sleep problems, fatigue severity, wellbeing, and mental health	Cross-sectional; subjective; International	*n* = 406; 92%; 41 ± 11 years	PHQ stress = 5.0 ± 3.5; WHO5 PR (wellbeing) = 55 ± 20; PHQ-8 = 5.7 ± 4.4; SRQ-20 (common mental disorders) = 3.9 ± 4.0; Fatigue Severity Scale = 4.5 ± 1.0; Jenkins Sleep Scale = 2.0 ± 1.1; high fatigue = 33% and severe fatigue = 42%; PHQ8 ≥ 10 = 19%; GAD-7 = 3.9 ± 3.8; GAD7 ≥ 10 = 7.2%	Fatigue Severity Scale; Jenkins Sleep Scale; WHO5; Self-Reporting Questionnaire -20 (SRQ20); Patient Health Questionnaire (PHQ-8); Generalized Anxiety Disorder-7 (GAD-7)
Widyahening (2007) (Widyahening,	Identify the effect of work stressors and other factors on	Cross-sectional; subjective;	*n* = 109; 100%; < 40 years = 65%, > 40	Mental–emotional disturbance = 39%; poor physical conditions, high work	Symptom Checklist 90 (SCL90)

2007)	mental–emotional disturbances among airline pilots	Indonesia	years = 56%	stressors, and household tension were associated with mental–emotional disturbance	questionnaire
Wilson et al. (2021) (Wilson et al., 2021a)	Evaluate the efficacy of an intervention for enhancing health behaviours	Clinical trial; subjective; New Zealand	*n* = 79; 82%; 42 ± 12 years	Sleep = 7.2 ± 0.5 h; PSQI global score = 5.4 ± 2.7; weekly walking min = 110 ± 117; weekly MVPA min = 145 ± 72; < 150 MVPA min per week = 49%; fruit and vegetable intake (servings/day) = 3.6 ± 0.9; < 2 fruit (servings/day) = 65%; < 3 vegetables (servings/day) = 47%; < 5 fruit and vegetables (servings/day) = 84%; physical health score (SF-12v2) = 48 ± 7; mental health score (SF-12v2) = 51 ± 5	Pittsburgh Sleep Quality Index (PSQI); International Physical Activity Questionnaire (IPAQ) Short Form; Short Health Form 12v2 (SF-12v2); dietary recall
Wilson et al. (2022) (Wilson et al., 2022a)	Explore the prevalence and distribution of health risk factors in airline pilots and	Cross-sectional; subjective and objective; New	*n* = 504; 91%; 46 ± 10 years	BMI = 26.6; overweight = 51%; obesity = 16%; SBP = 131 ± 13; DBP = 81 ± 9; hypertension = 27%; sleep < 7 h = 34%;	International Physical Activity Questionnaire (IPAQ) Short Form; Short

	compare these with the general population	Zealand		sleep = 7 h 11 min; weekly MVPA = 141 ± 87; insufficient physical activity = 48%; physical health score (SF-12v2) = 47 ± 6; mental health score (SF-12v2) = 49 ± 8; fruit and vegetable intake (servings/day) = 3.7 ± 1.7; < 2 fruit (servings/day) = 60%; < 3 vegetables (servings/day) = 48%; < 5 fruit and vegetables (servings/day) = 68%; poor or fair self-rated health = 25%	Health Form 12v2 (SF-12v2); dietary recall
Wirawan et al. (2013) (Wirawan et al., 2013)	Investigate the prevalence of excessive CVD risk score	Cross-sectional; subjective and objective; Oceania	*n* = 595; 100%; 46 ± 12 years	BMI = 26.5 ± 4.0; smoking = 2%; alcohol consumption 5 ± 6 u/week; known hypertension = 6%; SBP = 128 ± 15; DBP = 78 ± 10; hyperlipidemia history = 10%; TC = 5.3 ± 1.1; HDL = 1.3 ± 0.5; TG = 1.1 ± 0.8; cholesterol–HDL ratio = 3.9 ± 1.4; pilots who	Instruments not specified

				were found to have 5-year CVD risk score of 10–15% or higher = 3.5%	
Wu et al. (2016a) (Wu et al., 2016a)	Investigate the prevalence of depression	Cross-sectional; subjective; international	*n* = 1826; 86%; not reported	13% of males and 11% of females met depression threshold; 4.1% reported suicidal thoughts within the past two weeks; 5% reported experiencing fatigue daily	Patient Health Questionnaire 9 (PHQ-9)
Wu et al. (2016b) (Wu et al., 2016b)	Characterize sleep behaviours	Cross-sectional; objective; international	*n* = 332; 100%; 52 years, range 23–64 years	Sleep = 7.6 h (self-report) and 6.8 h (objective); sleep ≤ 6 h = 23%; sleep > 9 h = 1%	Actigraphy and self-report

Note: AIS = Athens Insomnia Scale; BMI = body mass index; BP = blood pressure; CIS = Checklist Individual Strength; CRP = C-reactive protein; CSF = Chronic Fatigue Scale; CVD = cardiovascular disease; DBP = diastolic blood pressure; ESS = Epworth Sleepiness Scale; FSS = Fatigue Severity Scale; GAD-7 = Generalized Anxiety Disorder-7; HADS = Hospital Anxiety and Depression Scale; HDL = high-density lipoprotein; IPAQ = International Physical Activity Questionnaire; JSS = Jenkins Sleep Scale; KSS = Karolinska Sleepiness Scale; LDL = low-density lipoprotein; mmHg = millimeters of mercury; MS = metabolic syndrome; MVPA = moderate-to-vigorous physical activity; OSA = obstructive sleep apnea; PHQ-8 = Patient Health Questionnaire 8; PHQ-9 = Patient Health Questionnaire 9; PSQI = Pittsburgh Sleep Quality Index; SBP = systolic blood pressure; SCL90 = Symptom Checklist 90; SF-36 = Short Form 36-item Health Survey; SLS = Satisfaction with Life Scale; SRQ20 = Self-Reporting Questionnaire-20; TG = triglycerides; VAFS = Visual Analog Fatigue Scale; WHOQOL-BREF = World Health Organization Quality of Life Brief Form.

Discussion

To our knowledge, this is the first comprehensive synthesis of published research pertaining to physiological, behavioural, and psychological cardiometabolic health risk factors among this unique occupational group. Our findings provide stakeholders including aviation medical professionals, policymakers, researchers, clinicians, and occupational health authorities with a scientific synthesis of the magnitude of prevalence of cardiometabolic health risk factors among commercial pilots. These findings may be beneficial to inform developments in aviation health practices and policies to support pilot health and wellness, to mitigate risks of occupational morbidity, medical conditions causing loss of license, and medical incapacity, and to support flight safety (International Civil Aviation Authority, 2012).

Findings from the review suggest similar health risk factor prevalence to the general population, yet higher sleep duration, less physical activity, lower smoking rates, higher regular alcohol consumption, less obesity, and a higher overall rate of body mass index > 25 among pilots. We discovered, within the literature reviewed, a dominance of self-reported data, with most studies exhibiting moderate to high risk of methodological bias. Indeed, there are limited high-quality studies within the field, warranting the need for future research to address the gaps within and strengthen the body of knowledge.

Prevalence of Physiological Cardiometabolic Risk Factors among Pilots

As described by the International Civil Aviation Organization (ICAO) aviation medical regulations, cardiometabolic health risk data are acquired routinely during aviation medical examinations for pilots > 35 years old for CVD risk assessment, which include BMI, BP, resting heart rate, blood lipids, and HbA1c (International Civil Aviation Authority, 2012). In 2015, the global prevalence of overweight, obesity, and overweight plus obesity in the general population was reported as 38.7%, 16.4%, and 55.1%, respectively (GBD 2015 Obesity Collaborators, 2017). This general population estimate is relative to the country, age, and sex characteristics represented in the present review of studies conducted among pilots. Past research has reported a lower prevalence of overweight and obesity in pilots compared to the general population (De Stavola et al., 2012; Pizzi et al., 2008; Sykes et al., 2012). Indeed, the present review found that pilots had a 4.7% lower prevalence of obesity than the general population (GBD 2015 Obesity Collaborators, 2017). As obesity is a major risk factor for diseases such as CVD and T2D (Janssen et al., 2002), the lower rate of obesity within pilots may promote a lower pilot population cardiometabolic disease relative risk compared to the general population.

Interestingly, with overweight and obesity pooled together, we discovered that pilots had an overall 3.5% higher rate of overweight plus obesity compared to the general population (58.6% and 55.1%, respectively). This finding suggests that past reports of lower rates of overweight and obesity within pilots (De Stavola et al., 2012; Pizzi et al., 2008; Sykes et al., 2012) compared to the general population may be archaic, and future research should investigate the underlying causal mechanisms that contribute to overweight and obesity rates among pilots. A noteworthy consideration for interpretation of this information is the lack of random sampling and potential response bias within studies on pilots compared to the general population, which adds a notable limitation to the validity of prevalence comparisons between populations.

Most countries represented within the present review were high-income countries. In 2010, the global hypertension prevalence was estimated as 31.1% (30.0–32.2%), while that among high-income countries was estimated as 28.5% (27.3–29.7%) (Mills et al., 2016). We found four studies reporting the prevalence of hypertension within pilots, ranging from 11% to 29% (Bhat et al., 2019; Chen et al., 2016; Houston et al., 2010; Wilson et al., 2022a), with a pooled prevalence slightly lower than the general population at 27.6%. Airline pilots undergo regular medical examinations evaluating BP (International Civil Aviation Authority, 2012), and this regular active monitoring may promote the observed lower hypertension prevalence. However, one study reported a 38% (Alonso-Rodriguez & Medina-Font, 2012) prevalence of pilots exhibiting elevated BP (≥ 130/85 mmHg); thus, it would be valuable for future epidemiological research to report the prevalence of elevated BP, accompanying hypertension rates in order to better inform researchers on the distribution of BP ranges across the pilot population.

Prospective epidemiological studies have consistently reported that unfavorable blood lipid profiles are associated with increased incidence of metabolic syndrome (MS) and NCDs such as CVD (Kopin, 2017). We found three studies reporting the prevalence of markers of dyslipidemia in pilots, with prevalence of low HDL ranging from 8% to 57% and of elevated TG ranging from 24% to 29% (Alonso-Rodriguez & Medina-Font, 2012; Chairina et al., 2018; Chen et al., 2016) whereas MS prevalence ranged from 15% (Alonso-Rodriguez & Medina-Font, 2012) to 38% (Chen et al., 2016). These evident variances in prevalence rates based on the small sample of studies (*n* = 3) (Alonso-Rodriguez & Medina-Font, 2012; Chairina et al., 2018; Chen et al., 2016) illustrate the need for further research to be conducted regarding quantification of these risk factors in pilots to reach valid inferences of their prevalence.

The global prevalence of diabetes is rising, and it has been estimated that 49.7% of people living with diabetes are undiagnosed (Cho et al., 2018). Investigation of impaired glucose tolerance and hyperglycemia is scarce in the airline pilot literature, with only two studies reporting the prevalence of hyperglycemia (30.4–31.3%) (Alonso-Rodriguez & Medina-Font, 2012; Chen et al., 2016) and scant research reporting on the prevalence of elevated HbA1c, which is the leading diagnostic criteria for T2D (Cho et al., 2018). This dearth of information may be attributable to past barriers for diabetic pilots to operate commercials flights due to the risk of incapacitation from hypoglycemia while flying, yet recent advances in insulin therapies, monitoring techniques, and modes of administration have given rise to policy developments reducing barriers for diabetic pilots to operate commercial flights (Russell-Jones et al., 2021). Seemingly, there is a need for more research attention on glycemic control and identifying the prevalence of elevated risk markers for T2D among airline pilots.

Prevalence of Behavioural Cardiometabolic Risk Factors among Pilots

From the 31 studies we found reporting on behavioural risk factors, sleep was the most frequently reported risk factor (*n* = 21). Sleep disruption is an inherent risk for pilots as occupational characteristics such as extended duty periods, work schedules, crossing time zones, and sleep restrictions cause perturbance of sleep routine consistency (Wingelaar-Jagt et al., 2021). Recent research has indicated that sleep difficulty is frequently expressed as a primary source of work induced stress among pilots (Cahill et al., 2021). The present review found the mean pooled sleep hours per night to range from 7.0 h to 7.1 hours, indicating that the population mean falls within the lower range of sleep guidelines for health in adults, which has been reported as the attainment of 7–9 hours (Hirshkowitz et al., 2015). We found three studies reporting the prevalence of short sleep (< 6 hours) ranging from 20% to 23% (Aljurf et al., 2018;

van Drongelen et al., 2017; Wu et al., 2016b), which is comparably lower than a USA-based study noting a prevalence of ≤ 6 hours sleep as 29% among the general population in 2012 (Ford et al., 2015). Indeed, due to the influence of fatigue on flight safety, pilots are often subject to fatigue management training via aviation medical management (Petrie et al., 2004; Wingelaar-Jagt et al., 2021), facilitating the implementation of adaptive coping strategies to mitigate fatigue which may support the attainment of sleep guidelines within the population.

Past research has reported lower sex- and age-adjusted prevalence for smoking and higher levels of physical exercise among aircrews compared to the general population (Pizzi et al., 2008). Indeed, we found a pooled smoking prevalence of 9% among pilots, which is considerably lower than a 2015 prevalence estimate of 25% for smoking among the global male general population (Reitsma et al., 2017). Interestingly, for physical activity, we found a pooled prevalence of 51.5% for insufficient physical activity among pilots, which is markedly higher than a recent global prevalence estimate of 32% (30–33%) in 2016 among the general population within high-income countries (Guthold et al., 2018). However, our findings were only derived from four studies using self-recall data and small samples, making comparisons with the general population of scant validity. Future research utilising objective outcome measures is important to further evaluate the accuracy of current findings.

Alcohol use is a leading risk factor for global disease burden, with the global prevalence of current drinking estimated as 47% in 2017 (Manthey et al., 2019). According to five studies we found, the pooled mean for regular alcohol intake among pilots was 52%. However, the lack of quantity and the low-quality methodology among studies minimize the validity of prevalence estimation. Furthermore, pilots may be inherently biased to misrepresent their true alcohol intake to aviation medical professionals or researchers due to aviation regulations prohibiting alcohol consumption within 8 h of acting as a crew member and existing alcohol testing mandates (Kraus & Li, 2006).

Dietary behaviours are a leading risk factor for obesity and cardiometabolic diseases such as CVD and T2D (Aune et al., 2017). Previous studies have conveyed occupational factors such as inconsistent mealtimes, physical inactivity on duty, suboptimal airport and airline catering options, and shift work as factors that may be detrimental to healthy dietary patterns among pilots (Alonso-Rodriguez & Medina-Font, 2012; Sykes et al., 2012; Wilson et al., 2021b). There is a dearth of literature pertaining to the quantification of dietary behaviours among pilots, with only two studies identified in this review reporting the prevalence of pilots who were not achieving daily fruit and vegetable intake guidelines of ≥ 5 servings ranging from 68–84% (Wilson et al., 2021a; Wilson et al., 2022a). Although lacking validity, this estimate is comparable to the estimated global prevalence estimate of 79% derived from the World Health Survey 2002–2004 (Murphy et al., 2014), relative to the country and sex characteristics represented in the present review.

Prevalence of Psychological Cardiometabolic Risk Factors among Pilots

High levels of psychological fatigue are associated with elevated risk of CVD and excess mortality within the general population (Basu et al., 2016) and are detrimental to a pilot's ability to safely operate the aircraft or perform safety-related duties (International Civil Aviation Authority, 2012). We found the prevalence of elevated psychological fatigue to range from 5% to 77% (Alhejaili et al., 2021; Pellegrino & Marqueze, 2019; Pellegrino et al., 2019; Reis et al., 2013; Reis et al., 2016a; van Drongelen et al., 2014; van Drongelen et al., 2017; Venus, 2021; Wu et al., 2016a) and of severe psychological fatigue to range from 33% to 68% (Alhejaili et al., 2021; Aljurf et al., 2018). The heterogeneity of methodology among studies within pilots inhibits valid comparisons with the general population. Nonetheless, with numerous studies reporting noteworthy rates of elevated psychological fatigue during nonduty periods, this warrants further research regarding the development of innovative interventions to better facilitate fatigue mitigation in this occupational group.

Major depressive disorder is associated with elevated cardiometabolic risk factors and poor health outcomes (Lasserre et al., 2017). Depression and mental health issues among pilots have been proposed as contributing factors in numerous flight incidents resulting in mass casualties (O'Hagan et al., 2017). Thus, psychological risk factors are pertinent to pilot health and wellness and, in turn, flight operation safety. We discovered a pooled mean of 21% for mild depression (Alhejaili et al., 2021; Cahill et al., 2021; Guo et al., 2017; Venus, 2021; Wu et al., 2016a) among pilots. Comparatively, a prevalence of 21% for mild depression was reported within a general population sample using congruent methodology, delineating a similar prevalence between populations.

Study Strengths

To the authors' knowledge there is no published scientific synthesis of cardiometabolic health risk factor data for airline pilots. The studies included in the systematic review were derived from 20 different countries from around the globe. Therefore, the findings are not localized to a certain region and are relevant data pertaining to the global airline pilot population. This review revealed insights that diverge from previous assumptions regarding cardiometabolic health among airline pilots, thus providing useful data which may inform public health practice and the development of targeted initiatives to support occupational health and safety.

Study Limitations

As this review sought to identify baseline nonwork duty-related prevalence of cardiometabolic health risk factors, we did not examine risk factor quantification during or immediately following flight duty periods, as these work characteristics often elicit acute inflated risk prevalence for factors such as psychological fatigue, sleep disruption, and other psychological distress-related parameters (Marqueze et al., 2017; Sallinen et al., 2021). Thus, the present review did not capture the magnitude of work duty-induced perturbations to behavioural and psychological cardiometabolic health risks.

Furthermore, as we sought to identify the prevalence of cardiometabolic health risks among the overall airline pilot population, we did not stratify outcomes by fleet division, such as short-haul, long-haul, or mixed-fleet. The comparison of health risk prevalence between fleet divisions may be an appropriate scope for a future systematic review, which would add to the literature for understanding the magnitude of health risk difference between pilot rosters.

Due to the heterogeneity of publication dates among the literature featured in our review, the global general population prevalence comparison studies utilised may not optimally align with timepoints from studies among pilots and should be considered by readers with our presented population comparisons. Additionally, the heterogeneity of measurements of cardiometabolic parameters among the airline pilot studies reviewed and the general population estimates should be considered in the interpretation of our findings.

Lastly, the low quantity of robust studies limits the generalizability of the current findings reported within the literature. Future high-quality epidemiological research utilising validated measurements will be valuable to increase the probability of attaining reliable conclusions pertaining to the health risk prevalence within the pilot population. To provide further meaningful insight into pilot cardiometabolic health risk and to address gaps in the literature, research attention pertaining to the assessment of glycemic control (i.e., HbA1c) and blood lipids, objectively measured health behaviours (dietary behaviours, physical activity, alcohol intake), and wider assessment of depressive symptoms among the airline pilot population would provide valuable contributions to advance the body of knowledge.

Conclusion

The findings of this review provide synthesis on the prevalence and magnitude of cardiometabolic health risk factors among airline pilots. A wide range of prevalence rates were reported for many investigated health risk parameters in the literature, with pervasiveness of overweight and obesity, insufficient physical activity, elevated psychological fatigue, insufficient fruit and vegetable intake, and regular alcohol consumption among pilots. The inherent bias, dominance of self-report data, and heterogeneity of methodology mean that it was not possible to establish strong conclusions. Future research utilising objective measures and robust random sampling strategies are advocated to strengthen the validity of prevalence estimates and enhance the generalizability of findings.

CHAPTER THREE

The Prevalence and Distribution of Health Risk Factors in Airline Pilots: A Cross-Sectional Comparison with the General Population

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Prelude

As highlighted in Chapter Two, there is notable prevalence of cardiometabolic health risk factors among airline pilots on a global scale, including overweight and obesity, elevated blood pressure, and insufficient achievement of health guidelines for physical activity, nutrition, and sleep. Therefore, this chapter investigates cardiometabolic health risk factor prevalence among airline pilots in a local New Zealand context and draws direct comparisons with age, sex and ethnicity standardized general population estimates.

Abstract

The aim is to explore the prevalence and distribution of health risk factors in airline pilots and compare these with the general population. Health risk measures: age, sex, weight, height, body mass index (BMI), blood pressure, sleep, physical activity (PA), and fruit and vegetable intake (FV) were analyzed to determine the prevalence and distribution of health risk. Obesity prevalence and BMI was lower in pilots ($p = < 0.001$, -17.5%, $d = -0.41$, and $p = < 0.05$, -1.8, $d = -0.37$, respectively), yet overall overweight and obesity prevalence did not differ between groups ($p = 0.20$). No difference was observed between groups for hypertension ($p = 0.79$, $h = -0.01$), yet a higher proportion of pilots were "at risk" for hypertension ($p = < 0.001$, $h = -0.34$). The general population had longer sleep duration ($p = < 0.001$, $d = 0.12$), achieved more total PA minutes ($p = < 0.001$, $d = 0.75$), and had a higher prevalence of positive self-rated health ($p = < 0.001$, $h = 0.31$). More pilots achieved > 5 servings of FV daily ($p = 0.002$, $h = 0.16$). Pilots had lower obesity prevalence, higher FV, yet lower positive self-health ratings and total PA minutes, and shorter sleep duration overall. The results indicate notable health risk factor prevalence in airline pilots and the general population. Based on present findings, we advocate aviation health and occupational safety professionals and researchers to further examine targeted, cost-effective intervention methods for promoting healthy bodyweight, managing blood pressure, and enhancing health behaviours to mitigate risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety.

Key Words: Morbidity, non-communicable disease risk, health behaviour, overweight and obesity, hypertension, occupational health, diet, physical activity, sleep, subjective health.

Introduction

Generally, pilots are considered to have better health status than the general population (Houston et al., 2011; Sykes et al., 2012), however work characteristics of professional airline pilots may present unique risks which may negatively impact health (de Souza Palmeira & Cristina Marqueze, 2016; Liu et al., 2021; Miura et al., 2019; Reis et al., 2016b). Pilots are subject to circadian disruption from shift work and irregular flight schedules, perceived fatigue, cosmic ionizing radiation exposure, irregular mealtimes, mental stress demands associated with flight safety, the sedentary nature of the job, and noise, vibration and air quality of the cabin environment (Reis et al., 2016b; Sykes et al., 2012; van Drongelen et al., 2017; Wilson et al., 2021a). Some evidence has indicated an elevated incidence for melanoma and kidney disease compared to the general population (Miura et al., 2019; Sykes et al., 2012). Further, noteworthy risk prevalence has been reported for back pain (Albermann et al., 2020), obesity (de Souza Palmeira & Cristina Marqueze, 2016; Houston et al., 2011), metabolic syndrome (Chen et al., 2016), physical inactivity (van Drongelen et al., 2014; Wilson et al., 2021a), poor sleep (van Drongelen et al., 2014; Wu et al., 2016a), and depressive symptoms in pilots (Cahill et al., 2021).

In contrast, protective factors associated with being an airline pilot, such as socioeconomic status, the healthy worker effect, and being subject to regular medical examinations are thought to mitigate some health risk (Houston et al., 2011; Sykes et al., 2012). Indeed, based on some previous investigations (Houston et al., 2011; Sykes et al., 2012), pilots are generally considered to have a lower prevalence of non-communicable diseases (NCDs) and a lower risk for most health conditions than the general population. However, to date there is a limited literature base pertaining to the quantification of behavioural risk factors in airline pilots and the distribution of health risk factors among different age groups.

Non-communicable diseases such as cardiovascular disease, cancer, chronic respiratory diseases and diabetes are the leading cause of mortality worldwide (Bennett et al., 2020), highlighting the importance for community integration of measures to counteract NCDs. With global strategic targets to reduce premature deaths from NCDs (Bennett et al., 2020), surveillance and quantification of health risks associated with NCD pathogenesis are vital to inform health initiatives to prevent, manage or treat NCDs.

The global obesity prevalence nearly doubled from 7% in 1980 to 13% in 2015 (Chooi et al., 2019). Obesity is a complex, multifactorial, and largely preventable physiological state that adversely affects nearly all functions of the body and comprises a significant public health threat and NCD risk (Chooi et al., 2019). Chronic high blood pressure is associated with numerous cardiovascular system pathologies and is a leading risk factor for global disease burden, with the worldwide prevalence of hypertension estimated as 31.1% in 2010 (Mills et al., 2020).

Sleep, nutrition, and physical activity are each modifiable behavioural risk factors of chronic disease (Mozaffarian et al., 2008). Obtaining adequate sleep, habitually consuming healthy dietary patterns, and engaging in sufficient physical activity have a positive effect on physical and mental health (Mozaffarian et al., 2008; Wilson et al., 2021a), significantly lower all-cause mortality and likely attenuate numerous NCD pathogenic processes (Bellavia et al., 2013; Cappuccio et al., 2010; Lear et al., 2017). Global prevalence of physical inactivity in 2016 were estimated as 27.5%, with an elevated rate of 42.3% in high income Western countries (Guthold et al., 2018). Eighty-eight percent of countries were estimated to be on average consuming insufficient vegetable intake in 2013 (Kalmpourtzidou et al., 2020), and global figures indicating a decline in the average total number of hours of sleep obtained per night by adults (Chattu et al., 2018).

To date, the literature base pertaining to causal mechanisms between occupational factors and health outcomes in pilots is weak, and there is limited research quantifying the variance in health risk prevalence between pilots and the general population in New Zealand. The aim of this study is to explore the prevalence and distribution of NCD risk factors within airline pilots and compare these characteristics with an age and ethnicity matched general population representative sample.

Methodology

Design

A between-group, retrospective cross-sectional study was performed to evaluate the prevalence and distribution of health risk among airline pilots and the general population. This study examined health risk variables; age, sex, weight, body mass index (BMI), blood pressure, sleep duration, fruit and vegetable intake, physical activity levels, and self-rated health. The outcome measures selected for this study were congruent with the 2018-19 New Zealand Health Survey (NZHS) (Ministry of Health, 2020d), which was utilised to represent general population health risk data for comparison with pilots. This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand (reference number 2019#35).

Participants

The pilot population consisted of commercial pilots from an international airline. Five hundred and four pilots volunteered to participate in the study (see Table 6). Pilots were invited to participate in the study at the time of completing their routine aviation medical examinations between 5 November 2019 and April 2021. Participants were from a combination of short-haul and long-haul rosters (n = 261 and 243, respectively). Inclusion criteria were pilots who had a valid commercial flying license and worked on a permanent basis. All participants provided written informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wish to do so. Age, sex and ethnicity adjusted means, confidence intervals, and prevalence rates for health measures in the general population (n = 2,033) were derived from the 2018-19 NZHS dataset, a National annual health survey that utilises a geographic sampling strategy with weights representative of the resident population, which is detailed elsewhere (Ministry of Health, 2020d). Data were collected for the 2018-19 NZHS between 1 July 2018 to 30 June 2019. The NZHS micro-dataset was provided by Statistics New Zealand for analysis in this study.

Table 6: Demographic characteristics of the study populations.

Parameters	**All subjects (n = 2537)**	**Pilots (n = 504)**	**NZHS (n = 2033)**
Sex (f / m)	44 / 2547	44 / 460	0 / 2033
Age (y)	46 ± 11	46 ± 10	46 ± 12
Caucasian (f / m)	44 / 2481	44 / 448	0 / 2033
Māori (f / m)	0 / 3	0 / 3	0 / 0
Indian (f / m)	0 / 7	0 / 7	0 / 0
Asian (f / m)	2 / 1	2 / 1	0 / 0

Note: Mean ± SD reported for age, total values are reported for all other variables. Abbreviations: SD = standard deviation. f = female. m = male. NZHS = New Zealand Health Survey.

Procedures

At the time of their aviation medical appointment, pilots were invited to participate in the study by completing an electronic health questionnaire via an iPad (Apple, California, CA, USA) and providing consent to allow the researchers to access their anonymized aviation medical cardiovascular risk factor data. The electronic survey was constructed in Qualtrics software (Qualtrics, Provo, UT, USA) and consisted of questions pertaining to demographic information and health risk factor measures for sleep, nutrition, physical activity, and self-rated health. To support anonymity and dataset blinding during data analysis, participants were provided with a unique identification code on their informed consent form and were instructed to input it into their electronic survey instead of their name. Objective health risk measures for bodyweight and blood pressure were recorded by a clinical aviation medical professional during the pilot's aviation medical examination. All data from the NZHS were collected during interviews conducted at the respondent's home, which were carried out by a specialist survey provider contracted by the Ministry of Health (Ministry of Health, 2020d).

Outcome Measures

Age at the date of response was calculated using date of birth. Measurements of height for pilots was recorded with a SECA 206 height measure and bodyweight was measured using SECA 813 electronic flat scales (SECA, Hamburg, Deutschland). In the NZHS measurements for weight were recorded using Tanita HD-351 electronic weighing scales (Tanita, Tokyo, Japan) and height was recorded using laser height measurement (Ministry of Health, 2020b). For bodyweight measurement, scales were placed on a hard, flat surface and participants were wearing clothes and were asked to stand in the centre of the scales with their arms loosely by their sides and weight distributed on both feet. Two weight measurements were made to the nearest 0.1 kg. If the two measurements differed by more than 1 percent, a third measurement was made. The final weight measurement for each participant was calculated by averaging the two closest measurements. Data on height and weight were used to calculate body mass index (BMI), which was used to identify the proportion of participants who were underweight, a normal weight, overweight, or obese, as determined by scores of < 18.5, 18.5-24.9, 25-29.9, and > 30 (kg/m^2), respectively (Houston et al., 2011; Ministry of Health, 2020d).

Measurements of blood pressure in pilots were conducted according to a standardized aviation medicine protocol (Civil Aviation Authority, 2021). Two blood pressure readings were measured with an OMRON HEM-757 device in a sitting position with arm supported held at the level of the atria. If the two initial readings were < 140/< 90, the lowest reading was recorded. If levels were > 140/> 90, two further readings at several minutes' intervals were taken. Measurements of blood pressure in the NZHS were made using standardized protocol (Ministry of Health, 2020b) using an OMRON HEM-907 device, which automatically records heart rate, systolic and diastolic blood pressure three times, with a 1-minute pause between measurements. Blood pressure ranges were classified "normal", "at risk", and "hypertension" as determined by values (systolic/diastolic) < 120/< 80, 120-139/80-89, and > 140 and/or > 90, respectively (Chobanian et al., 2003).

Physical activity levels were assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF), a validated self-report measurement tool of moderate-to-vigorous physical activity (MVPA) that has been widely utilised in large cohort studies including the NZHS (Ministry of Health, 2020b). The IPAQ-SF estimates physical activity achievement by quantifying weekly walking, moderate and vigorous physical activity duration and frequency. IPAQ-SF outcome measures derived were total weekly minutes of moderate and vigorous physical activity in bouts of ≥ 10 min, excluding walking (MVPA) and total weekly minutes of walking in bouts of ≥ 10 min. Responses were capped at 3h/day and 21 h/week as recommended by IPAQ Guidelines (IPAQ Research Committee, 2005). Physical activity guidelines for health are > 150 minutes moderate-intensity, or 75 minutes vigorous-intensity, or an equivalent combination MVPA per week (World Health Organization, 2010). Responses from the IPAQ were used to identify proportions of participants who were either obtaining little or no physical activity (< 30 min MVPA), insufficient physical activity (30-149 min MVPA), sufficient physical activity (150-299 min MVPA), or exceeding guidelines (> 300 min MVPA).

Fruit and vegetable intake were measured using two questions with acceptable validity and reliability derived from the New Zealand Health Survey (Ministry of Health, 2020b). The questions asked participants to report on average, over the last week how many servings of fruit and vegetables they eat per day. Showcards were utilised to help improve respondent engagement and the accuracy of their responses (Ministry of Health, 2020a). Responses to these questions were used to determine the proportion of participants who achieved daily intake health guidelines of ≥ 2 fruit servings, ≥ 3 vegetable servings, and ≥ 5 fruit and vegetable servings combined (Bellavia et al., 2013).

Average self-reported sleep duration was measured via one question which asked how much sleep the respondent usually gets in a 24-hour period, during the last month. Responses from this question were used to identify the proportion of participants who achieved health guidelines of ≥ 7 hours of sleep per night (Cappuccio et al., 2010).

Prospective cohort research suggests self-report health to be strongly associated with mortality risk and provides clinical and epidemiological value (Lorem et al., 2020). Subjective self-rated health was measured using a the questions derived from the Short Health Form 12v2 (SF-12v2), a short version of the SF-36 has demonstrated high correlation with SF-36 scores (Ware et al., 1995) and has demonstrated good test-retest reliability and convergent validity to detect changes in mental and physical health in adults (Cheak-Zamora et al., 2009). Responses were used to determine the responses for two discrete categories: (a) poor or fair self-rated health and (b) good, very good or excellent self-rated health. All self-report health measures were congruent with those reported in the NZHS.

Statistical Analysis

The NZHS data presented was age, sex and ethnicity adjusted to match the pilot population data. We reported absolute numbers, percentages, 95% confidence intervals (CIs), or means with standard deviations (mean ± SD). We calculated the prevalence and Clopper-Pearson binominal 95% CIs (exact method) for health risk measures and derived comparative values of the general population from the NZHS dataset. Additionally, we calculated the distribution by age group for each health risk. Subjects were categorised into age groups: 25-34y, 35-44y, 45-54y, and 55-64y, which were congruent with the NZHS data reporting. Adult age groups 18-24y and ≥ 65y were not included in this study due to no pilot respondents within these age groups. Age-specific incidence rates among pilots were compared with corresponding rates in the general population of the NZHS.

Mean values for all outcome measures pertaining to each pilot age group was compared with the mean value for the corresponding age-sex-ethnicity adjusted group of the general population using a factorial analysis of variance (ANOVA). Health risk prevalence comparisons of significance between populations were performed with a Chi-squared test. To evaluate magnitude of differences, effect sizes were produced utilising Cohen's h for proportions and Cohen's d for means (Cohen, 1988). The magnitude of each effect size was interpreted using thresholds of 0.2, 0.5 and 0.8 for *small*, *moderate* and *large*, respectively (Cohen, 1988). The α level was set at a p value of less than 0.05.

Raw data from survey responses were extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into statistical software SPSS v24 for Windows (IBM, New York, NY, USA) and MedCalc Statistical Software v20 (MedCalc, Ostend, Belgium, https://www.med-calc.org). Listwise deletion was applied for individual datasets with missing values or participants who did not complete all electronic survey components.

Results

The pilot population was heavily skewed towards male sex (91.2%) and Caucasian ethnicity (97.4%), which excluded analysis of data on female pilots and non-Caucasian ethnicities due to inadequate sample size to detect meaningful inferences for these subgroups. Similar demographic trends have been published in previous studies within commercial pilots (Houston et al., 2011; Sykes et al., 2012). Therefore, from the 504 pilots who volunteered to participate in this study, 460 were included in the data analysis. From the 13,572 adult responses available in the NZHS 2018/19, data from 2033 general population participants were included in our analysis after adjustment for age-sex-ethnic demographics of the pilot population. The NZHS recruited participants evenly among the age groups, whereas the age distribution of the airline pilots was more reflective of a working population with fewer pilots in the youngest and oldest age groups.

The health risk characteristics among pilots and the general population are given in Table 7 and comparison of health risk prevalence between groups are presented in Table 8. On average, pilots were significantly taller ($p = < 0.05$, $d = 0.45$) and had a lower BMI across all age groups ($p = < 0.05$, $d = 0.37$). Further, pilots had shorter sleep duration in age 45-54 y ($p = < 0.05$, $d = -0.19$), higher average blood pressure in age 35-44y ($p = < 0.001$, $d = 0.29$), and lower total weekly PA minutes across all age groups ($p = < 0.001$, $d = 0.74$-0.78) (see Table 7).

Table 7: Demographic and health risk characteristics among airline pilots and the general population.

	Airline pilots (n = 460)				General population (n = 2033)							
	25-34y (n = 68)	35-44y (n = 134)	45-54y (n = 153)	55-64y (n = 105)	25-34y (n = 433)	ES	35-44y (n = 438)	ES	45-54y (n = 527)	ES	55-64y (n = 635)	ES
Objective measures												
Height (cm)	182 (181-184)	181 (180-182)	180 (179-181)	179 (178-180)	178 (178-179)**	0.60	179 (178-179)*	0.27	178 (177-178)**	0.45	176 (175-176)**	0.48
Weight (kg)	86 (82-90)	86 (84-88)	88 (86-90)	87 (85-89)	88 (86-89)	-0.07	90 (88-91)*	-0.21	91 (89-93)*	-0.19	90 (88-91)	-0.17
BMI (kg/m^2)	25.9 (25-27)	26.3 (26-27)	27 (26-27)	27 (27-28)	28 (27-28)*	-0.33	28 (28-29)**	-0.35	29 (28-29)**	-0.38	29 (28-30)**	-0.40
Systolic BP (mmHg)	129 (126-132)	129 (127-131)	131 (129-133)	136 (133-138)	126 (125-127)	0.19	126 (125-127)*	0.23	130 (128-131)	0.08	135 (134-137)	0.02
Diastolic BP (mmHg)	76 (74-78)	80 (78-80)	83 (81-84)	84 (83-86)	74 (73-75)	0.17	76 (75-77)**	0.33	80 (79-81)*	0.24	80 (79-81)**	0.41
Average BP (mmHg)	102 (100-105)	104 (103-106)	107 (105-108)	110 (108-112)	100 (99-101)	0.20	101 (100-102)*	0.29	105 (104-106)	0.16	107 (106-109)	0.18
Subjective measures												
Sleep (hours)	7.3 (7.1-7.5)	7.1 (7.0-7.2)	6.9 (6.8-7.1)	7.0 (6.9-7.2)	7.4 (7.3-7.5)	-0.08	7.1 (7.0-7.2)	-0.06	7.2 (7.1-7.3)*	-0.19	7.1 (7.0-7.2)	-0.07
Total PA (min)	219 (194-245)	217 (199-235)	220 (201-239)	204 (185-224)	1001 (899-1103)**	-0.78	919 (816-1022)**	-0.73	859 (775-943)**	-0.74	872 (799-945)**	-0.77
Health “Excellent” (n,%)	1 (1.5%)	2 (2%)	2 (1%)	2 (2%)	42 (10%)	-0.39	53 (12%)	-0.46	49 (9%)	-0.39	73 (12%)	-0.42
Health “Very good” (n,%)	17 (25%)	22 (16%)	13 (9%)	11 (11%)	196 (45%)	-0.43	164 (37%)	-0.48	217 (41%)	-0.80	221 (35%)	-0.60
Health “Good” (n,%)	39 (57%)	81 (60%)	95 (62%)	59 (56%)	142 (33%)	0.50	167 (38%)	0.45	191 (36%)	0.52	249 (39%)	0.34
Health “Fair” (n,%)	10 (15%)	25 (19%)	37 (24%)	29 (28%)	48 (11%)	0.11	46 (11%)	0.23	60 (11%)	0.34	66 (10%)	0.45
Health “Poor” (n,%)	1 (1.5%)	4 (3%)	6 (4%)	4 (4%)	5 (1%)	0.03	8 (2%)	0.08	10 (2%)	0.12	26 (4%)	-0.02

Note: Data are means with Copper-Pearson 95% CIs in parentheses or counts and percentages in parentheses. * Indicates statistical significance ($p < 0.05$). ** Indicates statistical significance ($p < 0.001$). Abbreviations: n = sample size. BMI = Body Mass Index. PA

= Physical Activity. Total PA = combined weekly walking, moderate and vigorous physical activity minutes. BP = Blood Pressure. Average BP = systolic/diastolic. ES = Effect Size (Cohen's *d* for means and Cohen's *h* for percentages).

Table 8: The prevalence of health risk factors among airline pilots and the general population overall.

	Pilots (n = 460)	**NZHS (n = 2033)**	***p value***	**Effect size (Cohen's *h*)**	**OR (95% CI)**
Bodyweight					
Underweight BMI	4/460 (0.9%)	11/2033 (5.0%)	0.411	0.16	1.60 (0.50 – 5.06)
Normal weight	149/460 (32.4%)	515/2033 (25.3%)	0.002	0.16	1.27 (1.03 – 1.57)
Overweight	235/460 (51.1%)	833/2033 (41.0%)	< 0.001	0.20	1.24 (1.03 – 1.48)
Obese	72/460 (15.7%)	674/2033 (33.2%)	< 0.001	-0.41	0.47 (0.36 – 0.61)
Blood pressure					
Normal	88/460 (19.1%)	745/2033 (36.6%)	< 0.001	-0.39	0.52 (0.40 – 0.66)
At risk	250/460 (54.3%)	758/2033 (37.3%)	< 0.001	0.34	1.45 (1.22 – 1.73)
Hypertension	122/460 (26.5%)	527/2033 (25.9%)	0.791	0.01	1.02 (0.81 – 1.27)
Sleep					
< 5 hours per night	0/460 (0.0%)	45/2033 (2.2%)	0.001	-0.30	0.04 (0.00 – 0.78)
5-6 hours per night	3/460 (0.7%)	93/2033 (4.6%)	< 0.001	-0.26	0.14 (0.04 – 0.45)
6-7 hours per night	151/460 (32.8%)	360/2033 (17.7%)	< 0.001	0.35	1.85 (1.49 – 2.29)
7-8 hours per night	263/460 (57.2%)	697/2033 (34.3%)	< 0.001	0.46	1.66 (1.40 – 1.98)
8-9 hours per night	39/460 (8.5%)	666/2033 (32.8)	< 0.001	-0.63	0.25 (0.18 – 0.36)
> 9 hours per night	4/460 (0.9%)	172/2033 (8.5%)	< 0.001	-0.40	0.10 (0.03 – 0.27)
Nutrition					
< 2 fruit servings	277/460 (60.2%)	1156/2033 (56.9%)	0.189	0.07	1.05 (0.89 – 1.24)
> 2 fruit servings	183/460 (39.8%)	877/2033 (43.1%)	0.189	-0.07	0.92 (0.76 – 1.11)
< 3 vegetable servings	220/460 (47.8%)	1069/2033 (52.6%)	0.065	-0.10	0.90 (0.76 – 1.08)
> 3 vegetable servings	240/460 (52.2%)	964/2033 (47.4%)	0.065	0.10	1.10 (0.92 – 1.30)

< 5 fruit and vegetable servings	313/460 (68.0%)	1524/2033 (75.0%)	0.002	-0.16	0.90 (0.77 – 1.06)
> 5 fruit and vegetable servings	147/460 (32%)	509/2033 (25.0%)	0.002	0.16	1.27 (1.03 – 1.57)
Physical Activity					
Little or none	40/460 (8.7%)	193/2033 (9.5%)	0.596	-0.03	0.91 (0.64 – 1.30)
Insufficient	181/460 (39.3%)	669/2033 (32.9%)	0.008	0.13	1.19 (0.98 – 1.45)
Sufficient	208/460 (45.2%)	108/2033 (5.3%)	< 0.001	1.01	8.51 (6.60 – 10.96)
Heavy	31/460 (6.7%)	1063/2033 (52.3%)	< 0.001	-1.09	0.12 (0.08 – 0.18)
Self-rated health					
Poor or fair	116/460 (25.2%)	269/2033 (13.2%)	< 0.001	0.31	1.90 (1.49 – 2.42)
Good, very good or excellent	344/460 (74.8%)	1764/2033 (86.8%)	< 0.001	-0.31	0.86 (0.73 – 1.00)

Note: Data are proportion counts with percentage in parentheses. NZHS = New Zealand Health Survey. BMI = Body mass index. OR = Odds ratio.

The prevalence and distribution of health risk factors between pilots and the general population across age groups are depicted in Figure 4. Both groups had an increase in the prevalence of overweight and obesity, hypertension, short sleep, and poor and fair self-rated health with increased age (see Figure 4). Pilots had significantly lower (p = < 0.001, d = -0.41) prevalence of obesity across all age groups (see Figure 4). Overall, the difference between the prevalence of overweight and obesity was not statistically significant between the general population and pilots (p = 0.20, 74.5% and 66.8%, respectively).

The prevalence of hypertension did not significantly differ between groups overall (p = 0.79, h = -0.01). A significantly higher proportion of pilots were "at risk" for hypertension (p = < 0.001, h = -0.34). For the age group 35-44y, pilots had significantly higher prevalence of hypertension (p = < 0.001, h = 0.16), whereas pilots aged 55-64y had a significantly lower prevalence (p = 0.03, h = -0.11).

Overall self-report sleep duration was higher in the general population compared to pilots ($p = < 0.001$, $d = 0.12$, 7h 3.6min and 7h 11.4min, respectively). The proportion of participants who achieved > 7 hours of sleep per night was higher in the general population compared to pilots overall ($p = 0.12$, 75.5% and 66.5%, respectively) and was significantly higher for age groups 25-34y, 45-54y, and 55-64y ($p = < 0.05$, $h = 0.32$, 0.20, 0.14, respectively).

More pilots achieved > 5 servings of self-report fruit and vegetables daily compared to the general population ($p = 0.002$, $h = 0.16$). Total self-report PA weekly minutes were significantly higher in the general population across all age groups ($p = < 0.001$, $d = 0.74$-0.78), yet there was no overall significant difference in the prevalence of achieving > 150 min MVPA per week ($p = 0.22$, $h = 0.11$).

The prevalence of self-rated health being “good”, “very good” or “excellent” was significantly higher in the general population compared to pilots ($p = < 0.001$, $h = 0.31$), with the prevalence of “poor” or “fair” ratings increasing with age in both groups.

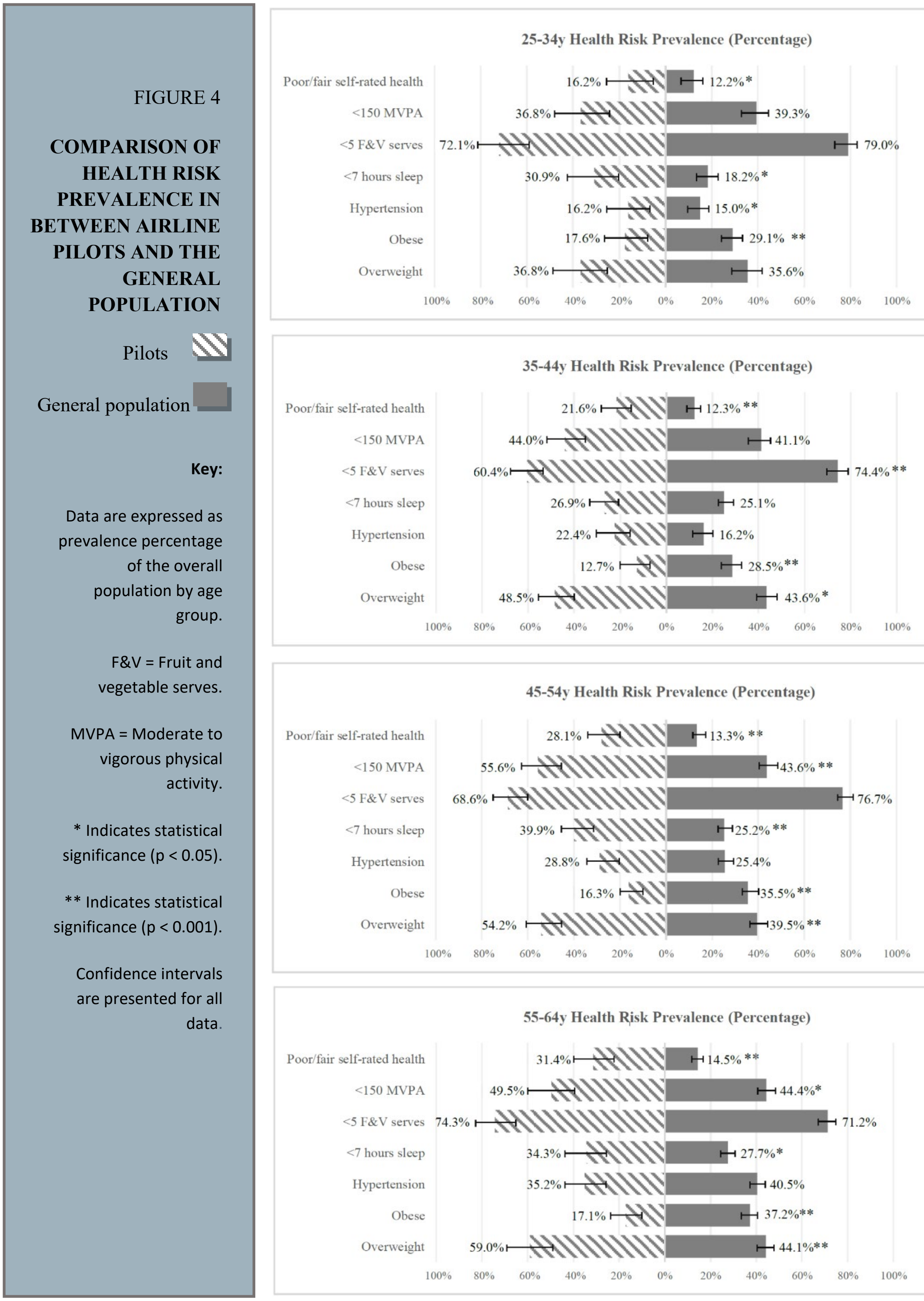

Figure 4: Comparison of health risk prevalence in between airline pilots and the general population.

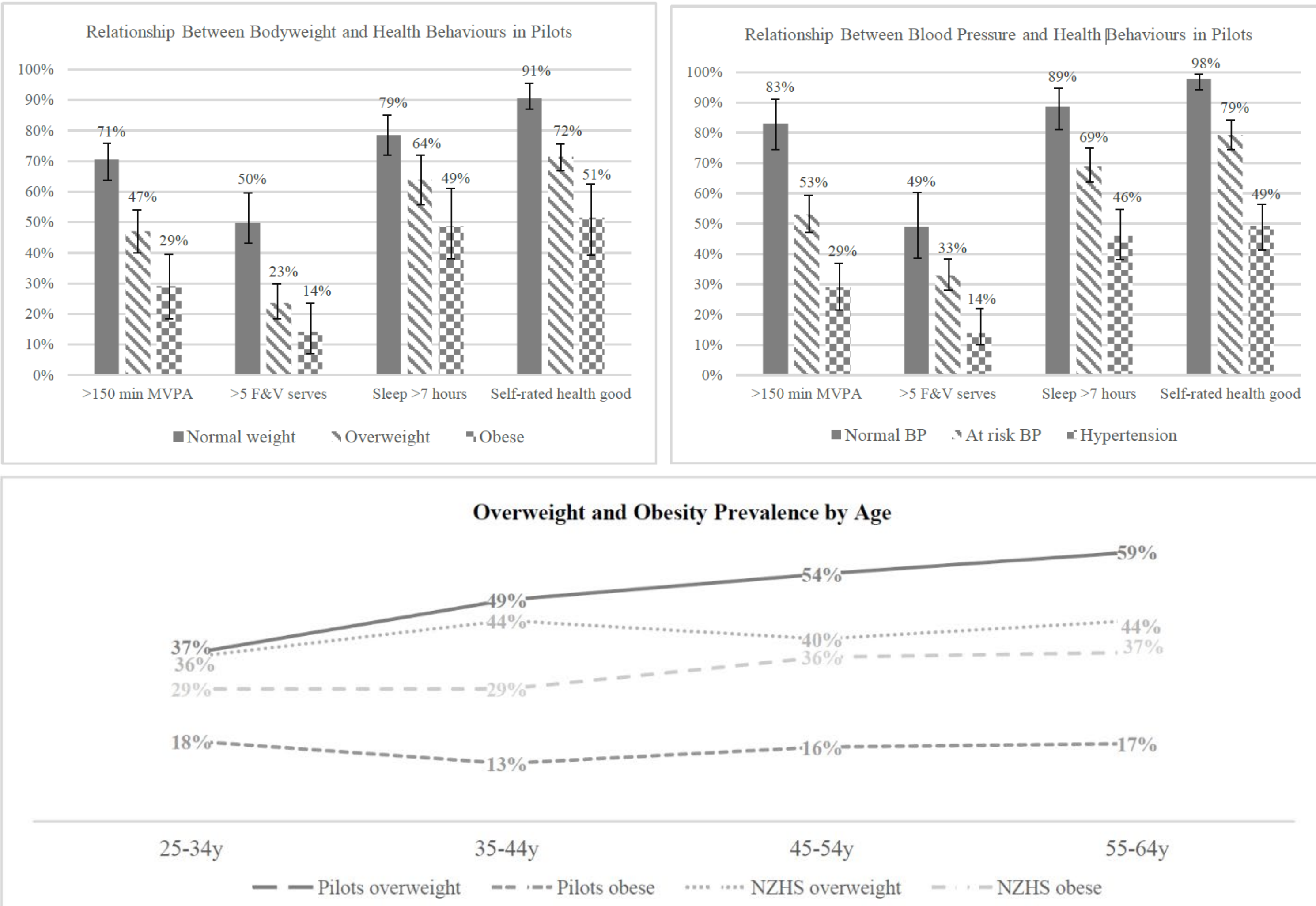

FIGURE 5

HEALTH RISK TRENDS WITHIN AIRLINE PILOTS

Key:

Data are expressed as prevalence percentage of the overall population.

F&V = Fruit and Vegetable serves.

MVPA = Moderate to vigorous physical activity.

The “underweight” bodyweight category was omitted from Chart 1 due to insufficient sample size for this subgroup (n = 4).

Figure 5: Health risk trends within airline pilots.

Discussion

To our knowledge, no previous studies have explored physical, health behaviour and self-report health risk factors together in an independent cross-sectional study among airline pilots, nor have any studies compared health behaviour characteristics in this occupational group with the general population. Some of our findings pertaining to demographic and health risks were identified that are consistent with past research in pilots. These included a high proportion of male pilots compared to females (Houston et al., 2011; Sykes et al., 2012), pilots having lower incidence of a BMI exceeding 25 (overweight and obesity) (Houston et al., 2011; Sykes et al., 2012), and notable prevalence of risk factors pertaining to sleep (van Drongelen et al., 2014; Wu et al., 2016a), nutrition (Wilson et al., 2021a), and physical activity (de Souza Palmeira & Cristina Marqueze, 2016; Wilson et al., 2021a). Our research adds preliminary quantification of the prevalence of hypertension in NZ pilots and behavioural health risk factors sleep duration, fruit and vegetable intake and physical activity in pilots, which to date have been largely unexplored in the literature.

Studies have previously examined cardiovascular disease related health risk factors within commercial pilots. Past research in NZ pilots identified the mean BMI as 27.1 and obesity incidence as "almost 20%" (Sykes et al., 2012). Comparatively, we found an overall lower mean BMI of 26.6 and an obesity prevalence of 15.7%. Overall, we found pilots had a significantly lower prevalence obesity than the general population. Similarly, a previous cross-sectional United Kingdom (UK) based study reported significantly lower overweight and obesity in pilots (46.8% and 12.4%, respectively) compared to the general population (47% and 21%, respectively), with a significantly lower overall mean BMI in pilots (Houston et al., 2011). The prevalence in other countries have been reported as 39% (Bhat et al., 2019) and 53.7% (Alonso-Rodriguez & Medina-Font, 2012) for overweight and 7.3% (Bhat et al., 2019), and 14.6% (Alonso-Rodriguez & Medina-Font, 2012) for obesity, in Indian and Spanish pilots, respectively.

In the present study, an evident trend across age groups were statistically significant higher rates of overweight and lower rates of obesity in pilots compared to the general population, which is congruent with previous research (Houston et al., 2011). Thus, although the overall prevalence of overweight and obesity were not significantly different to the general population, less pilots are categorised as obese, which is associated with increased NCD risk compared to those who are <

29 BMI (Janssen et al., 2002). Consequently, the pilot population may have lower risk of obesity-related disease incidence than that of the general population. Previous studies have proposed potential protective factors which may contribute to mitigation of adverse health outcomes in pilots, including the healthy worker effect, pilot's being subject to regular medical examinations, and socioeconomic status (Pizzi et al., 2008; Sykes et al., 2012).

To our knowledge, hypertension incidence has not been previously reported for NZ pilots. Within UK pilots, a significantly higher prevalence of hypertension was reported for males in age groups < 25y and 35-44y, with significantly lower rates in age groups 45-54y and 55-64y, compared to the general population (Houston et al., 2011). We found an overall pilot population hypertension prevalence of 26.5%, and higher rates of hypertension in pilots across ages 25-54y compared to the general population, yet only the 35-44y age group was statistically significant. Comparatively, this incidence rate is lower than previously reported hypertension rates of 28.3% in Chinese pilots (Chen et al., 2016), 28.7% in UK pilots (Houston et al., 2011), and 38% in Spanish pilots (Alonso-Rodriguez & Medina-Font, 2012). Conversely, a much lower hypertension rate of 4.1% was reported in a sample of Indian pilots (Bhat et al., 2019).

A limited number of studies have reported sleep duration, dietary behaviours and physical activity within airline pilots and there are no studies comparing these health behaviours of pilots with the general population. There is a dearth of literature pertaining to the distribution of sleep duration among different pilot age groups. We found 66.5% of pilots overall achieved ≥ 7 hours of sleep, which was 9% lower than the general population. Further, we observed sleep duration decreased with increased age in both groups, which is consistent with previously reported age associated degradation of sleep quality and quantity (Li et al., 2018). Pilots had an average sleep duration of 7 hours and 4 minutes overall, with no difference to the general population for age groups below 45y, however a reduced sleep duration in age groups > 45y compared to groups younger that 45y was noted, which was significantly lower than the general population. Indeed, a previous study identified > 64% of pilots achieve less than 7 hours of sleep per night on average during off duty periods (van Drongelen et al., 2014). Whereas another study objectively measured sleep and reported 23% pilots averaged < 6 hours of sleep habitually (Wu et al., 2016a). Sleep disruption is an inherent risk for pilots, who have occupationally induced perturbations to the natural circadian rhythm, including shift work, extended duty periods, traveling across time zones, sleep restrictions associated with short layovers, regularly changing work/rest schedules, and regular changes in the sleeping environment (for example, at home, on board, and in hotels) (Caldwell, 2005; Roach et al., 2012a), all of which may contribute to a lower sleep duration in contrast to the general population. Furthermore, long-haul pilots often do not follow a normal day/night sleep pattern with a single long sleep at night-time as do the general population. For example, a long-haul pilot may have a pre-flight nap, potentially multiple short sleeps in the crew bunk during the flight (1 to 2 hours), and then a 4-to-5-hour post-arrival sleep, followed by an overnight sleep on subsequent layover nights and then repeating the process on the return leg. Thus, self-report questions pertaining to average sleep in a 24-hour period may be difficult to interpret for pilots and may influence the overall average sleep duration reported.

Occupational duties of airline pilots involve prolonged periods of sedentary time sitting in the cockpit and at airports (de Souza Palmeira & Cristina Marqueze, 2016; Sykes et al., 2012). Insufficient physical activity is a prevalent source of work related stress (Cahill et al., 2021) and indeed, lower levels of physical activity are associated with daytime sleepiness and fatigue in pilots (van Drongelen et al., 2017). Our study is the first to explore the proportion of pilots attaining the World Health Organization's MVPA guidelines (World Health Organization, 2010) compared with the general population. Fifty-one percent of pilots achieved ≥ 150 min MVPA per week, compared to 57.6% in the general population, indicating nearly half of the overall population in both groups were not sufficiently physically active. These findings are similar, yet higher than a previously reported 42.3% global estimate of physical inactivity in high-income Western countries (Guthold et al., 2018). Two previous studies have reported weekly physical activity on average, to be < 150 minutes of MVPA per week within pilot populations (de Souza Palmeira & Cristina Marqueze, 2016; Wilson et al., 2021a), whereas two other studies reported days per week achieving ≥ 30 minutes of moderate activity as 3.2 to 3.4 days per week (van Drongelen et al., 2014; van Drongelen et al., 2017). To date, the limited evidence base suggests low rates of physical activity in pilots, yet no research has critically examined the validity of self-report physical activity measurements compared to objective measures such as accelerometry in pilots.

Work related characteristics of pilots including irregular and long duty periods, perceived fatigue, disrupted sleep, and unhealthy food availability in the work environment may affect dietary behaviour (Cahill et al., 2021; Reis et al., 2016b; Sykes et al., 2012). Our study is the first to explore the proportion of pilots who achieve the widely advocated health behaviour of consuming ≥ 5 servings of fruit and vegetables per day for health risk reduction benefits (Bellavia et al., 2013). A previous study in a small sample (n = 79) of NZ based airline pilots reported an average of 3.6 servings of fruit and vegetable per day (Wilson et al., 2021a), yet extremely few published studies have addressed dietary behaviours in pilots.

We found the proportion of pilots overall who achieved a daily intake of ≥ 5 servings of fruit and vegetable was significantly higher than the general population ($p = 0.002$, 32% and 25%, respectively). Nevertheless, over two-thirds of pilots and the general population were not achieving fruit and vegetable intake guidelines, highlighting the major prevalence of this behavioural risk factor. Similarly, a global epidemiological analysis reported 88% of countries they examined did not achieve vegetable intake guidelines (Kalmpourtzidou et al., 2020). Thus, evidence-driven interventions to encourage vegetable consumption are of public health importance (Kalmpourtzidou et al., 2020).

In our study, a relationship between health behaviours, overweight and obesity was evident, where overweight and obesity were associated with lower fruit and vegetable intake, less weekly MVPA and shorter sleep duration compared to pilots having a BMI of ≤ 25 (see Figure 5). These findings are comparative to a previous study within Brazilian pilots, which identified factors associated with obesity were sleeping < 6 h on days off, < 150 min of weekly physical exercise, number of years working as a pilot, and presence of daytime sleepiness (de Souza Palmeira & Cristina Marqueze, 2016). Further, a cross sectional investigation into health-related quality of life and its related factors among civilian pilots concluded physical activity and fruit and vegetable intake were positively correlated with quality of life (Liu et al., 2021). Thus, targeted strategies to improve health behaviour in pilots may promote healthy weight, blood pressure management and quality of life, yielding positive NCD risk reduction effects.

Limitations of this study need to be considered regarding interpretation of our findings. Firstly, as outcome measures were recorded for pilots in the aviation medicine clinic during their routine aviation medical examination, and data collected for the general population in their home residence, these environmental differences may have potential influence on findings. In particular, in clinic blood pressure measurement may be less accurate in detection of true resting blood pressure values than measurement at home (Sivén et al., 2016) and may account for the increase in blood pressure observed in pilots. Nevertheless, measurements were taken congruent with standardized aviation medicine blood pressure protocols (Civil Aviation Authority, 2021) which are established to mitigate the risk of false readings. Future research in pilots should investigate home blood pressure measurement readings compared to blood pressure recordings during aviation medical examinations to quantify whether significant environmental variance exist. Secondly, as pilot population data collection coincided with the emergence of the COVID-19 pandemic, the global novel pandemic environmental circumstances may have influenced some differences observed between study populations. Third, some self-selection bias may be present due to those pilots who voluntarily participated may be more likely to have a greater active interest in their personal health than pilots who did not choose to participate. Finally, for feasibility reasons self-report methods were utilised in this study. These methods have their own inherent limitations including reliance on participant recall ability and they are subject to over or under estimation responses (Brutus et al., 2013). To strengthen the validity of our findings and better inform targeted health promotion interventions for pilots, future research should examine dietary behaviours via direct or indirect measures of dietary recall, such as photo food logging, food frequency questionnaires and 24-hour recalls on both flying and non-flying days, to provide more comprehensive characterization of dietary patterns in this occupational group. Further, quantification of sleep patterns and habitual physical activity levels should be explored using objectives methods such as actigraphy.

Civil Aviation Regulators are required to apply safety management principles to the pilot medical assessment process, evaluate data on areas of increased health risk, and implement appropriate health promotion for pilots to reduce future medical risks to flight safety, as outlined in the International Civil Aviation Organization's Annex 1 (International Civil Aviation Authority, 2018a). Based on present findings, we advocate aviation health and occupational safety professionals and researchers to further examine targeted, cost-effective intervention methods for promoting healthy bodyweight, managing blood pressure, and enhancing health behaviours to mitigate risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety.

Conclusion

This study found pilots had similar prevalence of NCD risk factors with the general population overall, yet a lower incidence of a BMI exceeding 30 (obesity) and a higher fruit and vegetable intake than the general population. We found preliminary evidence of those "at risk" for hypertension, less total weekly physical activity, shorter sleep duration, and lower self-rated health than the general population. Both pilots and the general population had an increase in the prevalence of overweight and obesity, hypertension, short sleep, and poor and fair self-rated health with increased age. Future research should investigate home blood pressure measurement and health behaviour quantification with objective measures to strengthen the validity of our study's findings.

CHAPTER FOUR

Healthy Nutrition, Physical Activity, and Sleep Hygiene to Promote Cardiometabolic Health of Airline Pilots: A Narrative Review

Wilson, D., Driller, M., Johnston, B., & Gill, N. (Under review). Healthy Nutrition, Physical Activity, and Sleep Hygiene as Preventive Medicine for Airline Pilots: A Narrative Review. *Journal of Lifestyle Medicine.*

Prelude

Chapter Two and Chapter Three identified the prevalence of cardiometabolic health risk factors among airline pilots. These findings highlighted the need for effective intervention methods for promoting healthy bodyweight, managing blood pressure, and enhancing health behaviours to mitigate the risks of occupational morbidity, medical conditions causing loss of license, and to support flight safety. This chapter provides practitioners with important information regarding health behaviour characteristics of airline pilots and evidence-based considerations for health promotion intervention development.

Abstract

Airline pilots experience unique occupational demands which may contribute to adverse physical and psychological health outcomes. Epidemiological reports have shown substantial prevalence of cardiometabolic health risk factors including excessive body weight, elevated blood pressure, poor lifestyle behaviors, and psychological fatigue. Achieving health guidelines for lifestyle behaviors nutrition, physical activity, and sleep are protective factors against noncommunicable disease (NCD) development and may mitigate unfavorable occupational demands of airline pilots. This narrative review examines (a) occupational characteristics for sleep, nutrition and physical activity, and (b) outlines evidence-based strategies to inform health behavior interventions to mitigate cardiometabolic health risk factors among airline pilots. Literature sources published between 1990 and 2022 were identified through electronic searches in PubMed, MEDLINE (via OvidSP), PsychINFO, Web of Science, and Google Scholar databases and official reports and documents were reviewed from regulatory authorities pertaining to aviation medicine and public health. The literature search strategy consisted of key search terms relating to airline pilots, health behaviors, and cardiometabolic health. The inclusion criteria for literature sources were peer-reviewed human studies, meta-analyses, systematic reviews, and reports or documents published by regulatory bodies. The results of the review discuss occupational factors influencing nutrition, sleep and physical activity behaviors and delineates evident occupational disruptions to these lifestyle behaviors. Further, evidence from clinical trials demonstrate efficacy of nutrition, sleep and physical activity interventions for enhancing cardiometabolic health of airline pilots.

Key Words: Lifestyle medicine; preventive medicine; exercise; dietary behaviors; occupational health

Introduction

Airline pilots experience unique occupational demands which present risks to physiological and psychological health which may be mitigated through achieving health guidelines for lifestyle behaviours; nutrition, physical activity (PA), and sleep. Cardiometabolic non-communicable diseases (NCDs) such as cardiovascular disease (CVD), stroke, and diabetes mellitus are the leading cause of mortality worldwide in the general population (World Health Organization, 2017). Professional airline pilots are susceptible to similar health concerns as those occurring in the general population (International Civil Aviation Authority, 2018b; Wilson et al., 2022a, 2022b). However, protective factors associated with being an airline pilot, such as favorable socioeconomic status (Dunn, 2010), the healthy worker effect (Shah, 2009), and being subject to regular medical examinations (Omholt et al., 2017) are thought to mitigate some health risk. Indeed, pilots have historically been considered to have a lower prevalence of NCD's and better health status than the general population (Hammer et al., 2014). Contrastingly, recent findings suggest the prevalence of cardiometabolic risk factors including body mass index > 25 (overweight or obese) and insufficient PA were higher among airline pilots globally compared with general population estimates (Wilson et al., 2022b).

Airline pilots experience numerous unique occupational risks related to aviation travel, such as shift work and flight schedule induced circadian disruption (Reis et al., 2016b), fatigue (Petrilli et al., 2006), irregular meal times, mental stress demands associated with flight safety (Choi & Kim, 2013) and the sedentary nature of the job (Sykes et al., 2012). Consequently, these factors adversely affect physiological and psychological health and may contribute to elevated risk of long-term cardiometabolic disease and/or disability prevalence among pilots (Nishtar, 2017; Wilson et al., 2022b). Furthermore, the average age of pilots is increasing, and a growing number of pilots continue to work beyond the age of 60 (Kagami et al., 2009). With greater age comes an elevated prevalence of medical conditions and complications (Chen et al., 2016).

According to the International Civil Aviation Organization's Annex 1, requirements of aviation medicine providers are to apply safety management principles to the medical assessment process, which includes evaluating data to concentrate on areas of increased risk (International Civil Aviation Authority, 2018a). Secondly, implementation of appropriate health promotion for license holders (pilots) to reduce future medical risks to flight safety is required (International

Civil Aviation Authority, 2018a). The prevalence of cardiometabolic NCD risk factors are associated with shorter life expectancy (Licher et al., 2019), elevated direct health-care costs (Miranda et al., 2019), reduced perceived health (Lasserre et al., 2017), impaired productivity (Keyes & Grzywacz, 2005), and higher disability-adjusted life-years (Ding et al., 2016). With pervasiveness of NCD's internationally (World Health Organization, 2017), there is a need for a paradigm shift towards more effective implementation of preventative health promotion strategies to offset these trends (Nishtar, 2017). Behavioural countermeasures are warranted to mitigate risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety (International Civil Aviation Authority, 2012).

Nutrition, PA, and sleep are each modifiable lifestyle determinants of chronic disease (Gbadamosi & Tlou, 2020) and influence employee work performance (Pronk et al., 2004). Habitually consuming healthy nutritional patterns, engaging in sufficient PA, and obtaining adequate sleep are three lifestyle behaviours that have a positive effect on physical health and psychological wellness (Mandolesi et al., 2018; Mozaffarian et al., 2008), significantly lower all-cause mortality, and likely mitigate numerous NCD pathogenesis processes (Bellavia et al., 2013; Lear et al., 2017).

Nutrition, PA, and sleep are modifiable behaviours that are interrelated through complex bilateral interactions involving physiological and psychological mechanisms (Chennaoui et al., 2015). Correlational studies have observed congruent directional change effects between behaviours, in that short sleep is associated with less engagement in PA (Creasy et al., 2019) and suboptimal nutrition behaviours (Greer et al., 2013). Whereas achievement of sleep guidelines has shown associations with better diet quality (Campanini et al., 2016) and may promote engagement in PA behaviour. However, sufficient sleep appears to reduce barriers to, rather than predict behaviour to healthy nutrition and exercise (Kline, 2014).

Reciprocally, some studies provide evidence for a role of diet intake (St-Onge et al., 2016) and exercise (Kredlow et al., 2015) as influencers of sleep quality. The proposed mechanisms of exercise which improve sleep include anxiolytic and antidepressant effects (Hallgren et al., 2016), adenosine upregulation (Youngstedt et al., 2000), circadian phase shifting, thermoregulatory adaptations, and sleep architecture (Uchida et al., 2012). Further, chronic adaptations from exercise such as enhanced glucose metabolism, heart rate variability, and body composition may positively affect sleep (Uchida et al., 2012). A meta-analysis reported regular exercise has small beneficial effects on total sleep time and sleep efficiency, small-to-medium beneficial effects on sleep onset latency, and moderate beneficial effects on sleep quality (Kredlow et al., 2015). Regular exercise may positively influence nutritional factors such as appropriate energy balance via influencing appetite regulation, total energy expenditure (Castro et al., 2020) and can promote positive psychological mechanisms related to body image, self-efficacy and mood (Carraça et al., 2013).

Regular adherence to healthy nutrition patterns is associated with factors that facilitate exercise engagement and promote positive adaptations to exercise including positive cognitive and physiological performance, enhanced mood, and positive health-related quality of life (Eslami et al., 2020; Milte et al., 2015). Nutrition habits influence hormones and inflammation status, which directly or indirectly contribute to insomnia (Zhao et al., 2020), and obesity promoted by chronic caloric surplus is associated with increased risk of sleep disordered breathing (Park et al., 2011).

Health promotion interventions for pilots aimed at improving nutrition, PA, and sleep behaviours are likely to produce positive outcomes toward common perceived work-related wellbeing issues expressed by pilots, including; sleep difficulties (Reis et al., 2016b), psychological fatigue (Bourgeois-Bougrine et al., 2003), musculoskeletal issues (Albermann et al., 2020), digestive problems (Cahill et al., 2021), and may mitigate NCD risks (Anderson & Durstine, 2019). Indeed, some evidence suggests that those who achieve health recommendations for sleep, PA and fruit and vegetable intake are more likely to achieve optimal health than those engaging in zero to one healthy behaviour (Prendergast et al., 2016). These observations suggest that targeting multiple behaviour lifestyle-based interventions to enhance health and wellbeing may be more efficacious than single behaviour interventions.

This narrative review examines (a) occupational characteristics for sleep, nutrition and physical activity, and (b) outlines evidence-based strategies to inform health behavior interventions to mitigate cardiometabolic health risk factors among airline pilots.

Methodology

Literature Search Strategy

This narrative review utilised an electronic search of bibliographic databases PubMed, MEDLINE (via OvidSP), PsychINFO, Web of Science, and Google Scholar. Eligible materials published between 1 January 1990 and 1 June 2022 were considered for inclusion, congruent with a recent review among airline pilots (Wilson et al., 2022b). The main search consisted of key search terms relating to airline pilots and cardiometabolic health parameters (see Table 9). A supplementary search was performed pertaining to health behaviour measurement instruments as follows: Measurement AND (nutrition OR diet OR dietary OR eating OR “body composition” OR fat OR sleep OR “sleep hygiene” OR “physical activity” OR exercise OR “health behaviours” OR “health behaviours” OR fitness OR “physical capacity” OR “cardiorespiratory fitness”). The reference lists of included publications were cross-checked for relevant articles. In addition, a gray literature search was performed pertaining to official reports and documents from regulatory bodies relevant to aviation and public health including the International Civil Aviation Authority, International Air Transport Association, Civil Aviation Authority, International Federation of Air Line Pilots' Associations, Federal Aviation Administration, Joint Aviation Authority, World Health Organization, and Center for Disease Control.

Table 9: Search terms blocks were combined for text and word search in PubMed and adapted to the remaining databases: 1 and 2.

1. Airline Pilots	**2. Cardiometabolic Risk Markers and Health Behaviours**
Pilots OR “airline pilot*” OR “commercial pilot*” OR “professional pilot*” OR “civil pilot*” OR “civilian pilot*” OR “aviation pilot*” OR “commercial airline*” OR aircrew OR “cockpit	“Health risk*” OR “risk factor*” OR cardiometabolic OR cardio-metabolic OR cardiovascular OR “cardiometabolic risk” OR “metabolic syndrome” OR “syndrome x” OR diabetes OR hypertension OR weight OR body mass OR overweight OR obesity OR “body composition” OR adipos* OR “physical activity” OR exercise OR sleep OR “sleep hygiene” OR circadian OR apnoea OR apnea OR nutrition OR diet OR dietary OR eating OR fruit*

crew*" NOT military* NOT army NOT "pilot study" NOT piloted NOT "pilot project" NOT "pilot research"	OR vegetable* OR stress OR lipids OR cholesterol OR glucose OR insulin OR "insulin resistance" OR "insulin sensitivity" OR "waist circumference" OR waist OR fat OR "blood pressure" OR hypertension OR "C-reactive protein" OR "inflammatory markers" OR inflammation OR "microvascular dysfunction" OR fatigue OR medical OR depression OR stress OR distress OR anxiety OR fitness OR cardiorespiratory OR VO2 max

Literature Inclusion Criteria

The inclusion criteria for literature sources were peer-reviewed human studies, meta-analyses, systematic reviews, and reports or documents published by regulatory bodies. Only articles published in English were included in the review. The population criteria for inclusion were fixed-wing pilots (airline, commercial, civilian), and no restrictions were placed on fleet type (short-haul, long-haul, mixed-fleet).

Results and Discussion

Sleep Characteristics of Airline Pilots

Circadian disruption is an inherent risk for pilots and they are likely to have better sleep quality and quantity when not at work (Wilson et al., 2021a). Confounding health behaviour consequences that often present with circadian disruption include inadequate quality of sleep (Åkerstedt & Wright, 2009), altered nutrition patterns (Antunes et al., 2010) and insufficient PA (Atkinson et al., 2008). Sleep difficulty is frequently expressed as a primary source of work induced stress among commercial pilots (Cahill et al., 2021; Reis et al., 2016b). Pilots are susceptible to a variety of regular perturbations to the natural circadian rhythm, such as shift work, extended duty periods, rotating work/rest schedules, traveling across time zones, and sleep restrictions associated with short layovers (Caldwell, 2005; Roach et al., 2012a). Sleep and wake routine consistency are a predominant challenge for both short-haul (SH) and long-haul (LH) pilots due to work schedule irregularities and shift work (Reis et al., 2016b). For LH pilots, trans meridian flight contributes to travel fatigue and circadian desynchronosis (jet lag). Travel fatigue can exhibit acute symptoms of fatigue, disorientation and headache due to sleep loss, dehydration, hypoxia, travel related discomfort and low air pressure and humidity after flying for > 8 hours (Roach & Sargent, 2019). Sleep debt can be substantially ‘‘made up’’ the next night, but jet lag lingers due to circadian misalignment with the destination time zone and the relatively slow moving internal circadian clock. Jet lag also can present symptoms including headaches, mood disturbances, daytime sleepiness, difficulty sleeping at night, poor mental and physical performance, and disrupted gastrointestinal function (Waterhouse et al., 2004).

Within a survey of 435 commercial Portuguese pilots, the prevalence of sleep complaints was 35%, daytime sleepiness 59% and fatigue 91% (Reis et al., 2016b). Compared to office workers within the same airline, the prevalence of night waking and sleep latency were higher in pilots but did not differ significantly between LH and SH (Lindgren et al., 2012). Pilots working SH often achieve less sleep on the nights before a duty period, with fatigue progressively increasing for each hour that work starts before 09:00 hours (Roach et al., 2012b). Comparatively, a study reported LH pilots achieved ≥ 7 hours sleep per night before flights, yet significantly reduced after flight duties (Petrilli et al., 2006). Concerning both LH and SH pilots, another study identified > 64% of pilots achieve < 7 hours sleep per night during off duty periods (van Drongelen et al., 2014). Among LH pilots during off duty periods, a comparative analysis of objective and subjective sleep assessments revealed objective actigraphy measured sleep was significantly lower than self-report measures (6.8 and 7.6 hours, respectively), indicating a tendency of pilots to overestimate their sleep duration with self-report measures (Wu et al., 2016a). Furthermore, this study revealed 23% of pilots averaged < 6 hours sleep habitually (Wu et al., 2016a). Thus, consistent with reports of insufficient sleep in the general population (Khubchandani & Price, 2020), a notable proportion of pilots do not achieve sleep recommendations of 7-9 hours per night during off duty periods, further facilitating the prevalence of fatigue. Chronic exposure to insufficient sleep is detrimental to acute physiological (Buxton et al., 2012) and psychological (Walker et al., 2020) health, and is linked to elevations in biological risk factors such as hypertension, excess body fat, dyslipidemia, insulin resistance and chronic low grade inflammation (Shi et al., 2013). Circadian disruption also leads to impaired cardiovascular and metabolic functions (Rajaratnam et al., 2013) and long-term shift work exposure has been associated with an increased risk for metabolic syndrome (Canuto et al., 2013), diabetes (Knutsson & Kempe, 2014), cardiovascular disease (Härmä et al., 2018), and some forms of cancer (Megdal et al., 2005).

Insufficient sleep is highly correlated with fatigue in airline pilots (Sieberichs & Kluge, 2016). Elevated fatigue is commonly reported in regional and international airline pilots (Bourgeois-Bougrine et al., 2003; Reis et al., 2016b), with circadian disruption, jet lag from frequent time-zone shifts, and working hour irregularities (Lock et al., 2018) known as contributing factors. Reported prevalence of perceived fatigue within commercial pilot populations range from 5% to 89%(Wilson et al., 2022b). Some evidence suggests LH pilots rate fatigue higher than SH pilots (Sallinen et al., 2017), with night flights and jet lag presenting as chief sleep complaints in LH pilots (Bourgeois-Bougrine et al., 2003), whereas prolonged duty periods, high workload, and successive early wake-ups are more prevalent complaints in SH pilots (Bourgeois-Bougrine et al., 2003; Roach et al., 2012b).

Fatigued pilots tend to decrease their PA, withdraw from social interactions and lose the ability to effectively divide mental resources among different tasks (Caldwell, 2005). Furthermore, fatigue from insufficient sleep is associated with impaired immune function, increased prevalence of micro-sleeps, elevated psychosocial stress (Puttonen et al., 2010), and increased likelihood of elevated alcohol use (Dawson & Reid, 1997). Fatigue is detrimental to a pilot's ability to safely operate the aircraft or perform safety-related duties (International Civil Aviation Authority, 2012), and has been identified as a causal factor in numerous aviation incidents and accidents (Petrilli et al., 2006; Roach et al., 2012a). NASA's Aviation Safety Reporting System indicates that 21% of reported aviation incidents are fatigue related (Jackson & Earl, 2006).

Measurement of Sleep Quality and Quantity

Valid and reliable measures of sleep duration, quality, timing, and efficiency that are cost efficient, and pose minimal patient and administrative burden are valuable to promote implementation of sleep evaluation in practice. Sleep quality is characterized by continuity (sleep latency, awakenings > 5 min, wake after sleep onset, sleep efficiency), architectural (rapid eye movement [REM] sleep, N1 sleep, N2 sleep, N3 sleep, arousals), and napping variables (naps per 24 hours, nap duration, and days per week with at least one nap) (Ohayon et al., 2017).

Objective measures of sleep provide more information than subjective measures, such as sleep fragmentation, sleep efficiency, daily sleep variability, and architecture (Yaffe et al., 2014). Polysomnography is the diagnostic gold standard for sleep disordered breathing and sleep measurement yet is the most invasive and costly method. For measurement of sleep duration within flight crew, actigraphy and subjective measures correlated highly with polysomnography (range 0.84–0.95) (Signal et al., 2005). Wrist actigraphy record movements that can be used to estimate sleep parameters (Martin & Hakim, 2011) and provides a lower cost alternative to polysomnography. However, indeed expense and data analysis interpretation training and software requirements are limitations to utilisation of actigraphy at scale.

Several self-report measures are available, which focus on subjective estimates of sleep duration, latency, waking during the night, and other factors that could impact sleep quality and duration such as comorbid conditions and medication. Advantages of subjective measures include cost and time effectiveness, minimal participant burden, and can be conveniently administered and scored electronically. However, these may be susceptible to cheating or mis-scoring and may not always reliably reflect objective performance measures (Orr, 2001).

The Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) are commonly used subjective self-report instruments to quantify sleep and excessive daytime sleepiness in older adults (Spira et al., 2011). The PSQI, which is a self-report questionnaire that assesses sleep quality and quantity over a 1-month retrospective time interval. The PQSI consists of 19 questions, grouped into seven components; sleep quality, sleep duration, sleep latency, sleep disturbances, sleep efficiency and the use of sleep medications and any daytime dysfunction, which collectively produce one global score indicating sleep quality. The PSQI has a high test-retest reliability and a good validity for patients with primary insomnia and is useful for psychological symptom ratings (Backhaus et al., 2002). The ESS was derived from observations about the nature and occurrence of daytime sleep and sleepiness and is designed to measure sleep propensity in a simple, standardized way (Johns, 1991). The ESS questionnaire has been validated [71], showing accurate measures of sleep propensity from healthy, control populations and a clinically sleep disturbed population. Low correlation with polysomnography indicates these instruments are not likely to be useful as screening measures for polysomnographic sleep abnormalities. However, the PSQI has been widely utilised in cohort and experimental studies among airline pilots (Wilson et al., 2021a; Wilson et al., 2022a; Wilson et al., 2022c; Wilson et al., 2021b).

Given the potential risks of OSA (Federal Aviation Admistration, 2015), and the prevalence of sleep quality complaints within pilots (Reis et al., 2016b), measurement of OSA risk is warranted. In absence of polysomnography, the diagnostic gold standard for OSA, two subjective questionnaires available are the Berlin and STOP-BANG. The STOP-BANG questionnaire is an eight-item screening tool for OSA, named by mnemonic which "S" stands for snoring, "T" for tiredness/fatigue, "O" for observed apneas, "P" for high blood pressure, "B" for BMI > 35, "A" for age > 50, "N" for neck circumference > 40 cm, and "G" for male gender (Chung et al., 2008). The Berlin questionnaire contains 11-items and is divided into three categories: snoring and witnessed apneas, rating daytime sleepiness, and presence or absence of hypertension, scored in conjunction with the pilot's BMI (Netzer et al., 1999). Each category is graded as "high risk" or "low risk" for OSA based on separate criteria. The patient is considered at overall "high risk" if the patient reports having persistent (> 3–4 times/week) symptoms in at least two symptom categories (Netzer et al., 1999). Compared with polysomnography, sensitivities of Berlin, and STOP-BANG were 86%, 81% and specificities were 53%, 82%, respectively (Amra et al., 2018). A recent study (Ibáñez et al., 2018) established a repository with downloadable sleep questionnaires and diaries (http://users.dsic.upv.es/~jsilva/Sleep/).

Promoting Sleep Hygiene for Airline Pilots

Good sleep health facilitates the ability to maintain attentive wakefulness and is characterized by duration, quality, timing, and efficiency (Buysse, 2014). Sleep duration guidelines proposed for adults > 18 y is seven to nine hours per night to support health and wellbeing (Hirshkowitz et al., 2015). Sleep hygiene represents a collective range of lifestyle and environmental practices congruent with supporting sleep heath, including; circadian aligned sleep schedule consistency that ensure 7-9 hours of sleep, strategic modulation of incandescent lighting and light exposure, avoidance of activities in bed other than sleep and intimacy, maintaining regular exercise and a healthy diet, sleep-disruptor avoidance in the evening (for example, caffeine or alcohol), and pre-bed routines supportive of arousal reduction and relaxation (Nishinoue et al., 2012; Perlis et al., 2000). Furthermore, targeted sleep hygiene strategies for pilots such as preemptive adjustment of sleep schedule and prior to commencement of a new shift schedule or time zone arrival, specifically timed bright light exposure and/or light filtering eyewear, and tailored or modified nutrient timing (Atlantis et al., 2006; Halson et al., 2019) may support in reducing decrements in sleep quality and support jet lag recovery time (Fowler et al., 2020; Janse van Rensburg et al., 2020). Thus, sleep hygiene is a valuable element of health promotion for pilots, particularly within pilots of advanced age, where occupational circadian disruption may be compounded by natural age associated degradation of sleep quality and quantity (Li et al., 2018).

Although circadian disruption is unavoidable due to occupational demands, targeted educational and behavioural interventions to improve sleep hygiene may help pilots optimize sleep behaviours around their continually changing rosters to support restorative sleep and mitigate fatigue. Guidelines suggest behavioural and cognitive interventions should be implemented whenever possible over pharmacological strategies due to their limited efficacy and side effects (Sateia et al., 2017). Common non-pharmacological approaches targeted to promote patient self-management of sleep health via educational and behavioural methods include Cognitive Behavioural Therapy for Insomnia (CBT-I), sleep hygiene, stimulus control, bedtime restriction, and relaxation improving techniques, each of which are defined elsewhere (De Niet et al., 2009).

CBT-I is a multimodal approach incorporating behavioural, cognitive and educational components, which is recommended as a first line treatment for insomnia due to its moderate to strong effects on improving sleep indices (Qaseem et al., 2016). However, due to the requirement of a trained practitioner and multiple treatment occasions for intervention delivery, this limits feasibility in practice, thus brief sleep interventions using components of CBT-I are more feasible. Sleep hygiene has demonstrated improvements in self-report sleep quality in blue collar employees (Nishinoue et al., 2012) via group-based sessions, with larger positive effects observed via one-on-one delivery. While CBT-I yields significantly more effective outcomes on sleep metrics such as duration, latency and efficiency, sleep hygiene interventions as a single therapy provide small to medium effects (Chung et al., 2018). A sleep hygiene intervention during travel and combined with light exposure following long-haul trans meridian travel has shown significant improvements in physical performance within athletes (Fowler et al., 2020), however this has yet to be tested in a cognitive performance context with pilots. Sleep restriction therapy has demonstrated moderate-to-large effect sizes for reducing night waking and enhancing sleep latency and efficiency, however the impact on daytime sleepiness is inconclusive and this strategy may not be appropriate for airline pilots (Miller et al., 2014). Stimulus control as a behaviour technique has demonstrated positive outcomes on sleep parameters in insomniacs (Riedel et al., 1998). An mHealth intervention within pilots involving tailored education pertaining to sleep, PA, and nutrition health behaviour elicited significant self-report improvements in fatigue, sleep quality, strenuous PA, and snacking behaviour at 3 months, however the magnitude of change reduced at 6 months, yet still significant from baseline (van Drongelen et al., 2014). Another multicomponent intervention targeting sleep, nutrition and PA involving personalised sleep hygiene goal setting, significantly improved sleep quality and quantity, nutrition and PA behaviours, and subjective physical and mental health within pilots over four months (Wilson et al., 2021a).

Nutrition Characteristics of Airline Pilots

Although nutrition behaviours and knowledge of pilots are largely unexplored in the literature, unique nutritional implications are evident based on commercial aviation occupational demands. For both LH and SH pilots, irregular and long duty periods encourage inconsistent meal timing opportunities, which inhibit meal routine regularity. For LH pilots, time away from home may result in poor eating habits and increased social alcohol consumption (Stark et al., 2008; Sykes et al., 2012). Difficulty getting healthy food is a common perceived barrier within airline pilots (Cahill et al., 2021), which may arise from unhealthy environmental food availability and/or lack of knowledge to make healthy eating choices. Indeed, concerns about poor nutritional content, portion sizes, and the high processed nature of food provision within airlines has been reported (Cullen et al., 2021).

Eating regular well-balanced meals supports stable blood sugar regulation, whereas skipping meals increases the risk of experiencing unstable blood sugar levels. Consequently, the behaviour of “quick fix” snack consumption can be triggered, which are often high in energy and low in nutrient density (Hess et al., 2016). Chronic snacking of low nutrient density foods between main meals is associated with a higher risk of developing the metabolic syndrome and obesity (Pot et al., 2016). Further, unstructured eating patterns may lead to inadequate intake of certain essential nutrients or over consumption of others (Souza et al., 2019).

Hormonal and metabolic functions are synchronized with the circadian rhythm (Scheer et al., 2009), hence shift work can alter thermoregulation, digestion, energy metabolism, and upregulate ghrelin production which can promote positive energy balance (Souza et al., 2019). The interaction between these physiological changes in conjunction with unhealthy food availability in the work environment facilitates lapses in nutritional control (Hill et al., 2003). Jet lag promotes symptoms of fatigue, mood and digestive disturbances, and impaired cognitive function, all of which may affect eating decisions (Halson et al., 2019). Associations between shift work and nutrition behaviours have been reported with alterations observed in meal patterns, skipping meals more frequently, consuming food at unconventional times, and increased consumption of saturated fats and sugar-sweetened foods (Atkinson et al., 2008). Some evidence suggests a propensity for insufficient micronutrient intake (e.g. vitamin A, C and iron) and overconsumption of processed and high sodium foods such as potato chips and processed meats (Lindseth & Lindseth, 1995) within pilots. A comparison of daytime and shift workers within the same airline reported significantly less fruit and vegetable intake and elevated saturated fat intake in shift workers (Hemiö et al., 2015). Similarly, a recent meta-analysis reported 68%-84% of pilots were not achieving fruit and vegetable guidelines (Wilson et al., 2022b).

The cabin environment of commercial aircraft may also influence nutrition behaviours and requirements of pilots. Altitude induced hypoxic stress affects taste and smell, and may increase palatability for sweetness (Singh et al., 1997). Indeed, food provided on airplanes is often salty and sweet dominant (You et al., 2020). Furthermore, low humidity of cabin air may accelerate dehydration (Singh et al., 1997), so an increase in fluid intake is required to counteract respiratory fluid losses.

Digestive complaints are common within commercial pilots (Cahill et al., 2021). Work related characteristics; irregular sleep, irregular meal times, large meals, inadequate fiber intake, dehydration, contaminated food ingestion and altitude pressure are associated with digestive symptoms such as epigastralgia, heartburn, bloating, constipation (Lindgren et al., 2012), and can be exacerbated in a high BMI (Fisher et al., 1999). A cross-sectional comparison of digestive symptoms between pilots and office workers within the same airline found that pilots more often had bloating and poor appetite, and insomnia was the strongest predictor of digestive symptoms (Lindgren et al., 2012), with no significance variance in complaints between SH and LH pilots.

Measurement of Dietary Behaviours and Body Composition

Dietary intake data provides value for epidemiological surveillance and with implementation and evaluation of nutrition interventions. Prospective weighed food records are often considered the most accurate option for measuring dietary intake, yet the participant burden of data logging and data analysis requirements limit the utility in practice. Dietary recall methods such as food frequency questionnaires and 24-hour dietary recall are widely used as cost-effective instruments for establishing trends in dietary intake and patterns that may influence health and body composition (Wharton et al., 2014). Drawbacks of dietary recall methods include reliance on recall accuracy and lack of consistency of reporting (Sharp & Allman-Farinelli, 2014). To date, literature among airline pilots have only utilised food frequency questionnaires for the evaluation of fruit and vegetable consumption (Wilson et al., 2022b).

Digital technology instruments such as food recording mobile apps (e.g. MyFitnessPal), photo logging and sensor-based strategies are becoming increasingly accessible and can assist with the task of simultaneously quantifying dietary intake and providing a platform for utilisation of behaviour change techniques such as self-monitoring and real-time feedback to support and motivate the individual (Burke et al., 2011). A review of dietary assessment methods deployed on digital platforms found that the feasibility and validity of mobile phones to assess dietary intake were not superior to traditional interviewer- or self-administered paper-and-pencil methods, but were equivalent (Sharp & Allman-Farinelli, 2014). However, participants' self-reported satisfaction and preferences for digital methods were higher than for conventional methods.

An important consideration for dietary assessment of airline pilots is their health behavioural patterns often change during workdays compared with off duty periods (Roach et al., 2012b; Wilson et al., 2022b). Thus, caution is advised with utilisation of single day 24-hour recall methods and collection of data including a flight day and non-flight day is advisable to assess nutrient intake variability. The National Cancer Institute have established a repository with downloadable dietary assessment questionnaires for research and clinical practice (https://www.nal.usda.gov/legacy/fnic/dietary-assessment-instruments-research).

Body composition is associated with numerous NCDs and is useful in assessing the effectiveness of health behaviour interventions (Kuriyan, 2018). Anthropometric methods such as height and weight are routinely utilised in aviation medical examinations, which can deduce body mass index, a simple and inexpensive body weight classification gradient to classify obesity and is associated with cardiometabolic risk. The inability of BMI to distinguish fat mass, lean mass and bone, limits its utility in health intervention assessment. Waist circumference provides both independent and additive information to BMI for morbidity and mortality prediction (Ross et al., 2020). Interestingly, waist circumference is not yet incorporated in the ICAO standard aviation medical assessment requirements for CVD risk, despite waist circumference being strongly associated with the absolute amount of visceral fat, and CVD mortality risk with or without adjustment for BMI (Ross et al., 2020). Neck circumference is an independent risk factor for OSA, therefore measurement in pilots is advisable (Ahbab et al., 2013).

Laboratory-based tests such as computed tomography, dual-energy X-ray absorptiometry, hydrodensitometry, and air displacement plethysmography produce strong validity and reliability for body composition assessment, yet are rarely indicated in practice due to expense and inaccessibility (Kuriyan, 2018). Compared with dual-energy X-ray absorptiometry, research grade bioelectrical impedance analysis (BIA) devices produce good reliability and low standard error, yet tend to overestimate fat free mass and underestimate fat mass and body fat percentage (McLester et al., 2020). Benefits of BIA include device portability and fast measurement, however drawbacks are equipment expense. Comparatively, skinfold measurements are cheap, reliable and allow the assessment of body composition due to the strong relationship between the amount of subcutaneous fat and total body fat (Hillier et al., 2014). Generally, both skinfolds and BIA produce acceptable agreement with values produced by dual-energy X-ray absorptiometry, yet inconsistent findings are reported as to which produces more accurate results (de Abreu et al., 2020; Silveira et al., 2020) due to the specific skinfold equation used, BIA model, and target population evaluated.

Promoting Healthy Nutrition for Airline Pilots

It is generally accepted that pilots who eat a well-balanced diet perform better, have increased energy levels, and have better physical and cognitive performance (Lindseth et al., 2011). Lack of adequate nutrition through poor eating habits can be a contributing factor to fatigue, accidents or errors (Johnson et al., 2007). A healthy diet is one that provides suitable proportions of macronutrients to support physiologic and energetic requirements, maintains stable blood glucose levels, delivers appropriate energy intake without excess to support healthy body weight, while providing adequate micronutrients and hydration (Cena & Calder, 2020).

Numerous nutritional patterns such as the Mediterranean Diet, Dietary Approaches to Stop Hypertension, Mediterranean-DASH Intervention for Neurodegenerative Delay, Healthy Nordic Diet, Da Qing Diabetes Prevention Study, and the Finnish Diabetes Prevention Study have demonstrated NCD risk reduction in longitudinal studies in non-pilot populations (Cena & Calder, 2020; Li et al., 2008; Lindström et al., 2013). Experimental studies with these diets have reported improvements in parameters relevant to pilot cardiometabolic health, including blood pressure, weight management, cholesterol, endothelial function, glycemic control, central adiposity, and delayed onset of CVD, type 2 diabetes, metabolic syndrome, cognitive decline and some cancers (Branca et al., 2019; Cena & Calder, 2020). The composition of these diets are details elsewhere (Cena & Calder, 2020), however congruent principles among the diets emphasize a low glycemic load and the promotion of colorful fresh foods, including fruits and vegetables, nutrient dense whole foods, a high proportion of plant-based foods, plentiful antioxidants and polyphenols, unsaturated fats such as nuts and seeds, a high polyunsaturated to saturated fat ratio, low trans-fat, lean proteins, legumes, fiber-rich whole grains, < 1500 mg/d of sodium, omega-3 fatty acid rich foods such as fish, and avoidance of Westernized diet characteristics such as foods containing refined sugar and highly processed foods (Bundy et al., 2021; Cena & Calder, 2020; Cordain et al., 2005; Di Noia, 2014). Further, mindful and slow eating is promoted in healthful diets as this facilitates awareness of internal physiological cues, sensations and emotions, nurtures parasympathetic nervous system dominance and may improve digestion (Cherpak, 2019). Collectively, these healthy nutrition characteristics play an important role also in strengthening the immune system which enhances natural antiviral defenses and combats certain NCD pathogenic processes (Valdés-Ramos et al., 2010).

Structural components of these interventions include diet and exercise educational support and materials, face to face individual and/or group sessions, adherence support, counselling from a health professional, and extended care (Lindström et al., 2003; Martínez-González et al., 2010). A review of nutrition interventions to reduce NCD risk reported frequent contact, the use of face-to-face methods, combining diet and PA interventions, and the application of behaviour change techniques as components most associated with effectiveness in promoting nutrition behaviour change (Browne et al., 2019). Further, common behaviour change techniques associated with positive outcomes on nutrition behaviour change (for example, increasing fruit and vegetable intake) include problem identification, goal setting, self-monitoring, stimulus control, problem solving, cognitive restructuring, and relapse prevention (Celis-Morales et al., 2015).

Indeed, comparative nutrition interventions within airline pilots demonstrate efficacy for promoting cardiometabolic health. In a study within Korean airline pilots at risk of hyperlipidemia (> 220mg/dl), a nutrition counseling intervention showed significant improvements at one year follow up for total cholesterol, BMI and HDL (Choi & Kim, 2013). The individualized nutrition prescription and educational counselling led by a dietitian involved nutritional intake evaluation, nutrition problem identification, education on nutrition therapy related to hyperlipidemia and educational print materials. Similarly, a personalised face-to-face nutrition goal setting session with a health coach and regular educational emails over a four-month period promoted significant improvements in fruit and vegetable intake, which was accompanied by improved weight and blood pressure management (Wilson et al., 2021a; Wilson et al., 2022c; Wilson et al., 2021b). Further, an intervention targeting nutritional education delivery via a multicomponent MHealth app in airline pilots reported improvements in snacking behaviour and decrease psychological fatigue (van Drongelen et al., 2014).

Due to pilot's elevated exposure to ionizing radiation, nutritional antioxidants have been investigated in relation to DNA damage and cancer risk in pilots (Fang et al., 2002). One study reported pilot's consuming a high intake of niacin from food or a diet high in whole grains but low in red and processed meat were associated with decreased chromosome translocation, a known biomarker of DNA damage (Yong & Petersen, 2011). Moreover, a diet high in vitamins C and E, β-carotene, β-cryptoxanthin, and lutein-zeaxanthin may also protect against cumulative DNA damage in pilots (Yong et al., 2009). These preliminary findings were observed in a small sample of pilots (n = 83) and further research is required to enhance generalizability. Abundant consumption of plant origin whole foods may reduce the risk of several types of cancer (Donaldson, 2004), due to the chemo-preventive effect related to the high levels of phytochemicals in this food. These phytochemicals interfere with several cellular processes involved in the progression of cancer and also with inflammatory processes that foster development of cancer (Béliveau & Gingras, 2007). Noteworthily, epidemiological studies indicate antioxidant intake via supplement form does not reduce cancer risk (Myung et al., 2010), however daily consumption of ≥ 600g of fruit and vegetables is associated with reduced total cancer risk (Aune et al., 2017), emphasizing the relevance of consuming a diet rich in plant-based, whole food sources.

Physical Activity Characteristics of Airline Pilots

A recent study reported a pooled prevalence estimate of 51.5% for insufficient PA among airline pilots globally (Wilson et al., 2022b). Occupational duties of an airline pilot involve extended periods of sedentary time sitting in the cockpit (de Souza Palmeira & Cristina Marqueze, 2016; Sykes et al., 2012). Lower levels of PA are associated with elevated levels of daytime sleepiness and fatigue in airline pilots (Chasens et al., 2007; van Drongelen et al., 2017) and the sedentary nature of the job as a pilot is a prevalent source of work related stress (Cahill et al., 2021) and contributing factor to musculoskeletal complaints in airline pilots (Cullen et al., 2021). Due to inflight responsibilities and limited space available in the cockpit, opportunities to exercise mid-flight or break up sedentary bouts are not easily accessible. A lack of time and energy are the commonly expressed barriers to being active in general population adults, which may be confounded in pilots due to the elevated prevalence of shift work and fatigue (Reis et al., 2016b). Further, being ‘too tired’ around work and life schedule is also frequently reported, yet paradoxically many people self-report that sufficient PA decreases stress and increases energy (Middleton et al., 2013).

Measurement of Physical Activity and Cardiorespiratory Fitness

Accurate assessment of PA, exercise, and/or cardiorespiratory fitness is important to evaluate whether an individual's activity levels are sufficient in relation to health guidelines, and to assess the effectiveness of interventions designed to increase activity levels and improve CRF (Melanson et al., 1996). The feasibility of PA measurement selection is influenced by cost-effectiveness, participant burden, sample size, data collection time frame, type of information required (e.g., steps, energy expenditure, exercise sessions per week, $VO2_{max}$), data management, and measurement error (Hills et al., 2014).

Doubly labeled water is the gold standard for assessing total energy expenditure, however it is not often used in practice due to high subject burden and expense (Westerterp, 2009). More frequently used objective methods of PA assessment include accelerometers and pedometers. Accelerometers demonstrate good validity and reliability, which can provide data on PA volume, intensity zones (e.g. sedentary, light, moderate, moderate-vigorous, and vigorous) and can provide indication of energy expenditure [(McClung et al., 2018)], suitable for data collection periods ≥ 7 days. The limitations include expense, lacking contextual information, and variability of results-based data collection protocols (e.g., hip versus wrist device placement). Pedometers suffice for the simple measurement of steps per day and can also be beneficial in assessing behavioural feedback and motivation (Normand, 2008). Findings suggest attainment of 7700 to 8000 steps/d represent the threshold associated with accumulation of ≥ 150 minutes per week of MVPA in adults (Cao et al., 2014). Capitalizing on the technology that many patients own provides a solution to the barrier of cost of PA measurement. Modern smartphones have a built-in accelerometer and gyroscope, allowing functionality as a pedometer, yet they are susceptible to larger measurement error compared to fixed accelerometer placement. Regardless, instruction of participants to carry their phone with them as much as possible and while performing exercise may be a cost-effective way of measuring PA levels may enhance validity compared to self-report measures.

Self-report measures of PA can be valuable for population based epidemiological assessment (such as estimation of weekly MVPA minutes) and are frequently used due to their practicality, low cost, and ease of administration. Further, these measures produce acceptable accuracy in determining discrete categories of activity levels (e.g., low, moderate, high) identifying trends in cohort studies, and showing improvement across groups or individuals (Shephard, 2003). However, reliance on participant recall ability can limit validity and reports of under and overestimations of PA levels are apparent compared with direct measures (Prince et al., 2008). Self-report measures vary in what components they specifically measure (e.g., mode of PA, duration, or frequency), how data are reported (e.g., activity scores, time, calories), quality of the data (e.g., intensity rating, differentiating between habitual and planned exercise, inclusion of leisure and non-leisure activity), and how data are obtained (e.g., paper-based, online questionnaire, interview) (Jacobs et al., 1993). Self-report questionnaires are significantly more reliable at the group than the individual level (Shephard, 2003). The International Physical Activity Questionnaire (IPAQ) short and long instruments have acceptable measurement properties (Craig et al., 2003) and have been utilised in epidemiological and experimental cohort studies among airline pilots (Wilson et al., 2021a; Wilson et al., 2022a; Wilson et al., 2022c; Wilson et al., 2021b).

Cardiorespiratory fitness is a well-established predictor of numerous health outcomes and is strongly correlated with PA levels (Zeiher et al., 2019). The Graded Exercise Test to either directly measure (maximal) or predict (submaximal) VO_{2max} is considered the benchmark to quantify cardiovascular functional capacity and aerobic fitness (Prince et al., 2008). However participant burden, cost of equipment and professional administration often limit the use of the Graded Exercise Test in non-research or clinical settings. The reduced subject burden of submaximal tests makes them a more viable alternative, with cost effective protocols demonstrating high test-retest reliability, such as the Chester Step Test (Buckley et al., 2004) which requires a step up box and heart rate monitor.

The WattBike (Woodway USA, Waukesha, WI, USA) electro-magnetically air-braked cycle ergometer utilises built in display protocols for evaluating CRF, is sensitive to change over time, and has produced good validity and reliability for use among airline pilots (Wilson et al., 2022c). The WattBike is space efficient and easy to use, however the drawback is the initial cost of the equipment. Numerous physiological metrics have consistently demonstrated correlations with CRF, including age, sex, BMI, waist circumference, body fat, resting heart rate, and habitual physical levels (Zeiher et al., 2019). Consequently, numerous non-exercise predictor equations for CRF have been developed (Peterman et al., 2019), however current evidence suggests considerable variability between equations, indicating limited clinical utility (Peterman et al., 2020). The development of population specific predictor equations is promoted.

Promoting Physical Activity for Airline Pilots

Sufficient PA to support general positive health, wellness and support NCD risk reduction in adults is suggested as the achievement of 150-300 minutes of MVPA per week, or 75-150 minutes of vigorous intensity, or an accumulative equivalent combination of both, with added health benefits of ≥ 300 total MVPA minutes per week (Bull et al., 2020). Furthermore, muscle strengthening activity should be performed ≥ 2 times per week (World Health Organization, 2010).

Exercise interventions positively influence weight management, prevention of musculoskeletal pain, enhances mood and the quality of sleep in patients with insomnia and sleep problems (Chennaoui et al., 2015). A meta-analysis reported acute bouts of aerobic exercise can significantly increases total sleep time, sleep efficiency, and slow-wave sleep and decreases sleep onset latency, wake after sleep onset, stage 1 Non-Rapid Eye Movement (NREM) sleep, and REM sleep in comparison with a day without exercise (Kredlow et al., 2015). In this study stronger effects were found in participants that exercised regularly, compared to those who did not. Physical activity interventions are generally effective in supporting short-term behaviour change, but increases are not always maintained (Murray et al., 2017). Thus, strategies should be incorporated into PA interventions to support adherence, such as extended care, follow up consultations or self-monitoring (Middleton et al., 2013).

Numerous reviews suggest combined diet and PA interventions produce superior results than diet or PA alone (Cradock et al., 2017), with a growing emergence of interventions additionally involving a sleep component (Wilson et al., 2021a). Intervention strategies to enhance PA include face-to-face, group-based, internet-based, community-based, and print based (George et al., 2012) delivery, and may focus on informational, behavioural and social, or environmental and policy approaches (Kahn et al., 2002). A review of behaviour change techniques associated with successful PA interventions identified; regular feedback, self-monitoring tools, elements of social support, variety in activities and a degree of friendly competition, as positive inclusions

(George et al., 2012). Counselling methods used in face-to-face sessions can be supportive of increasing stage of motivational readiness for PA and can significantly increase self-efficacy for participating in, and maintaining adequate levels of, PA (Swinburn et al., 1998).

Within airline pilots, an educational app-based intervention reported significant improvements in weekly moderate and strenuous activity (0.21 and 0.19 days per week, respectively) in pilots over a six-month intervention period (van Drongelen et al., 2014). In another study, a face-to-face personalised goal setting session with a health coach followed by weekly educational emails and a mid-intervention telephone call over a four month period promoted significant improvements in MVPA, which was accompanied by improved CRF, musculoskeletal fitness, weight and blood pressure management, and subjective health (Wilson et al., 2022c; Wilson et al., 2021b).

As individuals vary in barriers and facilitators to PA (Kulavic et al., 2013) and they have unique and often dynamic goals, personalisation of interventions to promote PA should be considered as a cornerstone in health intervention development as it takes into consideration factors that underpin sustainable behaviour change (Middleton et al., 2013). Type of PA should be determined by the individual's modality preferences for cardiovascular (such as walking, running, or cycling) and strengthening PA (for example, resistance equipment and/or bodyweight exercises), gym or non-gym-based settings, and individual-based or socially facilitated activities. Application of the frequency, intensity, time, and type (FITT) principles (Barisic et al., 2011) provides an effective framework for tailoring exercise prescription to support an individual's goals and level of experience and fitness. Gradual PA progression facilitated via patient self-monitoring where participants implement small progressive changes in PA at indicated intervals during an intervention (such as increase session duration; perform more repetitions; perform greater intensity; or accomplish more weekly bouts) promotes adaptation, behaviour adherence, and is associated with enhanced self-efficacy and self-actualization (Piercy et al., 2018).

Considerations for Health Interventions

Standard aeromedical practice lacks implementation of routine health promotion interventions targeting healthy diet, targeted sleep hygiene and PA routines. In a recent cross-sectional survey, the most prevalent coping strategies for work related stress within pilots were exercise, then sleep and relaxation, followed by diet (Cahill et al., 2021). Largely, pilots adopt their own coping mechanisms, rather than influence from employers (Cahill et al., 2020).

Airlines adhere to regulatory requirements pertaining to annual medical examinations of pilots, which serve as identification of potential incapacitating health conditions and assess the pilots fitness to fly (International Civil Aviation Authority, 2012). If the presence of serious physiological and/or psychological health issues are indicated, it can result in flying medical certificate suspension. Given pilots medical certificates are at stake during medicals, they are likely to underreport mental health problems and maladaptive stress coping mechanisms such as alcohol use, and are less likely to approach aeromedical examiners for help (Cahill et al., 2021).

Collective improvements in sleep, nutrition and exercise behaviours are associated with reduced fatigue (van Drongelen et al., 2014) and improved physical and mental health in commercial pilots (Wilson et al., 2021a). Preventive lifestyle interventions may promote work performance, flight safety, and positively impact pilot career longevity (Klonizakis et al., 2014; Kumanyika, 2012). Unaddressed modifiable health risks of disease and disability can result in substantial direct and indirect costs long term (Ding et al., 2016), thus cost-effective interventions likely translate to significant economic value long term (Hu et al., 2021).

Facilitation of behaviour change is a common goal of preventive health interventions. The prominent challenge in health behaviour change interventions is poor long-term adherence, despite promising initial improvements (Middleton et al., 2013). Accountability inherent in the social interaction between a patient and a health care provider encourages completion of a specified course of action and affects motivation to adhere to treatment (Oussedik et al., 2017). Within lifestyle-based health behaviour interventions, extended care (for example, a 15-20 week intervention followed by monthly contact with the treatment provider for 12 months) improves adherence and intervention effects (Perri et al., 1989). Extended care by a health care provider appears to be a strong predictor to maintaining behavioural changes in light of diminishing progress after the intervention (e.g. the lack of continued improvement in behaviour when moving from improvement phase to maintenance) (Ross Middleton et al., 2012). However, the main problem with increasing intervention duration is the corresponding cost of treatment due to the time and expertise required of health professionals to deliver care. Consequently, cost efficient methods for treatment delivery have been investigated including telephone, internet, and mobile based modes of delivery (Harvey-Berino et al., 2004).

Using components of digital technology may offer solutions to traditional challenges because of their low cost, high reach capability, anonymity, adaptability, and scalability (Bennett et al., 2010). Mobile application (mHealth) and internet-based interventions have reported short term effectiveness for improving diet and PA, with reduced effectiveness over time due to diminished engagement (van Drongelen et al., 2014; Williamson et al., 2006), reinforcing the importance of extended care via face-to-face sessions or telephone calls between the health care provider and participant to support treatment effects and intervention adherence. Indeed, it has been proposed that a face-to-face component combined with an mHealth platform may be an effective approach to satisfy the evident benefits of face-to-face care (Santarossa et al., 2018) and to minimize cost of long-term extended care (Helsel et al., 2007).

Interventions that integrate health behaviour theories (detailed elsewhere (Baranowski et al., 2003)) into their design, particularly incorporation of multiple behaviour change techniques, are more effective in improving health behaviour than those that do not (Michie & Abraham, 2004). The social cognitive theory provides a framework that relates to a reciprocal relationship between personal factors (for example, cognitions and emotions) and aspects of the social and physical environment which influence behaviour (Bandura, 1991). Health related knowledge, self-efficacy, self-regulation, and problem solving of barriers are four social cognitive theory constructs, which, when integrated into lifestyle interventions support health change sustainability. Health-related knowledge can be advanced by provision of educational content pertaining to the influence of sleep, healthy eating and PA on weight and risk for disease (van Drongelen et al., 2014). Self-efficacy beliefs and outcome expectancies are enhanced through the use of short-term, achievable goals that provide a series of successful experiences in changing eating and exercise behaviour (Weinberg, 2010). Self-regulatory skills are improved through the use of goal setting, use of self-monitoring tools, self-reinforcement, stimulus control, and cognitive restructuring strategies (Bandura, 1991). Finally, the ability to overcome barriers to change can be supported through extended care contact with the health care provider and direct training in problem-solving skills (Middleton et al., 2013).

Future Research and Conclusions

Future Research

The present study suggests that single or multicomponent interventions that comprise of evidence-based guidelines for sleep, healthy eating and PA may be helpful in the design of interventions to promote positive health and mitigate NCD risks in pilots. With pilots being subject to annual or biannual medical examinations, this presents an opportunity for aviation health care professionals to implement ongoing preventive health behaviour interventions. Indeed, some previous research has demonstrated nutrition counseling and education interventions delivered in this manner showed significant improvements at one year follow up for total cholesterol, BMI and HDL (Choi & Kim, 2013).

Given the multidirectional relationship between sleep, nutrition and PA and some evidence to suggest multiple-component interventions may elicit stronger participation and adherence (Prendergast et al., 2016), we suggest future research examine time-efficient and scalable strategies for implementation of multi component sleep, healthy eating and PA interventions through well controlled and adequately powered clinical trials. Future research should incorporate objective health metrics in evaluating the effectiveness of interventions on pilot health, including blood pressure, blood lipids and glycemic control, body composition, cardiorespiratory fitness, and objective methods for evaluating sleep, nutrition and habitual PA.

Currently, there is a dearth of research exploring the health behaviour characteristics of airline pilots utilising objective measurements. To better inform future targeted health behaviour interventions for pilots, future research should examine nutrition behaviours via direct or indirect measures of dietary recall, such as food frequency questionnaires and 24-hour recalls on both on duty and off duty periods. The measurement of sleep patterns and habitual PA levels should be explored using objectives methods such as actigraphy.

Conclusion

Professional airline pilots are susceptible to similar health concerns as those occurring in the general population and they experience numerous unique occupational risks related to aviation travel. With the pervasiveness of NCDs worldwide, a paradigm shift is needed towards increased implementation of preventive medicine to mitigate the risk of NCD occurring in order to reduce social, financial and health system burden while maximizing pilot health, wellness and work life longevity. The attainment of evidence-based guidelines for sleep, healthy eating and PA promotes health, wellness, and mitigation of risk for long-term health conditions. Preliminary evidence of health behaviour interventions in pilots suggest they promote positive effects on health behaviour status, enhance subjective health and wellness, and improve cardiometabolic health. Our evidence-based practical suggestions, presented in Appendix C, may inform health promotion intervention development for the airline pilot population regardless of age, ethnicity or sex. Aviation health and occupational safety professionals, representatives and researchers are encouraged to integrate sleep hygiene, healthy eating and PA interventions in order to pursue enhanced health care for airline pilots.

CHAPTER FIVE

The Effectiveness of a 17-Week Lifestyle Intervention on Health Behaviours Among Airline Pilots During COVID-19

Wilson, D., Driller, M., Johnston, B., & Gill, N. (2020). The Effectiveness of a 17-Week Lifestyle Intervention on Health Behaviours Among Airline Pilots During COVID-19. Journal of Sport and Health Science. 10(3) 333-340. https://doi.org/10.1016/j.jshs.2020.11.007 [Impact Factor: 13.077]

Prelude

Chapter Two and Chapter Three discovered the prevalence of cardiometabolic health risk factors among airline pilots, while Chapter Four identified the potential for promoting cardiometabolic health through attaining health guidelines for nutrition, physical activity and sleep. This controlled pilot study evaluates the acute effects of a personalised multicomponent nutrition, physical activity and sleep hygiene intervention for improving health behaviours and perceived health during a novel COVID-19 pandemic lockdown in New Zealand.

Abstract

The aim of this study was to evaluate the efficacy of a 17-week, three-component lifestyle intervention for enhancing health behaviours during the COVID-19 pandemic. A parallel-group (intervention and control) study was conducted amongst 79 airline pilots over a 17-week period during COVID-19. The intervention group (n = 38) received a personalised sleep, dietary and physical activity programme. The control group (n = 41) received no intervention. Outcome measures for sleep, fruit and vegetable intake, physical activity, and subjective health were measured though an online survey pre and post the 17-week period. The changes in outcome measures were used to determine the efficacy of the intervention. Significant main effects for time X group were found for IPAQ-Walk (p = 0.02) and for all other outcome measures (p = < 0.01). The intervention group significantly improved in sleep duration (p = < 0.01; d = 1.02), Pittsburgh Sleep Quality Index (PSQI) score (p = < 0.01; d = -1.01), moderate-to-vigorous physical activity (p = < 0.01; d = 1.32), fruit and vegetable intake (p = < 0.01; d = 3.11), Short-Form-12v2 physical score (p = < 0.01; d = 1.84), and Short-Form-12v2 mental score (p = < 0.01; d = 2.69). The control group showed significant negative change for sleep duration (p = < 0.01; d = -0.47), PSQI score (p = < 0.01; d = 0.28), and Short-Form-12v2 mental score (p = < 0.01; d = -0.64). Results provide preliminary evidence that a three-component healthy sleep, eating and physical activity intervention elicit improvements in health behaviours and perceived subjective health in pilots and may improve quality of life during an unprecedented global pandemic.

Key Words: COVID-19; healthy eating; lifestyle health; moderate-to-vigorous physical activity; sleep.

Introduction

The global COVID-19 pandemic has rapidly spread, showing capability to infect the world's population (Baker et al., 2020). Widespread infectious diseases such as COVID-19, are associated with- adverse mental health consequences (Bao et al., 2020), and perturbations in physical activity (PA) behaviours due to environmental factors such as forced self-isolation (Hammami et al., 2020). The confinement of an individual to their home may increase sedentary behaviour (Hobbs et al., 2015) and has a direct impact on their lifestyle, and consequently their sleeping, eating and PA patterns (Naja & Hamadeh, 2020). Furthermore, psychological and emotional responses to the pandemic (Wang et al., 2020) may lead to dysfunctional dietary and sleep behaviours (Di Renzo et al., 2020; Stanton et al., 2020). Numerous industries have experienced substantial operational perturbations emanating from COVID-19, including civil aviation (Sobieralski, 2020). Consequently, these conditions may have unexplored impacts on health behaviours within airline pilots. Vocational requirements of airline pilots present health risk, such as circadian disruption due to shift work and flight schedules (Reis et al., 2016b), flight schedule induced fatigue (Petrilli et al., 2006), irregular meal times, mental stress demands associated with flight safety (Choi & Kim, 2013) and the sedentary nature of the job (Sykes et al., 2012). Circadian disruption is detrimental to acute physiological (Buxton et al., 2012) and psychological (Walker et al., 2020) health metrics and is associated with elevated risk in some chronic conditions such as cardiovascular disease (Puttonen et al., 2010). Despite reduced workloads for airline pilots during COVID-19 (Sobieralski, 2020), substantial industry disruption, uncertainty (Matias et al., 2020), and financial concerns confounded by lockdown conditions may present adverse effects on pilot physical (Hammami et al., 2020; Woods et al., 2020) and mental health (Wilson et al., 2020).

Obtaining adequate sleep, consuming enough fruits and vegetables, and engaging in sufficient PA are three lifestyle behaviours that significantly reduce all-cause mortality (Bellavia et al., 2013; Cappuccio et al., 2010; Lear et al., 2017), and have a positive effect on physical and mental health (Mandolesi et al., 2018; Mozaffarian et al., 2008). Good sleep health facilitates the ability to maintain attentive wakefulness and is characterized by duration, quality, timing, and efficiency (Buysse, 2014). Sleep duration guidelines proposed for adults from 18 to 64 y is seven to nine hours per night (Hirshkowitz et al., 2015). Fruit and vegetables supply dietary fiber, vitamins and minerals, phytochemicals and anti-inflammatory agents (Slavin & Lloyd, 2012). Consumption of ≥ 400 g of fruit and vegetables per day, excluding starchy vegetables, is associated with protective effects against cardiovascular disease, some cancers (Aune et al., 2017), depression (McMartin et al., 2013), and total mortality (Bellavia et al., 2013). An inverse association between fruit and vegetable intake and mortality has been reported, with benefits observed in up to ≥ 7 daily portions (Oyebode et al., 2014). Sufficient PA is the achievement of ≥ 150 minutes of moderate-to-vigorous physical activity (MVPA) intensity per week, or ≥ 75 minutes of vigorous intensity, or an accumulative equivalent combination of both, with added health benefits of ≥ 300 total MVPA minutes per week (World Health Organization, 2010).

Adequate sleep, healthy dietary behaviours, and sufficient PA also play an important role in strengthening the immune system and its antiviral defenses (Valdés-Ramos et al., 2010; Walsh et al., 2011). Lack of sleep, poor dietary habits and physical inactivity are all independently associated with immunocompromisation effects (Butler & Barrientos, 2020; Tobaldini et al., 2017; Walsh et al., 2011), which impair host defenses against viral infection and may lead to individuals being at higher risk of more severe and complicated outcomes than those which are non-immunocompromised (Memoli et al., 2014). A lack of sleep (Cappuccio et al., 2008), dietary characteristics such as consuming a Western diet (Kanoski & Davidson, 2011), and insufficient physical activity are each associated with obesity (Cecchini et al., 2010) which is suggested to be a profound risk factor for adverse health outcomes from COVID-19 (Földi et al., 2020).

Avoidance of health behaviours during a pandemic outbreak may lead to immunocompromisation and increase susceptibility to viral propagation and elevate the risk of severe symptoms (Memoli et al., 2014; Shi et al., 2020). Behavioural countermeasures for individuals are vital determinants to health resilience amongst exposure to unprecedented environmental events such as the COVID-19 pandemic (Naja & Hamadeh, 2020). Thus, evidence driven interventions targeting the promotion of behaviours that enable individuals to protect themselves physically and psychologically during a pandemic are of public health importance (Naja & Hamadeh, 2020; Reissman et al., 2006). No previous studies have examined change in health behaviours in airline pilots before and after a pandemic event like COVID-19, nor have any studies evaluated the effectiveness of a controlled lifestyle-based health intervention during such times. The aim of this study was to evaluate the effectiveness of a three-component healthy eating, sleeping and physical activity programme in airline pilots during COVID-19 lockdown in New Zealand.

Methodology

Design

A between group, parallel controlled study with pre-and post-testing was performed to evaluate the effectiveness of a 17-week, three-component lifestyle intervention for enhancing health behaviours during a National COVID-19 pandemic response in New Zealand (NZ).

During the 17-week intervention period, the first five weeks preceded the NZ Government's enforcement of a four-tier response system to COVID-19 (Baker et al., 2020). Thereafter, five weeks were at alert level 4 (March 25th – 27th April), where all non-essential workers were instructed to stay home, and safe recreational activity was permitted in the local area whilst maintaining social distancing of ≥ 2 metres. Subsequently, two and a half weeks were at alert level 3 (27th April – 14th May), where some businesses could reopen, however people were instructed to work from home unless that was not possible. Finally, two weeks were at alert level 2 (May 14th – June 8th), where gatherings of up to 100 people were allowed and sport and recreation activities were also allowed. On June 8th NZ returned to alert level 1 (Ministry of Health, 2020c), where within community restrictions were removed, yet international border restrictions remained. Around the globe in the weeks following the World Health Organization's characterization of COVID-19 as a pandemic on March 11, 2020, the airline industry experienced an approximate 60-80% decrease in capacity at major carriers (Sobieralski, 2020). Consequently, pilots experienced limited flying duties during the time of conducting the intervention, which can be observed in Table 10. Pre-testing occurred between 14th February and 9th March 2020 and post-testing was conducted between 8th June and 19th June 2020. At pre-and post-testing an electronic survey was completed by participants measuring outcome variables, self-report physical activity levels, dietary behaviours, sleep quality and quantity, and subjective health.

This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07.

Participants

The study population consisted of commercial pilots from a large international airline. Seventy-nine pilots (mean ± SD, age; 42 ± 12y, 65 male, 14 female) participated in this study (see Table 10), which consisted of a combination of short haul, long haul, and mixed fleet rosters (n = 32, 35, and 12, respectively). Inclusion criteria were pilots with a valid commercial flying license and working on a full-time basis. Control group participants consisted of volunteers recruited at the time of completing their routine aviation medical examinations located at the airline medical unit during the time of the pre-test period. The intervention group volunteered to participate via self-selection in the lifestyle intervention by responding to an invitation delivered to all pilots within the company via internal organisation communication channels. In the control group, mixed fleet pilots had the most flights, followed by long haul and short haul (mean ± SD, 10 ± 9, 7 ± 7, and 6 ± 5, respectively). In the intervention group, mixed fleet pilots had the most flights, followed by short haul and long haul (mean ± SD, 14 ± 1, 9 ± 9, and 6 ± 4, respectively). All participants provided informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wish to do so. Participants were provided with a unique identification code on their informed consent form, which they were instructed to input into their survey instead of their name, in order to support anonymity and dataset blinding during data analysis.

Table 10: Baseline demographic characteristics of participants.

Parameters	**All subjects (n = 79)**	**Intervention (n = 38)**	**Control (n = 41)**
Sex (f / m)	14 / 65	8 / 30	6 / 35
Age (y)	42 ± 12	39 ± 10	44 ± 13
Short Haul (n)	32	22	10
Long Haul (n)	35	14	21
Mixed Fleet (n)	12	2	10
Flights during lockdown (n)	7.8 ± 7.3	5.9 ± 7.5	7.2 ± 7.1

Note: Mean ± SD reported for all subjects, intervention and control. Abbreviations: SD = standard deviation. SE = Standard error. * Indicates statistical significance ($p < 0.05$).

Intervention Group

Participants who registered their interest to participate in the intervention and agreed to attend a face-to-face consultation session at the airline medical unit were included in the intervention group. The intervention group received an initial one-on-one 60-min consultation session with an experienced health coach, followed by provision of an individualized health programme, weekly "educational" content emails during the intervention, and a mid-intervention phone call. The health advice provided was evidence-based and derived from experts in the area of physical activity, nutrition and chronobiology.

Personalised goal setting was carried out for each participant for the intervention with relevant outcome, performance and process goals (Weinberg, 2010) discussed pertaining to each of the three intervention components (1) dietary behaviours, (2), physical activity, (3) sleep habits. Moreover, individual perceived barriers to health change were assessed with methods outlined elsewhere (Kulavic et al., 2013) which were factored into the individualized program.

Sleep hygiene as an educational strategy has demonstrated improvements in self-report sleep quality in blue collar employees (Nishinoue et al., 2012). Stimulus control as a behaviour technique has demonstrated positive outcomes on sleep parameters in insomniacs (Riedel et al., 1998). An evidence-based sleep health checklist was developed for utilisation in this study (see Appendix D), which consisted of the standard recommendations derived from that which have been used in previous sleep hygiene and stimulus control studies (Morgenthaler et al., 2006; Perlis et al., 2000). Application of the sleep health checklist involved collaborative identification of which strategies participants were achieving at baseline. Pilots completed the PSQI prior to attending their consultation. During the face-to-face consultation the health coach discussed suboptimal PSQI component scores with the participant and identified individual sleep priorities. Thereafter, participants collaboratively set personalised sleep practice goals with support from the health coach. Personalised collaborative goal setting was implemented as a behavioural technique to support development of sleep habits that support restorative sleep (Weinberg, 2010).

Physical activity prescription was individualized based on participant perceived barriers and facilitators to exercise (Kulavic et al., 2013), application of the frequency, intensity, time, and type (FITT) principles (Barisic et al., 2011), and progression to attainment of sufficient MVPA to meet guidelines (World Health Organization, 2010) in congruence with individual capabilities. Frequency and time of PA sessions were tailored to participant time availability. Intensity was tailored based on participant exercise experience, physical health, and goal orientation (Norton et al., 2010). Type of PA was determined by the individual’s modality preferences for cardiovascular (such as walking, running, or cycling) and strengthening (for example, resistance equipment and/or bodyweight exercises) PA. Physical activity progression self-monitoring was indicated, and participants were advised to implement small progressive changes in PA during the intervention (such as; increase session duration; perform more repetitions; perform greater intensity; or accomplish more weekly bouts) (Piercy et al., 2018). Healthy eating principles were emphasised through individualized advice and educational materials focused on “adding colour” via consumption of fruit and vegetables (Slavin & Lloyd, 2012) and choosing nutrient dense foods (Di Noia, 2014), limiting processed foods and enhancing whole food consumption (Shahidi, 2009), and reducing white carbohydrates, refined carbohydrates and added sugar (for example, energy dense food) (Drewnowski, 2004). Relative to participant baseline behaviours, collaborative individualized process behaviour goals were established (for example, adding colour to meals; replace high glycaemic index (GI) foods with low GI options). Prescribed dose of fruit was ≥ 2 serves and vegetables were ≥ 3 serves per day. A mid-intervention (during week

8 ± 1, approximately 10 minutes duration) follow up phone call consisted of a semi-structured interview emphasizing discussion of progress and compliance pertaining to individualized sleep, physical activity and dietary goals established during the pre-test consultation. Advice was provided where necessary, consistent with that which was provided at the pre-test. Phone calls were utilised as this may support adherence to health interventions (Nesari et al., 2010). Weekly emails consisted of educational blog posts of varying topics related to sleep health, physical activity and nutrition, and supporting a healthy immune system, congruent with evidence-based methods previously outlined. Content was derived from health authorities via publicly available information from the World Health Organization and the Centers for Disease Control and Prevention. During the COVID-19 lockdown, content was tailored to the pandemic conditions, including strategies for physical activity at home, healthy recipes, and immune system health information.

Control Group

The participants in the control group were blind to the intervention and received no intervention or instruction regarding health behaviours between pre-and post-tests. Pilots were invited to voluntarily complete an electronic survey. Pilots who completed this survey during the previously defined pre-testing period prior to COVID-19 lockdown, were sent an invitation via email to voluntarily complete the survey again during the post testing period in order to provide insight into the effects of COVID-19 lockdown on their health behaviours.

Instruments

The PSQI was utilised to evaluate subjective sleep quality, and scores were obtained before the start of the study at the pre-test and were compared to scores obtained at the post-test stage. The PSQI is a self-rated 19-item questionnaire designed to measure sleep quality and disturbances over a 1-month retrospective period (Buysse et al., 1989). Sleep quality component scores are derived for subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, daytime dysfunction, and collectively produce a global sleep score (Buysse et al., 1989). Lower scores denote a healthier sleep quality, ranging from 0 (no difficulties) to 21 (severe sleep difficulties) (Buysse et al., 1989). The PSQI has demonstrated good test-retest reliability, validity and has been implemented in many population groups (Buysse et al., 1989; Manzar et al., 2018). The outcome measurements were the change in global score between each group at post-testing.

PA levels were assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF), a validated self-report measurement tool of moderate-to-vigorous PA (MVPA) that has been widely utilised in large cohort studies including NZ population surveys (Ministry of Health, 2019). The IPAQ-SF estimates PA achievement by quantifying weekly walking, moderate and vigorous PA duration and frequency. Responses were used to compare participants PA levels with the health guidelines of 150 minutes moderate-intensity, or 75 minutes vigorous-intensity, or an equivalent combination MVPA per week (World Health Organization, 2010). IPAQ-SF outcome measures derived were (a) total weekly minutes of moderate + vigorous PA in bouts of ≥ 10 min, excluding walking (IPAQ-MVPA) and (b) total weekly minutes of walking in bouts of ≥ 10 min (IPAQ-Walk). Responses were capped at 3h/day and 21 h/week as recommended by IPAQ Guidelines (IPAQ Research Committee, 2005). Fruit and vegetable intake were measured using two questions with acceptable validity and reliability derived from the New Zealand Health Survey (Ministry of Health, 2019). The questions asked participants to report on average, over the last week how many servings of fruit and vegetables they eat per day. Responses to these questions were combined to determine total daily fruit and vegetable intake.

Subjective self-report physical and mental health was determined using the Short Health Form 12v2 (SF-12v2), a short version of the SF-36 which reduces burden on participants and has demonstrated high correlation with SF-36 physical and mental component summary scale scores (Ware et al., 1995). The 12 item survey produces a physical component summary scale (PCS-12) and a mental component summary scale (MCS-12), which have good test-retest reliability and convergent validity to detect changes in mental and physical health over time in adults (Cheak-Zamora et al., 2009). Scoring of the SF-12v2 was carried out in accordance with standard summary scoring methods (Ware et al., 1995). The summary scores are on a scale of 0-100, with clinical significance change scores suggested to be 5-10 points (Samsa et al., 1999).

Statistical Analysis

Raw data was extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into the Statistical Package for the Social Sciences (version 26; IBM, New York, NY, USA) for all statistical analyses. Listwise deletion was applied for individual datasets with missing values or participants who did not complete post-testing. Stem and leaf plots were inspected to ascertain whether there were any outliers in the data for each variable. A Shapiro-Wilk's test ($p > .05$) and its histograms, Q-Q plots and box plots were inspected for normality of data distribution for all variables. Levene's test was used to test homogeneity of variance. Time related effects within and between groups on pre-test and post-test were assess using t-tests and repeated measures mixed-design analysis of variance (ANOVA). Age, sex and number of flights were included as covariates in the ANOVA. Effect sizes were calculated using Cohen's *d* to quantify between group effects from pre-testing to post-testing. Effect sizes thresholds were set at > 1.2, > 0.6, > 0.2, < 0.2 were classified as *large*, *moderate*, *small*, and *trivial* (Cohen, 1988). The alpha level was set at $p < 0.05$.

Results

The demographic and baseline health characteristics between the intervention and control groups can be observed in Table 10. The attrition rates were 16% and 30%, for the intervention and control group, respectively. Intervention group attrition were influenced by employment layoffs, whereas control group attrition was due to non-response to the online invitation to voluntarily complete the survey at the post-test period. At the time of the mid-intervention phone call, average sleep hours, exercise sessions per week and daily fruit and vegetable consumption was collected to measure compliance. Of the intervention group, 35 (92%) were achieving ≥ 7 hours sleep per night and 3 (8%) were obtaining ≤ 6.9 hours per night. For fruit and vegetable servings per day, 36 (95%) were achieving ≥ 5 serves of fruit and vegetables per day, whereas 2 (5%) were eating 2-4 serves per day. Thirty-three were achieving ≥ 150 minutes MVPA (87%), and 5 (13%) were completing ≤ 149 minutes MVPA per week.

At baseline, the control group achieved significantly ($p = < 0.05$) more sleep per night (36 min), a lower global PSQI score (-1.8) denoting a healthier score, higher consumption of daily fruit and vegetables (1.2 servings), greater weekly walking (94 min), and higher SF-12v2 physical and mental component scores (8.4 and 6.7, respectively). At baseline, the control group exhibited weekly MVPA (171 ± 78 min) achieving health guidelines of ≥ 150 min/week (World Health Organization, 2010), whereas the intervention group were achieving below (116 ± 51 min) the health guideline threshold. However, the between group difference in MVPA was not statistically significant between groups ($p = > 0.05$).

Group changes from pre-test to post-test are presented in Table 11. Significant main effects for time X group were found for IPAQ-Walk ($p = 0.02$) and for all other outcome measures ($p = < 0.01$), associated with *small* to *large* effect size differences between groups (Table 11). Significant main effects for time were found for PSQI, fruit and vegetable intake, PCS-12, and MCS-12 ($p = < 0.01$). Further significant time effects were found for hours slept and MVPA ($p = \leq 0.05$). The within group analysis revealed the intervention elicited significant improvements ($p = < 0.01$) in all health metrics at post-test excluding IPAQ-Walk. The control group reported a significantly higher PSQI score ($p = < 0.01$), decreased hours of sleep and MCS-12 score ($p = < 0.01$), yet no significant change was reported in other health metrics. Significant differences ($p = < 0.05$) for group were reported for IPAQ-Walk, PCS-12 and MCS-12. No significant group differences were reported in other health metrics.

Table 11: Changes in health behaviours from baseline to post-test at 17-weeks.

	Intervention group			Control Group			ANOVA (time X group) interaction	Effect Size
	Pre	Post	Change	Pre	Post	Change	p	*d*
Hours slept (h:mm)	7:00 ± 0:54	7:48 ± 0:48**	0:48 ± 0:54	7:36 ± 0:48	7:12 ± 1:00**	-0:24 ± 0:42	< 0.01	1.35, *Large*
PSQI Global	6.4 ± 2.7	4.1 ± 1.8**	-2.3 ± 2.4	4.5 ± 2.5	5.3 ± 2.9**	0.8 ± 0.9	< 0.01	1.14, *Large*
IPAQ-Walk	61 ± 69	93 ± 96	32 ± 105	155 ± 135	136 ± 111	-19 ± 79	0.02	0.45, *Small*
IPAQ-MVPA	116 ± 51	201 ± 77**	85 ± 100	171 ± 78	146 ± 75	-26 ± 82	< 0.01	1.44, *Large*
Fruit and Vegetable Intake	3.0 ± 0.6	6.1 ± 1.7**	3.1 ± 1.5	4.2 ± 0.9	4.1 ± 1.5	-0.1 ± 1.3	< 0.01	2.09, *Large*
PCS-12	43.3 ± 5.2	52.6 ± 4.9**	9.4 ± 5.5	51.7 ± 5.7	51.5 ± 6.0	-0.2 ± 2.2	< 0.01	1.52, *Large*
MCS-12	48.0 ± 4.0	54.8 ± 1.0**	6.8 ± 4.1	54.7 ± 4.3	51.9 ± 4.5**	-2.8 ± 4.4	< 0.01	2.09, *Large*

Note: Data are means ± SD. * indicates statistical significance ($p < 0.05$). ** indicates statistical significance ($p < 0.01$). *d* = Cohen's *d* effect size, effect threshold. Abbreviations: IPAQ = International Physical Activity Questionnaire. MCS-12 = SF-12v2 Mental Component Summary Scale Score. MVPA = Moderate-to-Vigorous Physical Activity. PCS-12 = SF-12v2 Physical Component Scale Score. PSQI = Pittsburgh Sleep Quality Index. SE = Standard error of difference.

Discussion

To our knowledge, this is the first controlled experiment that has explored the effects of a lifestyle intervention on health outcomes during a national pandemic lockdown in pilots. This study aimed to improve health-related behaviours and promote positive change in subjective health of pilots through personalised advice on healthy eating, sleep hygiene and physical activity. The controlled trial demonstrated significant improvements in the intervention group for most outcome measures, compared to the control group. These results are important for researchers and health care professionals to provide insight into potential health and quality of life perturbations resulting for COVID-19 that may have potential implications to flight safety. Furthermore, given the dearth of published data pertaining to health behaviour interventions during a pandemic and the limited availability of preventive lifestyle-based interventions in pilots, these findings provide novel contributions to this field.

The average PSQI score for the intervention group decreased (-2.25), compared to a significant increase in the control group (0.76). These effects support previous studies within non-pilot populations, which have reported PSQI score decreases of -1.54 to -1.8, following a sleep hygiene education intervention (Falloon et al., 2015; Nishinoue et al., 2012) and -2.5 after a physical activity and sleep education app-based mobile health intervention (Murawski et al., 2019). Within pilots, an app-based intervention to reduce fatigue in a pilot population reported a smaller effect on PSQI score (-0.59) after a 6-month intervention period focusing on advice regarding daylight exposure and sleep duration. None of these studies were conducted under global pandemic conditions. A potential cofounding factor to sleep quality and quantity improvements during COVID-19 due to social isolation and lockdown constraints has been proposed (Arora & Grey, 2020), where more time at home and flexible sleep-wake schedules may promote enhancements in sleep. Furthermore, sleep disruption is an inherent risk for pilots, and they are likely to have better sleep quality and quantity when not at work.

Curiously, in the present study the control group significantly increased PSQI score. Similar findings have been reported elsewhere in a general population-based study in Australia (n = 1491), which reported 40.1% indicating negative change in sleep quantity during lockdown (Stanton et al., 2020). In another study, sleep quantity improved while sleep quality was degraded in Austrian adults (n = 435) (Blume et al., 2020). In that study, an increase in subject burden and decreased physical and mental wellbeing were also observed. Cognitive states of elevated distress and emotional disturbances are associated with unhealthy dietary patterns and poor diet quality and may impair health behaviour motivation (Naja & Hamadeh, 2020). Researchers have advocated for implementation of strategies to mitigate the effects of 'lockdown' on sleep quality, including obtaining sufficient physical activity, exposure to natural daylight (Blume et al., 2020), and well balanced meals rich in vitamins and minerals (Naja & Hamadeh, 2020). Our study findings support these messages by observing significant improvements in PCS-12 and MCS-12 scores compared to the control group, after implementation of a three-component healthy sleep, eating and physical activity intervention during an unprecedented global pandemic.

The average MVPA and fruit and vegetable consumption significantly increased in our intervention group, compared to no significant change in the control group. The intervention group increased MVPA from 116 minutes to 201 minutes at post-testing, which crossed the MVPA guidelines threshold of ≥ 150 minutes per week (World Health Organization, 2010). Conversely, the control decreased MVPA from 171 minutes to 146 minutes per week at post-testing, decreasing to below the guideline threshold. Both the control and intervention groups did not achieve recommendations of ≥ 5 servings per day for fruit and vegetable intake at baseline (Moore et al., 2015). The intervention group elevated their intake per day, achieving guidelines at post-testing. Our study findings suggest the three-component intervention supported achievement of PA and fruit and vegetable guidelines and significantly improved PCS-12 and MCS-12 scores in the intervention group. Further, the intervention appeared to mitigate decay in both SF-12v2 summary scales which were observed in the control group.

Research exploring the relationship between COVID-19, PA and dietary behaviours have revealed mixed outcomes. Within an Italian population (n = 3533) during COVID-19 lockdown, similar proportions of the participants stated that they eat less or more healthily (35.8% and 37.4%, respectively), in regard to intake of fruit, vegetables, nuts and legumes (Di Renzo et al., 2020). Furthermore, in this study physical activity behaviours did not significantly change, however a greater amount of exercise was completed at home (Di Renzo et al., 2020). Amongst Australians, 48.9% expressed a negative change in PA during lockdown (Stanton et al., 2020). This study also reported that negative changes in physical activity and sleep were associated with expression of higher anxiety, depression and stress levels (Stanton et al., 2020). Elsewhere, in a Canadian sample (n = 1098) during lockdown, those who engaged in more outdoor PA time had lower anxiety levels than those who did not. The COVID-19 lockdown in NZ at level 3-4 presented barriers for engaging in PA, such as social distancing, travel restrictions, inaccessibility to parks, gyms, and other recreational facilities which may have promoted sedentary behaviour and contributed to the decline in PA observed in the control group (Hobbs et al., 2015; Matias et al., 2020). Furthermore, life stressors including job uncertainty (Sobieralski, 2020), anxiety, psychological stress (Bao et al., 2020), financial loss, and disconnection with community and nature may have impacted health behaviours during this time. In contrast, the reduced time at work has been suggested as a potential facilitative factor in enhancing health behaviours during lockdown (Arora & Grey, 2020), as this naturally alleviates one of the most commonly expressed barriers to engagement in PA, a "lack of time".

Limited studies have investigated the efficacy of interventions targeting healthy dietary and physical activity behaviours within pilots. An app-based intervention reported significant improvements in weekly moderate and strenuous activity (0.21 and 0.19 days per week, respectively), and a reduction in snacking behaviour (-0.88 serves per duty), in pilots over a six-month intervention period (van Drongelen et al., 2014). Diet and physical exercise consultation among pilots has showed positive change in blood lipids and body mass index (Choi & Kim, 2013). Our findings pertaining to MVPA, fruit and vegetable intake, PSQI and SF-12v2 provide promising preliminary outcomes regarding the effects of a three-component intervention in pilots and warrant further investigation with objective outcome measures.

Limitations and Future Research

The differential recruitment strategies and limited exclusion criterion for the intervention and control is a limitation and may have contributed to the significant differences which were observed at baseline for sleep quantity and PSQI score, IPAQ-walk, MVPA, fruit and vegetable consumption, and SF-12v2 subjective health scores between groups, with superior results in favor of the control group. Thus, it is recommended that future research implements more robust randomisation assignment conditions for participant allocation to groups in order to increase the probability of capturing the true population average and enhance the generalizability of findings. Future research should increase the sample size due to the apparent variances in health behaviours amongst the pilot population, which in itself warrants further investigation to characterize these variances.

Future research within pilots comparing single-behaviour to multiple-behaviour interventions would provide valuable insight into the magnitude of difference between these intervention approaches. Given the bidirectional relationship between each of these variables and some evidence to suggest multiple-component interventions may have stronger participation and adherence (Robroek et al., 2009), we suggest future research examine more time efficient and scalable strategies for implementation of a three-component sleep, nutrition and physical activity programme. Self-report methods were utilised in this study for feasibility reasons, however limitations of this approach have been discussed elsewhere (Brutus et al., 2013). To enhance outcome measure validity and reliability, utilisation of objective methods would be preferential such as actigraphy to monitor sleep and physical activity, and photo logging of dietary behaviours to quantify health behaviour metrics. Comparisons to related studies are limited to interventions conducted under 'normal' societal conditions, in the absence of a global pandemic. Thus, we were unable to compare our present intervention findings to similar studies under pandemic conditions due to the dearth of published literature in this field.

Conclusion

Behavioural countermeasures for individuals are vital determinants to health resilience amongst exposure to unprecedented environmental events such as the COVID-19 pandemic (Naja & Hamadeh, 2020). The attainment of sleep, fruit and vegetable intake and physical activity guidelines are associated with, increased physical health and mental health (Mandolesi et al., 2018; McMartin et al., 2013), enhanced immune defenses (Valdés-Ramos et al., 2010), and reduces the risk of obesity (Cecchini et al., 2010). Evidence-based interventions targeting the promotion of these behaviours will enable individuals to protect themselves physically and psychologically during a pandemic and are of public health importance (Naja & Hamadeh, 2020; Reissman et al., 2006). The three-component healthy sleep, eating and physical activity intervention implemented in this study elicited significant improvements in sleep quality and quantity, fruit and vegetable intake, and MVPA and suggests that collectively achieving sleep, fruit and vegetable intake and PA guidelines promotes perceived mental and physical health and may improve quality of life in pilots during an unprecedented global pandemic. This intervention provides preliminary evidence that a low-intensity, multi-behaviour intervention may be efficacious during a pandemic and similar outcomes may be transferrable to other populations. However, more robust recruitment methods are required to confirm present findings and increase generalizability.

CHAPTER SIX

The Effects of a Brief Lifestyle Intervention on the Health of Overweight Airline Pilots During COVID-19: A 12-month Follow-Up Study

Wilson, D., Driller, M., Winwood, P., Johnston, B., & Gill, N. (2021). The Effects of a Brief Lifestyle Intervention on the Health of Overweight Airline Pilots During COVID-19: A 12-month Follow-Up Study. Nutrients. 13(12) 4288. https://doi.org/10.3390/nu13124288 [Impact Factor: 6.706]

Prelude

Given the acute efficacy of a personalised nutrition, physical activity and sleep hygiene intervention as observed in Chapter Five, Chapter Six endeavored to build upon the findings by investigating the chronic effects of the controlled trial at 12-months follow up.

Abstract

The aim of this study was to perform a 12-month follow-up of health parameters after a 17-week lifestyle intervention in overweight airline pilots. A parallel-group (intervention and control) study was conducted amongst 72 overweight airline pilots (body mass index > 25) over a 12-month period following the emergence of COVID-19. The intervention group ($n = 35$) received a personalised dietary, sleep and physical activity program over a 17-week period. The control group ($n = 37$) received no intervention. Measurements for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) via an electronic survey, and objective measures of body mass and blood pressure were taken at baseline and at 12 months. Significant interactions for group × time from baseline to 12-months were found for all outcome measures ($p < 0.001$). Body mass and mean arterial pressure significantly decreased in the intervention group when compared to the control group ($p < 0.001$). Outcome measures for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) significantly increased in the intervention group when compared to the control group ($p < 0.001$). Results provide preliminary evidence that a brief three-component healthy sleep, diet and physical activity intervention can elicit and sustain long-term improvements in body mass and blood pressure management, health behaviours, and perceived subjective health in pilots and may support quality of life during an unprecedented global pandemic.

Keywords: healthy eating; weight loss; moderate-to-vigorous physical activity; sleep; lifestyle medicine.

Introduction

The COVID-19 pandemic has impacted operations of numerous industries, including the aviation industry which has been significantly disrupted by global travel restrictions, causing a substantial economic decline within the industry (Dube et al., 2021). Following the World Health Organization's characterization of COVID-19 as a pandemic on March 11, 2020, the global commercial airline industry experienced an approximate 60-80% decrease in flight operations during the proceeding months (Sobieralski, 2020). Accordingly, airline pilots have been affected by decreased work availability (Dube et al., 2021), job security, financial concerns, increased time spent confined to the indoors due to self-isolation requirements during travel (Parmet & Sinha, 2020), and limited control over food choices during hotel self-isolation after flying internationally. The consequent psychosocial impacts of these conditions may adversely affect the engagement in health promoting behaviours (McBride et al., 2021).

The COVID-19 pandemic has influenced considerable changes to behaviour, and subsequent physical and mental health related outcomes (McBride et al., 2021). Authorities in countries worldwide have implemented strict control strategies in attempt to limit the spread of the virus (Douglas et al., 2020). Consequently, these viral spread mitigation measures in the community pose significant barriers to engagement with health promoting behaviours (Hamer et al., 2020). For example, financial insecurity, elevated psychosocial stress, and emotional dysregulation may lower motivation and limit accessibility to healthful dietary behaviours (Naja & Hamadeh, 2020; Naughton et al., 2021). Further, stay at home isolation and lockdown measures present an inhibitory effect on engagement in physical activity (Herle et al., 2021; McBride et al., 2021).

Negative effects on physical (Fernández-Abascal & Martín-Díaz, 2021) and mental wellbeing, along with elevated levels of psychosocial stress (Ammar et al., 2021) have been reported in research exploring the effects of COVID-19 environmental conditions, such as social distancing and lockdown confinement in adults. Decreases in physical and mental health during COVID-19 have shown associations with unhealthy lifestyle behaviours; sedentary behaviour, physical inactivity, poor sleep quality and unhealthy dietary intake (Ammar et al., 2021). Prospective cohort studies exploring health behaviour status during lockdowns have reported increased sedentary behaviour and physical inactivity (Stockwell et al., 2021), decreased fruit and vegetable intake (Litton & Beavers, 2021) increased alcohol intake (Naughton et al., 2021), and increased sleep problems (Jahrami et al., 2021), yet little evidence has been reported regarding the prolonged effects after lockdown.

Overweight, obesity and hypertension are independently associated with unhealthy lifestyle behaviours; insufficient sleep, poor diet, and physical inactivity (Broussard & Van Cauter, 2016; Cecchini et al., 2010; Drewnowski, 2004; Valenzuela et al., 2021). Widespread societal and economic implications of COVID-19 present perturbations to these health behaviours (Fernández-Abascal & Martín-Díaz, 2021; McBride et al., 2021; Naughton et al., 2021; Parmet & Sinha, 2020). Unhealthy lifestyle risk factors synonymous with an elevated risk of non-communicable disease are a risk factor for COVID-19 complications and severity of health outcomes following infection (Hamer et al., 2020). Markedly, obesity is associated with chronic low-grade inflammation, impaired innate immunity and immunologic compromise (Michalakis et al., 2021). Indeed, recent studies report increased morbidity and mortality risk from COVID-19 in those with obesity (Popkin et al., 2020). Overweight and obesity are also major risk factors for essential hypertension, of which emerging evidence denotes as a risk factor strongly associated with adverse outcomes from COVID-19 (Tadic et al., 2021).

Behavioural countermeasures for individuals are vital determinants to health resilience amongst exposure to unprecedented environmental events such as the COVID-19 pandemic and its widespread implications (Naja & Hamadeh, 2020). Obtaining seven to nine hours of sleep per night (Hirshkowitz et al., 2015), consuming ≥ 400 g of fruit and vegetables per day fruits and vegetables (Bellavia et al., 2013), and engaging in ≥ 150 minutes of moderate-to-vigorous physical activity intensity per week are three protective lifestyle behaviours that significantly reduce all-cause mortality (Bellavia et al., 2013; Cappuccio et al., 2010; Lear et al., 2017), and have a positive effect on physical and mental health (Mandolesi et al., 2018; Mozaffarian et al., 2008), support healthy bodyweight and blood pressure management (Valenzuela et al., 2021), and support immune system function (Walsh et al., 2011). Given the evidence for physical activity, healthy nutrition and sleep quality in promoting health outcomes, it is of public health importance that effective evidence-based interventions targeting the promotion of these behaviours are established for intervention preventive measures to mitigate the adverse health effects of future lockdowns (Naja & Hamadeh, 2020).

Our previous research investigated the use of a personalised three-component healthy eating, physical activity and sleep hygiene intervention for promoting health during a COVID-19 lockdown in New Zealand (Wilson et al., 2021a). The intervention's effectiveness at 4-months has been reported (Wilson et al., 2021a), which revealed significant improvements in health behaviour and subjective health. The aim of the current study is to report on the longer-term outcomes of the intervention; specifically, to evaluate the effects on weight loss maintenance. Further, to evaluate what health behavioural changes are sustained or decayed over a period of 12-months and what influence they have on health parameters. It was hypothesized that the intervention group would have significantly greater improvements in health behaviours and health parameters compared to the control group at 12-months. It was also hypothesized that some decay in health behaviours and parameters would be evident in the intervention group from post intervention (4-months) to 12-months.

Methodology

Design

A two-arm, parallel, controlled design was utilised to evaluate the effectiveness of a brief three-component lifestyle intervention for enhancing and maintaining health behaviours, body mass and blood pressure management during the COVID-19 pandemic in New Zealand. The acute (17-week) effects of this lifestyle intervention on subjective measures for physical activity, sleep duration, and fruit and vegetable intake have been previously reported (Wilson et al., 2021a). Therefore, the purpose of the present study was to complete a 12-month follow up to that study (Wilson et al., 2021a).

This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07. The trial protocol is registered at The Australian New Zealand Clinical Trials Registry (ACTRN12621001105831).

Intervention Timing

After baseline testing, the first five weeks of the intervention period preceded the New Zealand (NZ) Government's implementation of a four-tier response system to COVID-19 on 21 March 2020 (Baker et al., 2020). Thereafter, five weeks were at highest alert level 4, two and a half weeks were at alert level 3, and two weeks were at alert level 2. Thereafter, NZ returned to alert level 1 (Ministry of Health, 2020c). Restrictions associated with each alert level is defined elsewhere (Wilson et al., 2021a). Pre-testing occurred between 14th February and 9th March 2020 and follow up testing was carried out during February and March 2021.

Participants

The study population for both groups consisted of commercial pilots from a large international airline. Inclusion criteria were (a) pilots with a valid commercial flying license, (b) working on a full-time basis, (c) having a body mass index (BMI) of ≥ 25, and (d) a resting blood pressure of ≥ 120/80 (systolic/diastolic).

Control group participants consisted of airline pilot volunteers recruited at the time of completing their routine aviation medical examinations located at the airline medical unit during the time of the pre-test period. The intervention group volunteered to participate in the lifestyle intervention by responding to an invitation delivered to all pilots within the company via internal organisation communication channels. Participants consisted of pilot rosters including long haul (international flights), short haul (regional flights), and mixed-fleet (variable schedule of regional and short international flights).

All participants provided informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wish to do so. Participants were provided with a unique identification code on their informed consent form, which they were instructed to input into their electronic health survey instead of their name at each data collection timepoint, in order to support anonymity and dataset blinding during data analysis.

The sample size was based on previous research with congruent outcome measures (Wilson et al., 2021a). Clinically significant weight loss is defined as at least a 5% reduction in body mass from the baseline level (Donnelly et al., 2009). Our power calculation suggested that 37 participants were required in each group to achieve an 80% power and 5% significance criterion to detect a 4kg body mass reduction difference between the intervention and the control. To account for 20% attrition (Curioni & Lourenço, 2005), we recruited 89 participants.

Intervention Group

The intervention group participated in a 17-week health intervention consisting of individualized goal setting for physical activity, healthy eating and sleep hygiene. The intervention commenced with a one-hour individual face-to-face consultation session with an experienced health coach at the airline medical unit. For the intervention group, all participants conducted consultations with the same health coach. In this initial consultation session, the pilots' barriers and facilitators to health behaviour change were assessed with methods outlined elsewhere (Kulavic et al., 2013), which were factored into the development of an individualized health programme. Further, personalised collaborative goal setting was carried out for the pilot with assistance from the health coach, establishing appropriate outcome, performance, and process goals (Weinberg, 2010) for (a) sleep hygiene, (b) healthy eating, and (c) physical activity. A mid-intervention phone call was utilised to support adherence, monitor progress and measure compliance to health behaviours. The intervention utilised 20 participant contacts; including 2 face-to-face consultations (baseline and follow-up), 1 telephone call and 17 intra-intervention emails. For full detail of the procedures associated with the intervention readers are referred to the study of Wilson and colleagues (Wilson et al., 2021a).

Control Group

The participants in the control group received no intervention or instruction regarding health behaviours during the study timeframe. Pilots were invited to voluntarily complete an electronic survey and consent to providing records of their cardiovascular disease risk factor data from their aviation medical examinations. Pilots who volunteered to participate during the previously defined baseline testing period were sent an invitation via email to voluntarily complete the electronic survey again during the post intervention period and then finally again at the completion of their proceeding annual aviation medical examination to provide insight into the effects of COVID-19 on their health. The control group were invited to participate in the intervention after follow-up testing.

Outcome Measures

Measurements for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) via an electronic survey, and objective measures of body mass and blood pressure were taken at baseline and 12-months follow up (see Figure 6).

Prior to attending data collection sessions, participants were instructed to avoid any strenuous exercise, stimulants (for example, caffeine or energy drinks), or large meals 4 hours before testing. Height was recorded with a SECA 206 height measures and body mass was measured with SECA 813 electronic scales (SECA, Hamburg, Deutschland). For body mass measurement, participants were wearing clothes with emptied pockets and footwear removed. Blood pressure was measured with an OMRON HEM-757 device (Omron Corporation, Kyoto, Japan), which has been successfully validated independently against international criteria (El Assaad et al., 2003). Measurements of blood pressure were conducted according to the standardized aviation medicine protocol (Civil Aviation Authority, 2021). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) readings were used to calculate mean arterial pressure (MAP) with the following formula: DP + 1/3(SP – DP) (Sesso et al., 2000). Resting pulse was measured using a Rossmax pulse oximeter SB220 (Rossmax Taipei, Taiwan, China) after a 5-minute period of sitting in a chair quietly. All measurement instruments were calibrated prior to data collection.

Outcome measures for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) have been previously described in detail (Wilson et al., 2021a). In brief, moderate-to-vigorous physical activity was determined using the International Physical Activity Questionnaire Short Form (IPAQ) (Ministry of Health, 2019). To measure subjective sleep quality and quantity, the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al.,

1989) was utilised. Daily fruit and vegetable intake were measured using dietary recall questions derived from the New Zealand Health Survey (Ministry of Health, 2019), and self-rated health was determined using the Short Health Form 12v2 (SF-12v2) (Ware et al., 1995).

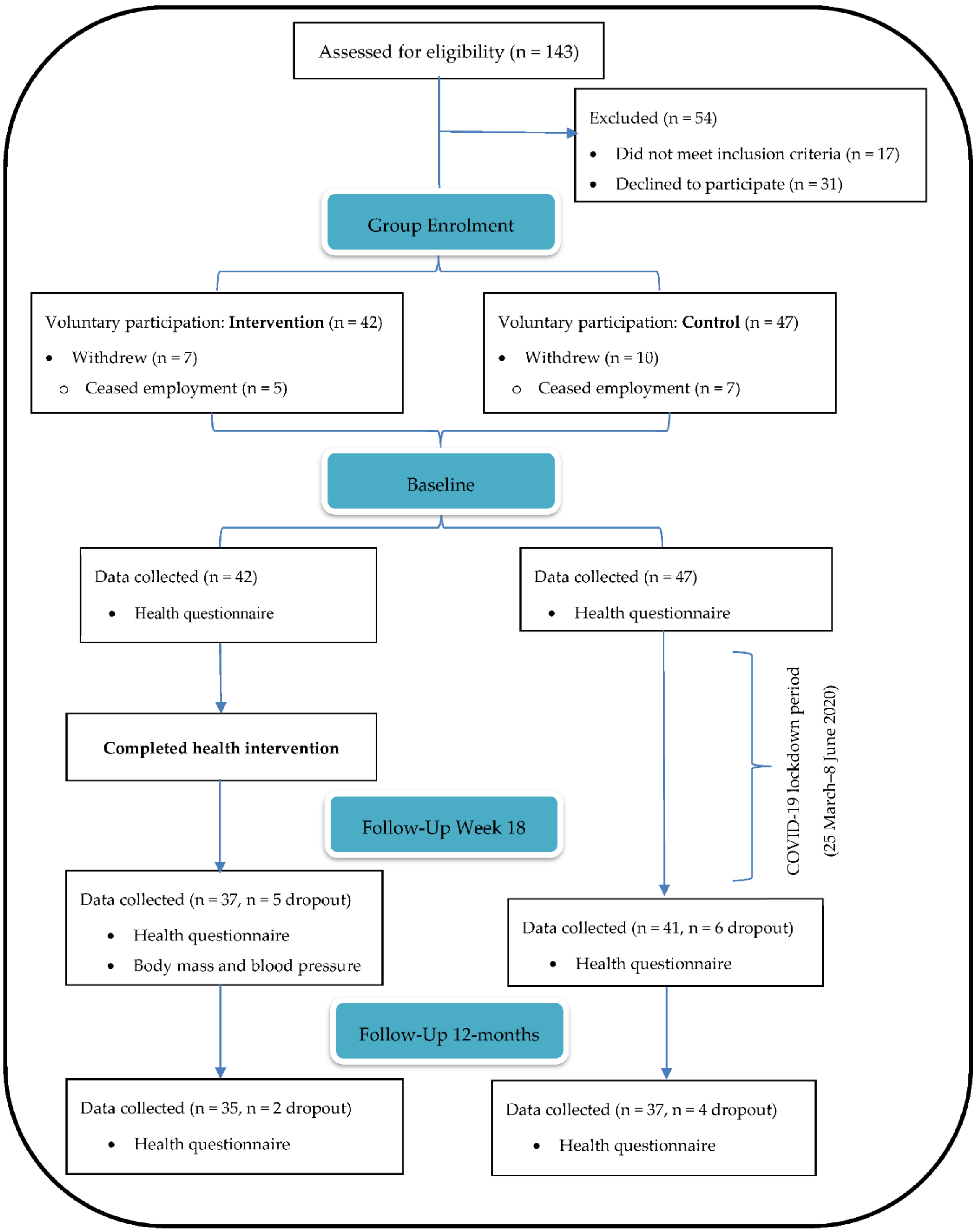

Figure 6: Flow diagram of participant recruitment and data collection.

Statistical Analysis

Raw data was extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into the Statistical Package for the Social Sciences (SPSS, version 27; IBM, New York, NY, USA) for all statistical analyses. All variables were assessed using the Shapiro-Wilk's test ($p > 0.05$) and its histograms, Q-Q plots and box plots for inspection for data normality. Levene's test was used to test homogeneity of variance. Listwise deletion was applied for individual datasets with missing values or participants who did not complete post-testing.

T-tests were utilised to explore baseline differences between groups. A Chi-squared test was utilised to calculate whether any significant differences exist between fleet type at baseline. A one-way analysis of variance (ANOVA) was utilised to calculate whether any significant differences exist between fleet type for flight frequency and flight hours. Repeated-measures ANOVA using the General Linear Modelling function in SPSS was utilised test for group x time interactions, group effects, and time effects (baseline to 12-months). Age, sex and flights were included as covariates in the ANOVA. As an additional analysis utilising paired t-test, we examined change in health parameters within the intervention group from post intervention at 4-months to 12-months follow up. Effect sizes were calculated using Cohen's *d* to quantify between group effects from pre-testing to post-testing. Effect sizes thresholds were set at > 1.2, > 0.6, > 0.2, < 0.2 were classified as *large*, *moderate*, *small*, and *trivial* (Cohen, 1988). The alpha level was set at $p < 0.05$.

Results

Baseline characteristics of the study population

143 airline pilots were initially assessed for eligibility and 89 were recruited to participate (see Figure 6). 72/89 (81%) pilots (mean ± SD, age; 46 ± 11y, 11 females, 61 males) provided outcome measure data at all data collection timepoints, which consisted of a combination of short haul, long haul, and mixed fleet rosters (n = 28, 35, and 9, respectively). The attrition rates from baseline to 12-months were 17% and 21% (for intervention and control, respectively).

As displayed in Table 12, at baseline the control and intervention group were of similar height, body mass, DBP, resting pulse and flight hours. The control group were of advanced age ($t(70) = 2.342$, $p = 0.02$, $d = 0.55$), consumed more fruit and vegetables ($t(70) = 4.570$, $p = < 0.001$, $d = 1.08$), performed more walking ($t(70) = 5.650$, $p = < 0.001$, $d = 1.33$), higher PCS-12 and MCS-12 scores ($t(70) = 7.751$, $p = < 0.001$, $d = 1.82$, and $t(70) = 4.798$, $p = < 0.001$, $d = 1.13$, respectively), achieved greater sleep duration ($t(70) = 3.012$, $p = 0.004$, $d = 0.71$), and had a lower MAP ($t(70) =-2.598$, $p = 0.011$, $d = 0.61$). No significant differences were observed between groups for flights during lockdown and flight hours after lockdown.

Table 12: Baseline characteristics of participants.

Parameters	**All Participants (*n* = 72)**	**Intervention (*n* = 35)**	**Control (*n* = 37)**
Sex (f/m)	11/61	7/28	4/33
Age (year)	45.8 ± 11.1	42.8 ± 10.4	48.7 ± 11.2*
Height (cm)	178.6 ± 7.2	178.5 ± 8.1	178.6 ± 6.3
Body mass (kg)	90.4 ± 13.9	91.6 ± 13.5	89.3 ± 14.5
BMI ($kg·m^2$)	28.3 ± 3.3	28.7 ± 3.3	27.9 ± 2.8
Systolic BP (mmHg)	134.4 ± 11.8	138.4 ± 10.6	130.6 ± 11.7
Diastolic BP (mmHg)	84.8 ± 8.3	86.7 ± 8.1	83.1 ± 8.2
MAP (mmHg)	101.3 ± 8.5	103.9 ± 8.0	98.9 ± 8.5*

Pulse (bpm)	68.7 ± 9.5	69.2 ± 7.8	68.1 ± 10.9
Hours slept (h/day)	7.3 ± 0.9	7.0 ± 0.8	7.6 ± 0.8*
IPAQ-walk (min)	102.4 ± 58.5	69.0 ± 37.9	134.0 ± 57.2*
IPAQ-MVPA (min)	144.5 ± 89.0	125.9 ± 79.7	162.1 ± 94.7
F&V Intake (serve/day)	3.5 ± 1.4	2.8 ± 1.3	4.1 ± 1.1*
PCS-12 (score)	46.7 ± 6.6	42.1 ± 4.1	51.1 ± 5.5*
MCS-12 (score)	49.1 ± 7.5	45.3 ± 8.2	52.7 ± 4.5*
Short Haul (*n*, %)	28 (39%)	20 (57%)	8 (22%) *
Long Haul (*n*, %)	35 (49%)	13 (37%)	22 (59%)
Mixed Fleet (*n*, %)	9 (12%)	2 (6%)	7 (19%)
Flights during lockdown (*n*)	8.0 ± 7.4	7.9 ± 7.7	8.1 ± 7.2
Flight hours after lockdown (h)	152.1 ± 71.9	153.9 ± 63.8	150.5 ± 79.7

Note: Mean ± SD reported for all participants, intervention and control. Abbreviations: SD = standard deviation. BMI—body mass index. BP = blood pressure. MAP = mean arterial pressure. IPAQ = International Physical Activity Questionnaire. MVPA = moderate-to-vigorous physical activity. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * Indicates statistical significance between groups ($p < 0.05$). Flight hours after lockdown = flight hours during the 6-months prior to 12-months follow up testing.

Intervention adherence

For the intervention group, compliance was measured mid-intervention for health behaviours, including average sleep hours, weekly MVPA and daily fruit and vegetable consumption. Thirty-two (91%) were achieving ≥ 7 hours sleep per night and 3 (9%) were obtaining ≤ 6.9 hours per night. For fruit and vegetable servings per day, 33 (94%) were achieving ≥ 5 serves of fruit and vegetables per day, whereas 2 (6%) were eating 2-4 serves per day. Thirty were achieving ≥ 150 minutes MVPA (86%), and 5 (14%) were completing ≤ 149 minutes MVPA per week.

Body mass, BMI, BP and pulse

Group changes from baseline to 12-months are presented in Table 13. Significant interactions for group x time were found for all variables (p = < 0.001), associated with *small* to *large* effect size differences between groups from baseline to 12-months (see Table 13). The within-group analysis revealed that the intervention elicited significant improvements (p < 0.001) in all physical metrics at 12-months, associated with *large* effect sizes (see Table 13). The control group reported a significantly higher body mass and BMI (p < 0.001) at 12-months, yet no significant changes were observed in other physical metrics.

Health behaviours and self-rated health

Significant interactions for group x time were found for all subjective health measures (p = < 0.001). The within-group analysis reported significantly greater improved health changes from baseline to 12-months for all subjective health measures in the intervention group (p < 0.001), associated with *moderate* to *large* effect sizes (see Table 13; Figure 7). In contrast, the control group experienced significant decreases in all outcome measures: sleep duration (t(36) = -2.589, p = 0.014, d = -0.42), PSQI global score (t(36) = 3.853, p = < 0.001, d = 0.63), and MCS-12 scores (t(36) = -2.300, p = 0.027, d = -0.38). No significant group differences were reported in other health metrics.

Additional analysis: 4-month post-intervention to 12-month follow up change

Table 14 presents changes within the intervention group between 4-months (post-intervention) and 12-months follow up. There were significant within group differences reported for body mass, BMI, MAP, weekly MVPA ($p = < 0.05$), and DBP ($p = < 0.001$), which were associated with *small* to *moderate* effect sizes towards positive health change. Conversely, a decay of *small* magnitude was observed for health parameters average sleep hours ($d = -0.23$), PCS-12 score ($d = -0.22$), and MCS-12 score ($d = -0.20$). No significant differences were observed for other health parameters.

Table 13: Changes in objective and subjective health metrics from baseline and follow up at 12-months.

		Intervention (*n* = 35)			**Control** (*n* = 37)			**ANOVA (Time × Group Interaction)**	**Between Group ES**
	Time (Months)	**M**	**SD**	**Follow Up Change (95% CI)**	**M**	**SD**	**Follow Up Change (95% CI)**	***p***	***d***
Body mass (kg)	0	91.7	13.5		89.3	14.5			0.2, *Trivial*
	12	86.8	11.3	−4.9 (−3.5–−6.3)	90.5	14.5	1.3 (0.6–1.9)	< 0.001	−0.3, *Small*
BMI (kg/m^2)	0	28.7	3.3		27.9	2.8			0.2, *Trivial*
	12	27.1	2.7	−1.6 (−1.1–−2.0)	28.3	3.7	0.4 (0.2–0.6)	< 0.001	−0.4, *Small*
Systolic BP (mmHg)	0	138.4	10.6		130.6	11.8			0.7 *, *Moderate*
	12	128.1	10.3	−10.4 (−7.2–−13.5)	134.4	9.9	3.8 (0.0–7.6)	< 0.001	−0.6 *, *Moderate*
Diastolic BP (mmHg)	0	86.7	8.1		83.1	8.3			0.4, *Small*
	12	78.9	8.0	−7.8 (−5.0–−10.6)	83.2	7.0	0.2 (−2.6–2.8)	< 0.001	−0.6*, *Moderate*
MAP (mmHg)	0	104.0	8.1		98.9	8.5			0.6*, *Moderate*
	12	95.3	7.6	−8.6 (−6.0–−11.3)	100.2	7.2	1.4 (−1.2–4.0)	< 0.001	−0.7*, *Moderate*
Pulse (bpm)	0	69.3	7.7		66.6	10.9			0.1, *Trivial*
	12	63.4	8.5	−6.0 (−3.8–−8.2)	69.2	12.2	2.5 (−0.7–5.6)	< 0.001	−0.7 *, *Moderate*
Hours slept (h/day)	0	7.0	0.9		7.6	0.8			−0.7 *, *Moderate*
	12	7.7	0.7	0.7 (0.4–1.1)	7.5	0.7	−0.2 (0.0–−0.3)	< 0.001	0.4, *Small*
PSQI Global (score)	0	6.4	2.8		4.5	2.6			0.7 *, *Moderate*

	12	4.1	1.5	−2.5 (−1.7–−3.2)	5.0	2.7	0.5 (0.2–0.7)	< 0.001	−0.5 *, *Small*
IPAQ-walk (min)	0	54.3	64.6		127.3	105.8			−1.3 **, *Large*
	12	102.3	69.2	35.8 (22.1–49.6)	122.6	77.6	−3.4 (−16.2–9.4)	< 0.001	−0.6 *, *Moderate*
IPAQ-MVPA (min)	0	121	108		160	106			−0.4, *Small*
	12	227	83	94 (62–126)	159	100	−2.9 (−16.9–11.1)	< 0.001	0.8 *, *Moderate*
F&V Intake (serve/d)	0	2.8	1.3		4.2	1.2			−1.1 **, *Moderate*
	12	5.5	1.7	2.6 (2.0–3.2)	3.9	1.3	−0.2 (−0.5–0.1)	< 0.001	1.1 **, *Moderate*
PCS-12 (score)	0	42.9	4.9		51.3	5.7			−1.8 **, *Large*
	12	51.7	4.0	9.0 (7.1–10.8)	50.7	4.9	−0.6 (−1.3–0.2)	< 0.001	0.1, *Trivial*
MCS-12 (score)	0	47.9	10.4		53.8	5.7			−1.1 **, *Moderate*
	12	54.0	4.9	5.8 (3.6–8.0)	52.3	4.7	−0.9 (−0.1–−1.7)	< 0.001	0.2, *Trivial*

Note: Mean ± SD reported for all participants, intervention and control. Abbreviations: SD = standard deviation. BMI—body mass index. BP = blood pressure. MAP = mean arterial pressure. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * Indicates statistical significance between groups ($p < 0.05$). ** indicates statistical significance between groups ($p < 0.001$).

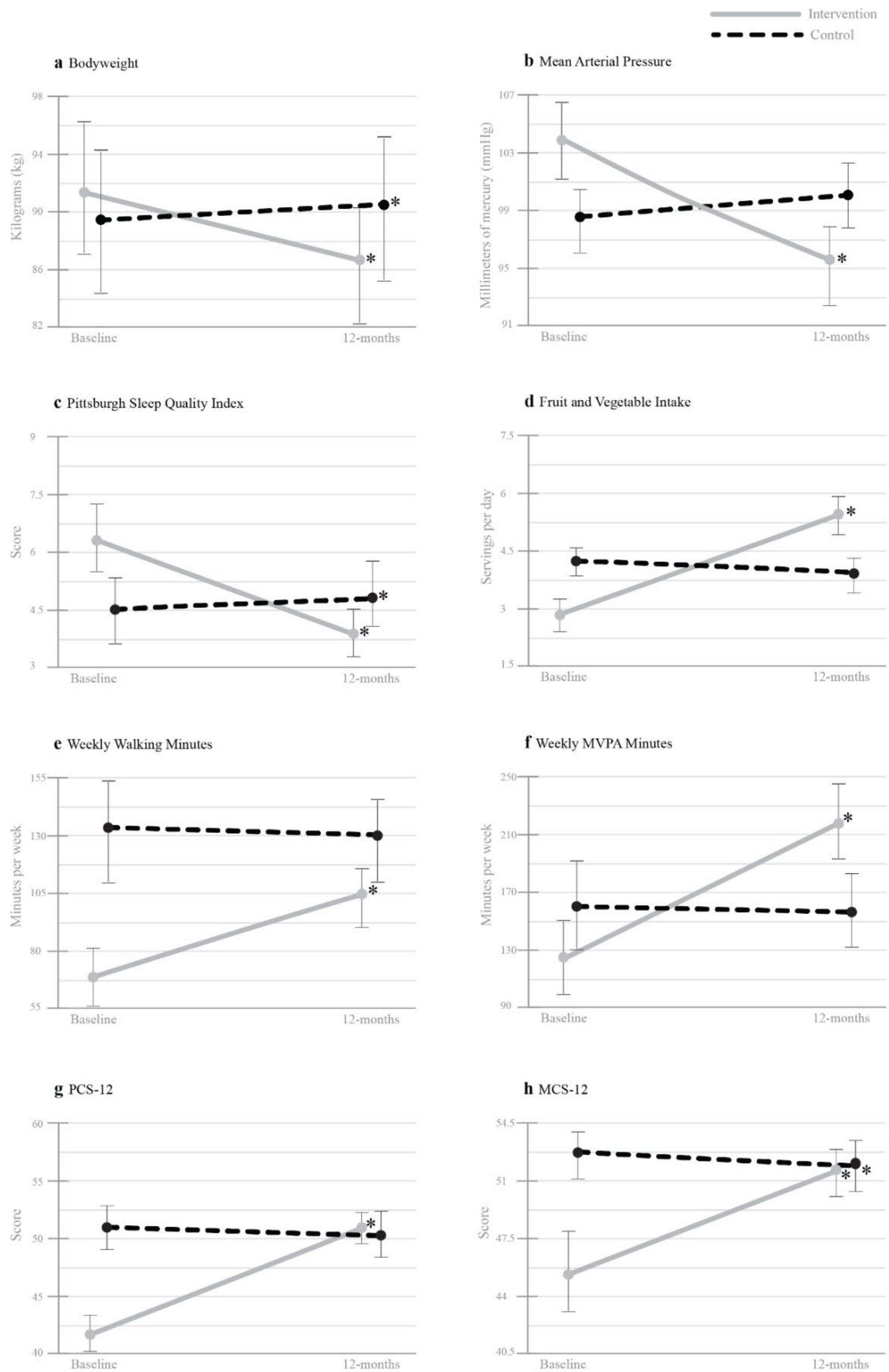

Figure 7: Mean values on objective and subjective health outcomes measured across time (Baseline and 12-months).

Note: Showing 95% confidence intervals. MVPA = moderate-to-vigorous physical activity. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * Indicates a significant difference compared to Baseline.

Table 14: Additional analysis: Changes in objective and subjective health metrics from post intervention at 4-months to follow up at 12-months in the intervention group.

		Intervention (*n* = 35)			**Effect Size**
	Time (Months)	**M**	**SD**	**Post-Follow up Change (95% CI)**	***d***
Body mass (kg)	4	87.7	12.8	-	-
	12	86.8	11.3	−0.97 (−1.81–0.1)	−0.47, *small* *
BMI (kg/m^2)	4	27.5	3.1	-	-
	12	27.1	2.7	−0.32 (−0.58–0.07)	−0.44, *small* *
Systolic BP (mmHg)	4	130.9	11.1	-	-
	12	128.1	10.3	−2.89 (−6.09–0.32)	−0.31, *small*
Diastolic BP (mmHg)	4	83.8	9.7	-	-
	12	78.9	8.0	−4.86 (−7.56–−2.15)	−0.62, *moderate* **
MAP (mmHg)	4	99.5	9.4	-	-
	12	95.3	7.6	−4.11 (−6.77–−1.46)	−0.53, *small* *
Pulse (bpm)	4	62.6	7.2	-	-
	12	63.4	8.5	0.74 (−2.0–3.5)	0.09, *trivial*
Hours slept (h/day)	4	7.8	1.0	-	-

	12	7.7	0.7	−0.11 (−0.27–0.05)	−0.23, *small*
PSQI Global (score)	4	4.1	1.8	-	-
	12	4.1	1.5	−0.09 (−0.31–0.14)	−0.13, *trivial*
IPAQ-walk (min)	4	94.3	96.5	-	-
	12	102.3	69.2	8.0 (−10.4–26.4)	0.15, *trivial*
IPAQ-MVPA (min)	4	207.6	79.0	-	-
	12	227.3	82.6	19.7 (5.57–33.74)	0.48, *small* *
F&V Intake (serve/day)	4	5.6	1.9	-	-
	12	5.5	1.7	−0.13 (−0.49–0.23)	0.12, *trivial*
PCS-12 (score)	4	52.3	4.5	-	-
	12	51.7	4.0	−0.54 (−1.38–0.29)	−0.22, *small*
MCS-12 (score)	4	54.5	5.7	-	-
	12	54.0	4.9	−0.52 (−1.41–0.36)	−0.20, *small*

Note: Mean ± SD reported for the intervention group. Abbreviations: SD = standard deviation. BMI—body mass index. BP = blood pressure. MAP = mean arterial pressure. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * Indicates statistical significance ($p < 0.05$). ** Indicates statistical significance ($p < 0.001$).

Discussion

This is the first 12-month follow up study after a lifestyle health intervention during the COVID-19 pandemic. The present intervention aimed to improve health-related behaviours and promote healthy changes in bodyweight and blood pressure within overweight and obese pilots through a personalised intervention on healthy eating, sleep hygiene and physical activity. The controlled trial showed that at 12-months follow up, there appeared to be a significant improvement on health parameters from being provided the 17-week intervention (Wilson et al., 2021a), relative to our control group which supports our initial hypothesis. These results are important for researchers and health care professionals to provide insight into prolonged health and quality of life perturbations resulting from COVID-19 that may have potential implications to flight safety. Furthermore, given the dearth of published data pertaining to health behaviour interventions during a pandemic and the limited availability of preventive lifestyle-based interventions in pilots, these findings provide novel contributions to this field.

Poor long term maintenance of weight loss and health behaviour change achieved from lifestyle diet and exercise interventions is frequently reported (Montesi et al., 2016). In our intervention group we observed sustained positive change in health behaviours at 12-months follow up, relative to baseline characteristics. Further, body mass, blood pressure, and weekly MVPA continued to improve at 12-months compared to post-intervention, whereas other health parameter improvements demonstrated non-significant *trivial* to *small* magnitudes of decay from post intervention. These findings support our secondary hypothesis and are consistent with other health behaviour research reporting reduced magnitude of change in health parameters at longitudinal follow up, compared to post-intervention (Varkevisser et al., 2019). A contributing factor that have been proposed is the discontinuation of health care professional support, following intervention completion (Middleton et al., 2013). Thus, highlighting the importance of ongoing care to facilitate additional health outcome improvements after a brief intervention.

Prospective cohort studies have reported significant increases in body mass within 4-months after the onset of the initial COVID-19 lockdown (Bakaloudi et al., 2021; Lin et al., 2021), yet limited studies have evaluated whether body mass gain is sustained longitudinally after lockdown conditions are lifted. In the present study, participants in the intervention group lost 4.9 kg (↓5.4%), while the control group gained 1.2 kg (↑1.3%) at 12-months, resulting in a 6.1 kg difference in body mass change between groups. Existing literature of lifestyle interventions targeting combined diet, physical activity, and sleep with longitudinal follow up measures are scarce, limiting comparison accuracy of the present findings to existing research. Airline pilot populations are often male dominant (Houston et al., 2011); indeed, our participant sample reflected this demographic. Contrarily, a recent meta-analysis reported the majority of participants in diet and exercise weight management interventions were women (Johns et al., 2014). Thus, our study provides important evidence regarding the effectiveness of lifestyle interventions within males.

The intervention utilised 20 participant contacts; including 2 face-to-face consultations, 1 telephone call and 17 intra-intervention emails. Comparatively, a recent review indicated a mean body mass reduction of 2.5 kg at 1 year follow up within dietary interventions consisting of 13-24 intra-intervention participant contacts (Singh et al., 2019). Another review reported a higher mean body mass reduction of 6.7 kg at 1 year follow up pertaining to intensive combined diet and exercise interventions (Curioni & Lourenço, 2005). However, the average length of treatment of these interventions were 37 weeks (Curioni & Lourenço, 2005), which is considerably higher than our 17-week intervention (Wilson et al., 2021a).

Another gap in the literature base is whether body mass gain observed during lockdown conditions is associated with increased blood pressure, which remains largely unexplored. The body mass gain evident in our control group was associated with a 3.8 mmHg increase in SBP at 12-months, compared to a reduction of 10.3 mmHg observed in the intervention group. The SBP reduction observed in the intervention group is comparable with previous research, which reported a 9.5 mmHg reduction in SBP at 12-months following an intensive diet and exercise lifestyle intervention (Elmer et al., 2006). Correspondingly, in our intervention group we observed a DBP reduction of 2.9 mmHg, and a further 4.9 mmHg at 4-months and 12-months, respectively. Compared with our present findings, a similar longitudinal relationship between body mass and blood pressure following intentional weight loss has been reported (Stevens et al., 2001). Stevens and colleagues reported participants who succeeded at weight loss maintenance at 36 months post-intervention also maintained blood pressure reduction obtained after the intervention, whereas participants who gained weight also experienced increased blood pressure (Stevens et al., 2001).

We discovered a significantly reduced MCS-12 score and increased PSQI global score (denoting worse sleep) at 12-months follow up in our control group, with no significant change in other subjective measures. Indeed, previous studies have demonstrated associations between sleep and mental health (Freeman et al., 2017). Further, negative changes in sleep quality during the pandemic have been associated with negative affect, worry and elevated psychosocial stress (Franceschini et al., 2020; Kocevska et al., 2020). These findings may be contributed to by additional factors acting on the pilot population during the time of this study, including decreased work availability (Dube et al., 2021), job security, financial concerns, increased time spent confined to the indoors due to self-isolation requirements during travel (Parmet & Sinha, 2020), and limited control over food choices during hotel self-isolation after flying internationally.

The magnitude of change observed in the present intervention may be at least partly attributable to; (a) the three-component diet, exercise and sleep approach, (b) behavioural approaches including collaborative goal setting, face-to-face coaching, telephone call and regular emails, and (c) the potential active interest of the pilot population in enhancing their health to support their aviation medical license. Weight loss factors such as restrictive diets and restrictive caloric patterns have been suggested as effective in the short term, but often have a poor long term success rate, leading to weight regain (MacLean et al., 2011). Whereas the methods utilised in the present study supported a physically active lifestyle, managing life stress with health behaviours, accountability, and facilitation of autonomy via self-determined goal setting, all of which are associated with successful weight loss maintenance (Elfhag & Rössner, 2005). Airline pilots have been reported to exhibit higher personality scores for maturity, emotional stability, and intelligence when compared to general population norms (Wakcher et al., 2003). These characteristics may positively influence intervention engagement and adherence, thus presenting an important consideration when generalizing our findings to the general population.

Potential limitations of the current study need to be considered in the interpretation of our findings. Firstly, although the sample size provided adequate power to distinguish statistically significant effects in the key outcome variables, the differential recruitment strategies and participant self-selection may have contributed to the differences which were observed at baseline for age, fruit and vegetable intake, weekly walking minutes, PCS-12 and MCS-12 scores, sleep duration, and MAP, with healthier characteristics in favor of the control group. Further, those who voluntarily participated in the intervention may have had strong motivation to engage in healthy change, which may have supported the magnitude of intervention effects observed. Thus, it is advisable that future research implements a randomisation design, assigning conditions to participants. Secondly, for feasibility purposes the present study utilised self-report measures for health behaviours, which inherently produce lower accuracy to more invasive objective measures. To enhance outcome measure validity and reliability, utilisation of objective methods would be preferential such as actigraphy to monitor sleep and physical activity, and photo logging of dietary behaviours to quantify health behaviour metrics, however, this would be somewhat difficult to achieve over a period of 12-months.

Conclusion

In conclusion, the individualized 17-week healthy eating, physical activity, and sleep hygiene intervention implemented in this study elicited sustained positive change in all outcome measures at 12-months follow up, relative to baseline characteristics. Further, body mass, blood pressure, and weekly MVPA continued to improve at 12-months compared to post-intervention, whereas other health parameter improvements demonstrated non-significant *trivial* to *small* magnitudes of decay from post intervention. These findings suggest that achievement of these three guidelines promote physical and mental health and improves quality of life among pilots during a global pandemic, yet more regular monitoring post intervention may further strengthen behaviour change maintenance. Our study provides preliminary evidence that a low-intensity, multi-behaviour intervention may be efficacious during a pandemic and that similar outcomes may be transferrable to other populations.

CHAPTER SEVEN

The Effectiveness of a Combined Healthy Eating, Physical Activity, and Sleep Hygiene Lifestyle Intervention on Health and Fitness of Overweight Airline Pilots: A Controlled Trial

Wilson, D., Driller, M., Winwood, P., Johnston, B., & Gill, N. (2022). The Effectiveness of a Combined Healthy Eating, Physical Activity, and Sleep Hygiene Lifestyle Intervention on Health and Fitness of Overweight Airline Pilots: A Controlled Trial. Nutrients. 14(9) 1988. https://doi.org/10.3390/nu14091988 [Impact Factor: 6.706]

Prelude

The preliminary personalised nutrition, physical activity and sleep hygiene intervention analyzed in Chapter Five and Chapter Six demonstrated acute and chronic utility for promoting subjective health parameters in addition to weight and blood pressure management among airline pilots. Chapter Seven further explored the effects of the intervention with utilisation of a wider range of objective cardiometabolic health parameters.

Abstract

The aim of this study was to evaluate the effectiveness of a three-component nutrition, sleep, and physical activity (PA) program on cardiorespiratory fitness, body composition, and health behaviours in overweight airline pilots. A parallel group study was conducted amongst 125 airline pilots. The intervention group participated in a 16-week personalised healthy eating, sleep hygiene, and PA program. Outcome measures of objective health (VO_{2max}, body mass, skinfolds, girths, blood pressure, resting heart rate, push-ups, plank hold) and self-reported health (weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) were collected at baseline and post-intervention. The wait-list control completed the same assessments. Significant group main effects in favor of the intervention group were found for all outcome measures ($p = < 0.001$) except for weekly walking ($p = 0.163$). All objective health measures significantly improved in the intervention group when compared to the control group ($p = < 0.001$, $d = 0.41$–1.04). Self-report measures (moderate-to-vigorous PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) significantly increased in the intervention group when compared to the control group ($p = < 0.001$, $d = 1.00$–2.69). Our findings demonstrate that a personalised 16-week healthy eating, PA, and sleep hygiene intervention can elicit significant short-term improvements in physical and mental health outcomes among overweight airline pilots. Further research is required to examine whether the observed effects are maintained longitudinally.

Keywords: weight loss; nutrition; fruit and vegetable intake; aerobic capacity; moderate-to-vigorous physical activity; lifestyle medicine.

Introduction

Adverse health outcomes promoted by occupational demands of airline pilots including shift and irregular work schedules, circadian disruption, sedentary activity, and high fatigue (Wilson et al., 2022b) may be mitigated through attainment of health guidelines for lifestyle behaviours: healthy diet, physical activity (PA), and sleep (van Drongelen et al., 2014; Wilson et al., 2021b). Non-communicable diseases (NCDs) including cardiovascular disease (CVD), stroke, type 2 diabetes, and their major risk factors are among leading causes of mortality and morbidity worldwide (Miranda et al., 2019). The presence of modifiable behavioural NCD risk factors including obesity, hypertension, physical inactivity, low cardiorespiratory fitness, unhealthy dietary patterns, short sleep, depression, high perceived stress levels, and high fatigue are each associated with adverse outcomes to acute and chronic health (Lasserre et al., 2017; Marmot & Bell, 2019; Miranda et al., 2019). Obesity is a complex, widespread, yet modifiable NCD risk factor that poses a significant public health threat (Chooi et al., 2019). The obesity prevalence worldwide was estimated as 13% in 2015, which is nearly double the prevalence from 1980 (Chooi et al., 2019). In 2020, 67% of male airline pilots in New Zealand were classified as overweight or obese with hypertension affecting 27% of the population (Wilson et al., 2022a). Moreover, this study reported the prevalence of insufficient fruit and vegetable intake, physical inactivity, and < 7 hours sleep per night among airline pilots as 68%, 48%, 33.5%, respectively (Wilson et al., 2022a).

The global economic burden associated with NCDs is estimated as $47 trillion between 2010 and 2030 (Miranda et al., 2019). Previous research has demonstrated evidence of significantly reduced longitudinal health care cost utilisation following diet and exercise lifestyle interventions (Klatt et al., 2016). Relevantly, airline pilots undergo annual or biannual medical examinations, results of which influence flight certification status (International Civil Aviation Authority, 2012). Ongoing health care costs associated with the presence of NCDs and their risk factors present economic implications for aviation medical care (International Civil Aviation Authority, 2012; Miranda et al., 2019).

Better health status is generally associated with enhanced productivity and work performance (Keyes & Grzywacz, 2005). In the context of commercial aviation, pilot work performance is imperative to flight operation safety. As established in the International Civil Aviation

Organization's Annex 1, aviation medicine providers are required to implement appropriate health promotion for license holders (pilots) to reduce future medical risks to flight safety (International Civil Aviation Authority, 2012). Thus, interventions that promote positive health of pilots, mitigate health risk factors for NCDs, and reduce longitudinal health care costs of employees are of importance to aviation medicine, health practices, and policies.

Limited studies have investigated the efficacy of health promotion interventions among airline pilots, and no studies to date have reported on cardiorespiratory fitness or body fat percentage among this occupational group (Wilson et al., 2022b). Based on the findings of our recent preliminary research (Wilson et al., 2021a; Wilson et al., 2021b), we found a personalised three-component healthy eating, sleep hygiene, and PA intervention produced favorable outcomes in subjective health and reductions in body mass and blood pressure among airline pilots. Utilising a different sample of pilots, the aim of the present study was to evaluate the effects of a three-component healthy eating, sleep hygiene, and PA program on cardiorespiratory fitness, body composition, and health behaviours in overweight airline pilots. It was hypothesized that the intervention group would have significantly greater improvements in physical fitness, body composition and health behaviours compared to the wait-list control group at 4-months.

Methodology

Design

A parallel controlled study (intervention and control) with pre- and post-testing was conducted to evaluate the effectiveness of a personalised three-component, 16-week lifestyle intervention for enhancing subjective and objective health indices in airline pilots. This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07. The trial protocol is registered at The Australian New Zealand Clinical Trials Registry (ACTRN12622000233729).

Participants

The participants comprised of self-selected airline pilots who were recruited from a large international airline in New Zealand. Invitations to participate in the study were distributed to all airline pilots within the company through internal communication networks. Group allocation was determined by a first in, first serve basis due to intervention implementation capacity. Accordingly, pilots who expressed interest to participate in the study early and satisfied the eligibility criteria were allocated to the intervention group (n = 86) and subsequent enrolments that exceeded initial capacity were allocated to the wait-list control (n = 80). Participants involved pilots from short-haul (regional flights) and long-haul (international flights) rosters. The participants allocated to the wait-list control group received no intervention and were invited to participate in the intervention after the study period.

Potentially eligible pilots who volunteered to participate were screened according to the following eligibility criteria: (a) aged > 18 years, (b) pilots with a valid commercial flying license, (c) working on a full-time basis, (d) having a body mass index (BMI) of ≥ 25 (overweight), and (e) a resting blood pressure of > 120/80 (systolic/diastolic). Pilots were excluded if medical clearance was deemed necessary prior to engagement in a PA program after completion of the 2020 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Warburton et al., 2019).

Informed consent was obtained from participants prior to commencement of participation in the study and participants were notified that they were permitted to withdraw at any time during the study if they wish to do so. To encourage data blinding and anonymity during data analysis, participants were allocated a unique identifier code on their informed consent form and were instructed to input this into their online health survey in lieu of their name.

Intervention

At baseline the intervention group completed an individual face-to-face 60-min consultation session with an experienced health coach practitioner located at the airline occupational health facility, followed by provision of a personalised health program. Participants also received weekly educational content emails throughout the intervention and a mid-intervention follow-up phone call with a health coach to discuss progress and support adherence. Health coaching advice delivered to pilots was evidence-based and derived from experts in the fields of dietetics, physical activity, and sleep science.

For extended details of the procedures associated with the three-component intervention readers are referred to the study of Wilson and colleagues (Wilson et al., 2021a). In brief, the intervention incorporated seven behaviour change techniques (BCT) including collaborative goal setting, action planning, problem solving, information about health consequences, self-monitoring, feedback on behaviours, and reviewing of outcomes. The intervention utilised 35 participant interactions: including two face-to-face consultations (baseline and post-intervention), one mid-intervention telephone call, 16 weekly emails, and 16 weekly self-monitoring surveys.

Between the participant and health coach, personalised collaborative outcome, process, and performance goals (Wilson et al., 2021a) were established at baseline for (a) sleep hygiene, (b) healthy eating, and (c) PA. Healthy eating goals were defined based on a healthy eating resource (see Appendix E, adapted from Beeken and colleagues (Beeken et al., 2012) with amendments derived from Cena and Calder (Cena & Calder, 2020)). Sleep goals were set based on a Sleep Hygiene Checklist (see Appendix D) which was derived from previous sleep hygiene and stimulus control studies (Wilson et al., 2021a). Physical activity prescription goals were established based on assessment of individual barriers and facilitators to physical activity, implementation of the frequency, intensity, time, and type principles (Barisic et al., 2011), and progression to fulfillment of sufficient moderate-to-vigorous-intensity physical activity (MVPA) to meet World Health Organization health guidelines (World Health Organization, 2010) according to individual capabilities. Sufficient physical activity was defined as ≥ 150 minutes moderate-intensity, or ≥ 75 minutes vigorous-intensity, or an equivalent combination MVPA per week (World Health Organization, 2010).

Outcome Measures

Objective measures of health (VO_{2max}, body mass, skinfolds, girths, blood pressure, resting heart rate, pushups, plank hold) and self-report measures (weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) were collected at baseline and 4-months (post-intervention). Self-report measures (weekly MVPA, sleep duration, fruit, and vegetable intake) were also collected weekly to monitor intervention adherence via an online survey delivered through Qualtrics software (Qualtrics, Provo, UT, USA).

Participants were instructed to avoid large quantities of food, stimulants such as caffeine, and strenuous exercise 4 hours prior to measurement of physiological outcome measures. Outcome measurement protocols for body mass, blood pressure, and subjective health have been previously described in detail (Wilson et al., 2021a; Wilson et al., 2021b). In brief, at the start of the consultation session participants completed an electronic questionnaire via an iPad (Apple, California, CA, USA) to provide data for self-report measures. Using standardized methods previously described (Wilson et al., 2021b), resting heart rate was measured utilising a Rossmax pulse oximeter SB220 (Rossmax Taipei, Taiwan, China), height was recorded with SECA 206 height measures, body mass was measured with SECA 813 electronic scales (SECA, Hamburg, Germany), and blood pressure was measured with an OMRON HEM-757 device (Omron Corporation, Kyoto, Japan).

Skinfold measurements were collected following standardized procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al., 2019). The skinfold sum was determined by measurements obtained for eight locations: biceps, triceps, subscapular, abdominal, supraspinale, iliac crest, mid-thigh and medial calf. All skinfold measurements were taken from the right side of the body twice, with a third measurement taken if the difference between recordings were greater than 4%. The anthropometrical technical errors were under the recommended limits (Esparza-Ros et al., 2019) for all final recorded measurements. Skinfold measurements were conducted by an accredited ISAK anthropometrist, using Harpenden calipers (British Indicators, Hertfordshire, UK) which were sufficiently calibrated as per the manufacturers' guidelines. Body fat percentage was derived from skinfold assessments and was calculated using updated sex and ethnicity specific equations reported elsewhere (Davidson et al., 2011). Girth measurements for the waist and hip locations were measured with a thin-line metric tape measure (Lufkin; Apex Tool Group, Sparks, MD, USA) congruent with standardized technique (World Health Organization, 2008).

Push-ups and the plank isometric hold were utilised as assessments of musculoskeletal fitness, using previously reported standardized methods (Clemons, 2019; Tong et al., 2014). For push-ups the hand release technique was utilised, where participants were instructed to keep their torso tight so that the shoulders, hips, knees, and ankles were aligned throughout the range of motion. At the bottom position, the hands were lifted from the floor between each push-up. Push-up cadence was coordinated by a metronome and participants completed maximum full range of motion repetitions until the onset of failure to maintain correct form (Clemons, 2019). The basic plank isometric hold technique was utilised, consisting of the participant holding a prone bridge position supported by their feet and forearms. Elbows were below the shoulders with the forearms and fingers extending forward. The neck was maintained in a neutral position so that the body remained straight from the head to the heels. Time was recorded from initiation of the position until the loss of the plank position (Tong et al., 2014).

For quantification of aerobic fitness, estimated maximal oxygen consumption (VO_{2max}) was obtained by participants performing a previously validated (Hanson et al., 2022; Storer et al., 1990) 3-minute aerobic test (3mAT) on a Wattbike (Woodway USA, Waukesha, WI) electro-magnetically and air-braked cycle ergometer. Participants were given a full explanation of the protocol, safety procedures, the Wattbike seat and handle were fitted appropriately for the participant, who was also fitted with a Polar H10 heart rate strap (Polar Electro, Kempele, Finland). Full details on the procedure have been detailed elsewhere (Hanson et al., 2022). Participants completed a 10-minute warmup consisting of self-paced cycling at 70–90 rpm with two 6-second sprints within that timeframe, as suggested by the manufacturer. The goal of the 3mAT was to maintain the highest power output possible for 3 full minutes. Verbal encouragement was provided, and participants were allowed to adjust the resistance and pedal cadence as needed throughout the test. Each participant's customized setup was noted, and the same procedures were carried out for the retest at 4-months.

Prior to baseline testing, the Wattbike was calibrated by the manufacturer, and a between session reliability assessment was conducted with the Wattbike utilising a convenience sample of seven untrained airline pilots (aged = 42 ± 12y, body mass = 80 ± 11kg, height = 173 ± 4cm, mean ±

SD, 5 males, 2 females). Following standardized procedures (Hanson et al., 2022; Storer et al., 1990), participants of the reliability trial performed the 3mAT twice separated by > 48 hours between assessments. For measurement of estimated VO_{2max}, the reliability trial produced a coefficient of variation (CV) of 4.3% and an intraclass correlation coefficient (ICC) of 0.98 (0.90 – 0.99), denoting acceptable CV (Atkinson & Nevill, 1998) and excellent ICC reliability (Koo & Li, 2016).

Self-report measures (PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) have been previously described in detail (Wilson et al., 2021a). In brief, self-rated health (physical and mental) were measured utilising the Short Health Form 12v2 (SF-12v2) (Ware et al., 1995). The International Physical Activity Questionnaire Short Form (IPAQ) was utilised to quantify self-report MVPA (Ministry of Health, 2019). Self-report subjective sleep quality and duration were measured with the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989). Daily fruit and vegetable intake were measured using dietary recall questions derived from the New Zealand Health Survey (Ministry of Health, 2019).

Statistical Analyses

G-Power software was utilised to calculate sample size required to detect a clinically significant change in primary outcome measures of ≥ 5% weight loss and a change of 3.5 $ml.kg^{-1}.min^{-1}$ for VO_{2max} (Myers et al., 2002). Our sample size power calculation suggested 65 pilots were required in each group to achieve 90% power and a 5% significance criterion to detect relevant differences between the intervention and wait-list control groups. To account for 20% dropout observed in a similar study (Wilson et al., 2021b), our target sample size was 156.

Statistical Package for the Social Sciences (SPSS, version 28; IBM Corp., Armonk, NY, USA) was utilised for all analyses. Listwise deletion (i.e., entire case record removal) was applied if individual datasets had missing values or for participants who did not complete post-tests. Stem and leaf plots were inspected to ascertain whether there were any outliers in the data for each variable. A Shapiro-Wilk's test ($p > 0.05$) and its histograms, Q–Q plots and box plots were analyzed for normality of data distribution for all variables. Levene's test was used to test homogeneity of variance.

Independent t-tests were utilised to calculate whether any significant differences existed between groups at baseline. For categorical variables (long haul and short haul) the Chi square test was used. Between group analysis of pre-test and post-test were assessed using paired t-tests and analysis of covariance (ANCOVA) (respectively). To control for baseline differences between groups, baseline data were included as a covariate in the ANCOVA (Egbewale et al., 2014), in addition to inclusion of age and sex. Effect sizes were calculated using Cohen's d to quantify between-group effects from pre-test to post-test. Effect size thresholds were set at > 1.2, > 0.6, > 0.2, and < 0.2, which were classified as *large*, *moderate*, *small*, and *trivial*, respectively (Cohen, 1988). The α level was set at a p value of less than 0.05.

Results

Characteristics of the Study Population

Two-hundred twelve airline pilots were considered for eligibility and 148 were recruited to participate (see Figure 8). Eighty-four percent (n = 125) of recruits provided data for both timepoints, which comprised a combination of short-haul and long-haul rosters (n = 60 and 65, respectively). The dropout rates from baseline to post-intervention were 12% (time commitment n = 5; ceased employment n = 3; testing not fully completed n = 1) and 19% (time commitment n = 8; ceased employment n = 4) for the intervention and wait-list control groups, respectively. As displayed in Table 15, at baseline both groups demonstrated similar characteristics for most health parameters, yet the wait-list control group had lower SBP (t(123) = 1.191, p = 0.03, *d* = 0.39) and lower MAP (t(123) = 2.113, p = 0.03, *d* = 0.38). No significant differences were observed between groups for sex and fleet type.

Intervention Adherence

For the intervention group, compliance was measured mid-intervention for health behaviours, including self-report weekly MVPA, daily fruit and vegetable intake and average sleep duration per night. Sixty-four (97%) were achieving ≥ 5 serves of fruit and vegetables per day, 94% reported sleeping ≥ 7 hours sleep per night, and 97% were obtaining ≥ 150 MVPA (min) per week. Comparatively, 36% of the wait-list control group were achieving ≥ 5 serves of fruit and vegetables per day, 71% were sleeping ≥ 7 hours per night, and 53% were obtaining ≥ 150 MVPA (min) per week.

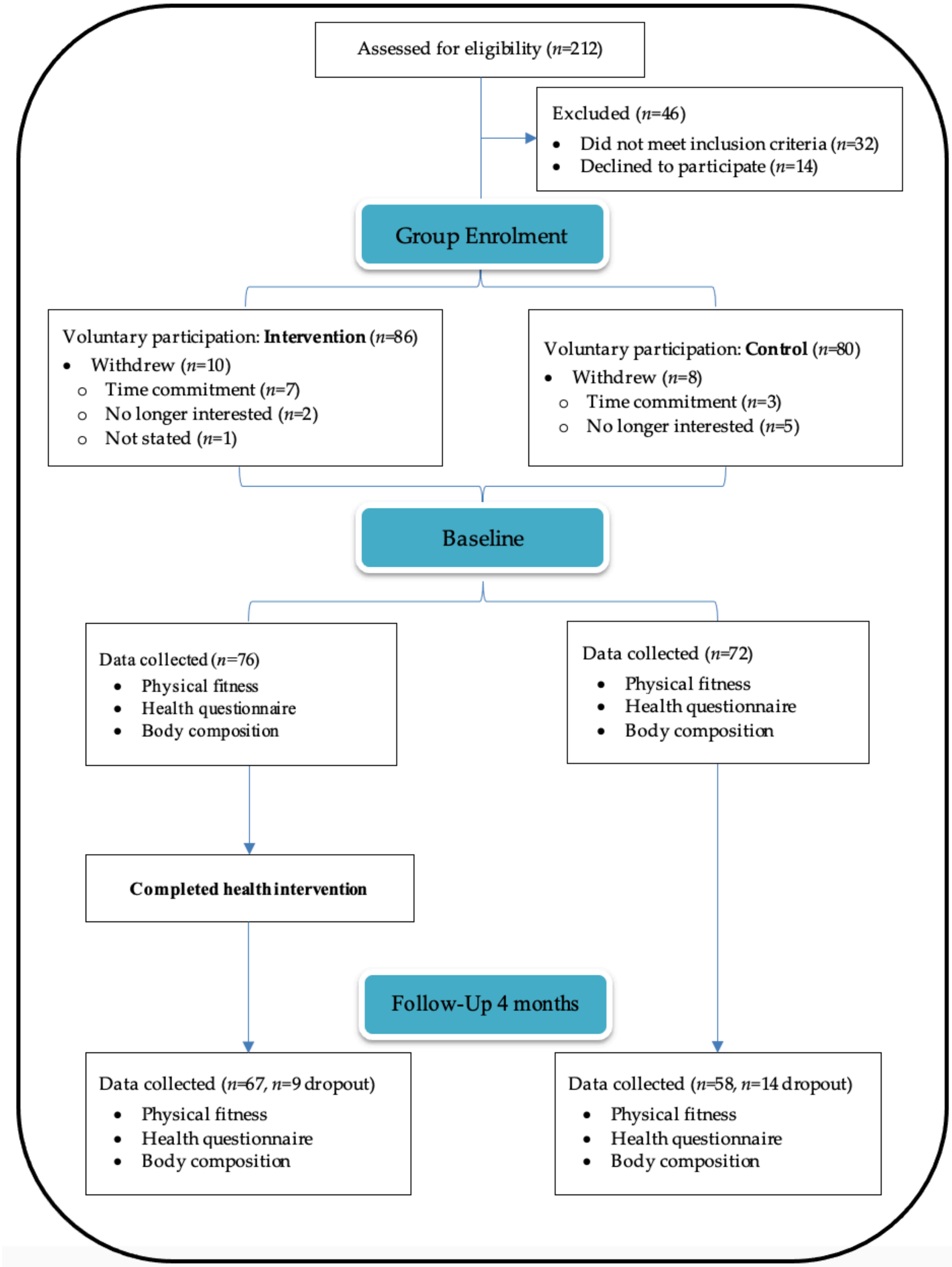

Figure 8: Flow diagram of participant recruitment and data collection.

Table 15: Baseline characteristics of participants.

Parameters	**All subjects (n = 125)**	**Intervention (n = 67)**	**Control (n = 58)**
Sex (f / m)	12 / 113	6 / 61	6 / 52
Age (y)	44.5 ± 10.7	43.7 ± 10.0	45.6 ± 11.4
Short haul (n)	60	34	26
Long haul (n)	65	33	32
Height (cm)	178.4 ± 7.4	179.2 ± 6.9	177.4 ± 7.8
Systolic BP (mmHg)	132.3 ± 5.6	133.3 ± 6.0	131.1 ± 4.9*
Diastolic BP (mmHg)	85.6 ± 3.8	86.0 ± 3.9	85.0 ± 3.6
MAP (mmHg)	101.1 ± 3.8	101.8 ± 3.8	100.4 ± 3.6*
Pulse (bpm)	66.9 ± 6.6	67.4 ± 6.1	66.4 ± 7.2
Body mass (kg)	90.5 ± 9.2	91.1 ± 8.0	89.8 ± 10.5
BMI ($kg{\cdot}m^2$)	28.4 ± 2.0	28.3 ± 1.7	28.5 ± 3.4
Skinfold sum x8 sites (mm)	136.5 ± 24.1	138.3 ± 17.7	134.4 ± 29.9
Bodyfat (%)	24.3 ± 3.6	24.7 ± 3.2	23.9 ± 4.0
Waist girth (cm)	96.6 ± 7.6	97.8 ± 8.1	95.2 ± 6.8
Waist to hip ratio	0.93 ± 0.07	0.94 ± 0.07	0.93 ± 0.08
VO_{2max} ($ml.kg^{-1}.min^{-1}$)	36.3 ± 5.4	35.6 ± 5.8	37.0 ± 4.8
Push-ups (repetitions)	17.2 ± 7.3	16.4 ± 6.8	18.1 ± 7.7
Plank hold (sec)	79.7 ± 24.7	77.2 ± 25.5	82.5 ± 23.7
Walking per week (min)	73.8 ± 42.5	70.5 ± 32.2	77.7 ± 52.0
MVPA per week (min)	141.8 ± 41.1	138.0 ± 41.6	146.2 ± 40.3

Fruit intake (serve/day)	1.3 ± 0.7	1.5 ± 0.8	1.0 ± 0.6
Vegetable intake (serve/day)	2.0 ± 0.7	1.8 ± 0.7	2.4 ± 0.5
F&V intake (serve/day)	3.3 ± 0.7	3.3 ± 0.7	3.4 ± 0.7
Sleep per day (hours)	7.0 ± 0.5	7.0 ± 0.4	7.0 ± 0.6
Global PSQI (score)	6.3 ± 2.1	6.4 ± 2.2	6.1 ± 1.9
MCS-12 (score)	48.9 ± 4.6	48.6 ± 5.8	49.3 ± 2.8
PCS-12 (score)	46.7 ± 3.4	46.3 ± 3.8	47.2 ± 2.8

Note: Mean ± SD reported for all subjects, intervention and control. Abbreviations: SD = Standard deviation; BMI = Body mass index; BP = blood pressure; MAP = mean arterial pressure; MVPA = Moderate-to-vigorous physical activity; F&V = Fruit and vegetable intake; MCS-12 = Short Health Form 12v2 mental component summary scale; PCS-12 = Short Health Form 12v2 physical health component summary scale; PSQI = Pittsburgh Sleep Quality Index. * Indicates statistical significance ($p = < 0.05$).

Body Mass, Skinfolds, Waist Girth, Bodyfat Percentage, Blood Pressure and Pulse

Significant group main effects ($p = < 0.001$) in favor of the intervention group were found for all variables. Small to large effect size differences were observed from baseline to post-intervention (see Table 16). The within-group analysis revealed that the intervention elicited significant improvements ($p = < 0.001$) in all measures at post-intervention associated with *moderate* to *large* effect sizes (see Table 16; Figure 9). The wait-list control group reported a significantly lower body mass ($t(57) = 2.538$, $p = 0.014$, $d = 0.33$) and reduced waist girth ($t(57) = 2.358$, $p = 0.022$, $d = 0.31$), yet no significant changes were observed in other measures.

VO_{2max}, Pushups and Plank Hold

Significant group main effects were found for all measures ($p = < 0.001$) in favor of the intervention group. The within-group analysis reported significantly greater improved changes from baseline to post-intervention for all physical performance measures in the intervention group (p = < 0.001), associated with *large* effect sizes (see Table 16; Figure 9). In contrast, the wait-list control group significantly increased push-ups (t(57) = 5.323, p = < 0.001, *d* = 0.69) and plank hold (t(57) = 3.365, p = 0.001, *d* = 0.44), yet no significant change was observed for VO_{2max}.

Health Behaviours and Self-Rated Health

Significant group main effects in favor of the intervention group were found for all self-report health measures (p = < 0.001) except for weekly walking minutes (p = 0.163). The within-group analysis reported significantly greater improved health changes from baseline to post-intervention for all self-report health measures in the intervention group (p = < 0.001), associated with *moderate* to *large* effect sizes (see Table 16; Figure 9). Further, the wait-list control group significantly improved weekly walking, weekly MVPA, global PSQI score, and Short Health Form 12v2 physical component summary scale score (PCS-12, p = < 0.001), enhanced fruit and vegetable intake (p = 0.008), and increased sleep hours (p = 0.020). The significant changes observed within the wait-list control group from baseline to post-intervention were associated with *trivial* to *small* effect sizes (see Table 16).

Table 16: Changes in objective and self-report health measures from baseline to post-intervention at 4-months.

		Intervention (*n* = 67)			**Control (*n* = 58)**			**ANCOVA (Group Main Effects)**	**Between Group ES**
	Time (Months)	**M**	**SD**	**Follow Up Change (95% CI)**	**M**	**SD**	**Follow Up Change (95% CI)**	***p***	***d***
Body mass (kg)	0	91.1	8.0		89.8	10.5			0.14, *Trivial*
	4	85.6	7.7	5.5 (4.8–6.1)	89.4	85.6	0.4 (0.1–0.7)	< 0.001	-0.41, *Small*
BMI (kg/m^2)	0	28.3	1.7		28.5	3.4			0.08, *Trivial*

	4	26.7 1.6	1.7 (1.5–1.9)	28.4 2.4	0.1 (0.0–0.2)	< 0.001	-0.86, *Moderate*
Systolic BP (mmHg)	0	133.36.0		131.14.9			0.39, *Small*
	4	125.25.8	8.1 (7.3–8.9)	132.55.9	1.3 (0.1–2.8)	< 0.001	-1.25, *Large*
Diastolic BP (mmHg)	0	86.0 3.9		85.0 3.6			0.27, *Small*
	4	80.8 5.4	5.2 (4.2–6.2)	84.8 4.7	0.2 (0.9–1.4)	< 0.001	-0.77, *Moderate*
MAP (mmHg)	0	101.83.8		100.43.6			0.38, *Small*
	4	95.6 5.0	6.2 (5.4–6.9)	100.74.7	0.3 (0.8–1.4)	< 0.001	-1.04, *Moderate*
Pulse (bpm)	0	67.4 6.1		66.4 7.2			0.15, *Trivial*
	4	61.0 6.5	6.3 (4.8–7.8)	67.0 8.8	0.6 (1.0–2.2)	< 0.001	-0.78, *Moderate*
Skinfold sum (mm)	0	138.317.7		134.429.9			0.16, *Trivial*
	4	110.114.5	28.2 (26–30.5)	133.029.8	1.5 (0.5–3.4)	< 0.001	-1.00, *Moderate*
Bodyfat (%)	0	24.7 3.2		23.9 4.0			0.21, *Small*
	4	21.0 2.8	3.6 (3.3–4.0)	23.7 4.1	0.2 (0.1–0.4)	< 0.001	-0.79, *Moderate*
Waist (cm)	0	97.8 8.1		95.2 6.8			0.35, *Small*
	4	91.8 7.9	6.0 (5.3–6.8)	94.3 6.9	1.0 (0.1–1.8)	< 0.001	-0.34, *Small*
Waist to hip ratio	0	0.94 0.07		0.93 0.08			0.09, *Trivial*
	4	0.90 0.07	0.03 (0.02–0.04)	0.92 0.07	0.1 (0.0–0.2)	< 0.001	-0.22, *Small*
VO_{2max} (ml.kg^{-1}.min^{-1})	0	35.6 5.8		37.0 4.8			-0.26, *Small*
	4	40.2 5.9	4.5 (4.0–5.0)	37.3 5.1	0.2 (0.1–0.6)	< 0.001	0.52, *Small*
Push-ups (repetitions)	0	16.4 6.8		18.1 7.7			-0.22, *Small*
	4	24.3 7.1	7.8 (6.5–9.1)	19.9 8.1	1.9 (1.2–2.6)	< 0.001	0.57, *Small*
Plank hold (sec)	0	77.2 25.5		82.5 23.7			-0.21, *Small*
	4	120.039.6	42.8 (34.4–51.3)	92.1 32.1	9.5 (3.8–15.1)	< 0.001	0.77, *Moderate*
Hours slept (h/day)	0	7.0 0.4		7.0 0.6			-0.17, *Trivial*
	4	7.6 0.5	0.7 (0.6–0.8)	7.1 0.5	0.1 (0.0–0.2)	< 0.001	1.00, *Moderate*

PSQI Global (score)	0	6.4	2.2		6.1	1.9			0.14, *Trivial*
	4	4.0	1.3	2.4 (2.0–2.8)	5.8	1.8	0.3 (0.1–0.5)	< 0.001	-1.16, *Moderate*
IPAQ-walk (min)	0	70.5	32.2		77.7	52.0			-0.17, *Trivial*
	4	97.0	30.0	26.5 (18.1–34.9)	95.4	49.0	17.8 (8.0–27.6)	0.163	0.04, *Trivial*
IPAQ-MVPA (min)	0	138.0	41.6		146.2	40.3			-0.20, *Small*
	4	210.3	44.3	72.4 (60.0–84.8)	156.9	46.4	10.8 (5.0–16.5)	< 0.001	1.18, *Moderate*
F&V Intake (serve/d)	0	3.3	0.7		3.4	0.7			-0.17, *Trivial*
	4	6.9	1.3	3.6 (3.3–4.0)	3.8	0.9	0.4 (0.1–0.7)	< 0.001	2.69, *Large*
PCS-12 (score)	0	46.3	3.8		47.2	2.8			-0.28, *Small*
	4	51.5	3.4	5.2 (4.4–5.9)	47.9	2.8	0.7 (0.3–1.1)	< 0.001	1.14, *Moderate*
MCS-12 (score)	0	48.6	5.8		49.3	2.8			-0.15, *Trivial*
	4	53.3	3.6	4.7 (3.7–5.8)	49.5	2.9	0.2 (0.2–0.7)	< 0.001	1.15, *Moderate*

Note: Mean ± SD reported for all participants, intervention and control. Abbreviations: SD = standard deviation. BMI = body mass index. BP = blood pressure. MAP = mean arterial pressure. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = Short Health Form 12v2 physical component summary score. MCS-12 = Short Health Form 12v2 mental component summary score. * Indicates statistical significance between groups (*p* = < 0.05). ** Indicates statistical significance between groups (*p* = < 0.001).

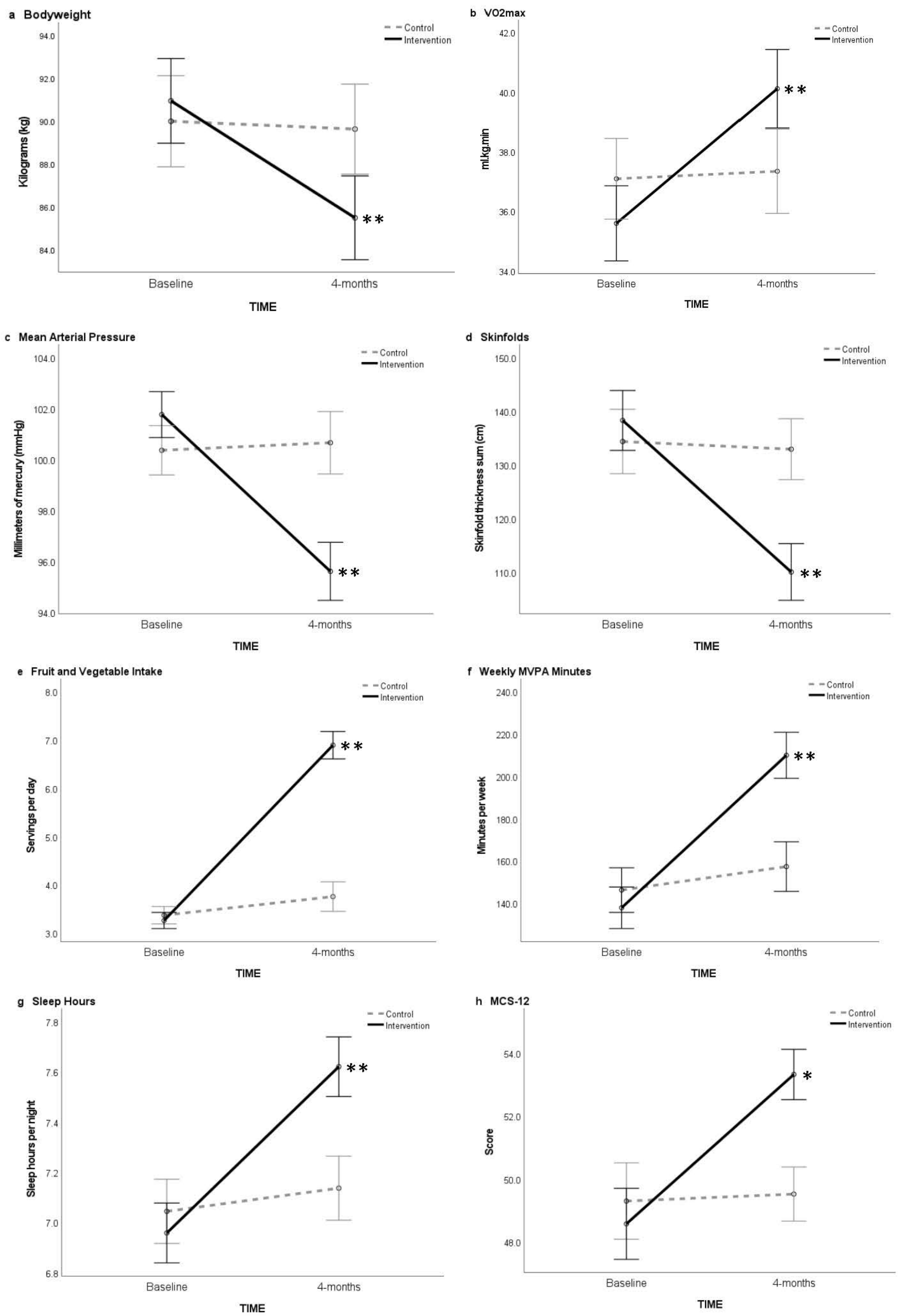

Figure 9: Mean values for health outcomes across time (baseline and 4-months), showing 95% confidence intervals.

Notes: * indicates *moderate* within group effect size from baseline to 4-months. ** indicates *large* within group effect size from baseline to 4-months. MVPA = moderate-to-vigorous physical activity. MCS-12 = Short Health Form 12v2 mental component summary score.

Discussion

To our knowledge, this study is the first clinical trial that has explored the effects of a lifestyle intervention on physical fitness and body composition measures among airline pilots. This study aimed to promote enhancement in cardiorespiratory and musculoskeletal fitness, body composition, and health behaviours through a personalised intervention on healthy eating, sleep hygiene, and PA.

For most outcome measures, in support of our initial hypothesis the controlled trial revealed significantly higher improvements in the intervention group compared to the wait-list control group. Our findings suggest that a face-to-face health assessment alone with no provision of an intervention may promote *small* short-term effects for improvements in health behaviours and weight management among airline pilots. Furthermore, provision of a personalised multicomponent lifestyle intervention may facilitate *moderate* to *large* short-term effects for promoting healthy changes in physical fitness, body composition, and health behaviours among airline pilots.

These findings are important for health care professionals and researchers to provide insight regarding the efficacy of lifestyle interventions for promoting health, and to inform practices relating to disease prevention, health promotion, and public health policymaking. Furthermore, in relation to the limited literature base pertaining to three-component sleep, nutrition and PA interventions and the insufficient depth of health behaviour intervention research among airline pilots, our findings provide novel contributions to this field.

Excessive adiposity is evidently associated with higher all-cause mortality and elevated risk of cardiometabolic NCDs (Di Angelantonio et al., 2016). Counteractively, clinically significant improvements in NCD risk factors have been reported with as little as 2–3% of weight loss among those with high BMI (Donnelly et al., 2009). A meta-analysis of 59 lifestyle weight loss interventions reported a pooled mean weight loss range of 5-8.5kg (5%-9% body mass) within the initial six months, and among studies exceeding 48 months a mean weight loss range of 3-6kg (3%-6% body mass) (Franz et al., 2007). Comparatively, in our intervention group we observed 6% weight loss and 1.6 reduction in BMI at 4-months. Weight loss and BMI alone as assessments of body composition change are inherently limited due to their inability to precisely measure central adiposity, fat distribution, bone density and lean mass (Ross et al., 2020).

In the present study we assessed additional body composition metrics with girth and skinfold measures. Waist circumference has been reported as being strongly associated with all-cause and cardiovascular mortality, with or without adjustment for BMI (Ross et al., 2020). Further, skinfold thickness has been reported as a better predictor of body fatness compared to BMI (Nooyens et al., 2007). We found the intervention elicited a decrease of 6 cm waist circumference and 28 mm skinfold thickness sum reduction, which were associated with an overall 3.7% reduction in predicted body fat percentage and a decrease of 8.1 mmHg for SBP. These findings are consistent, yet of higher magnitude than a previous meta-analysis which reported exercise training programs were associated with pooled mean reductions of 5.1 mmHg SBP and 2.2 cm waist girth (Lemes et al., 2018). This study also reported that reductions in BP and waist circumference were associated with reduced high-density lipoprotein (HDL) cholesterol and metabolic syndrome risk reduction (Lemes et al., 2018). Thus, interventions which induce these adaptations are of importance for risk reduction of these well-established NCD risk factors (Miranda et al., 2019).

To our knowledge, our study is the first to report on objective measures of cardiorespiratory capacity among airline pilots. Prospective cohort research suggests exercise capacity is an authoritative predictor of mortality among adults, and an increase of 1 MET ($3.5\ ml.kg^{-1}.min^{-1}$) is associated with a 12% CVD risk reduction (Myers et al., 2002). A meta-analysis of aerobic exercise training interventions among adults (aged 41 ± 5y) reported a pooled mean increase in VO_{2max} of $3.5\ ml.kg^{-1}.min^{-1}$ (1.9 – 5.2, 95% CI), associated with a *moderate* effect size of 0.6 (Huang et al., 2005). In comparison, we observed an increase of $4.5\ ml.kg^{-1}.min^{-1}$ within our intervention group, associated with a *large* effect size which exceeds previously suggested thresholds for clinical relevance (Koo & Li, 2016). However, future research is required to determine whether these acute adaptations are longitudinally maintained after the brief 16-week intervention.

The intervention promoted significant positive health outcomes for health behaviours and self-rated health, associated with *moderate* to *large* effect sizes. Sleep duration increased by 0.6 hours in the intervention group, which is a lower magnitude compared with a recent meta-analysis of behavioural interventions to extend sleep length, which reported a pooled increase of 0.8 hours per night (0.28 - 1.31, 95% CI) (Baron et al., 2021). In part this variance may be related to the different nature of interventions, where the present intervention targeted multiple-behaviour modification for nutrition, sleep, and PA simultaneously, compared with the individual component focus in other studies (i.e. targeting sleep modification alone) (Baron et al., 2021).

For weekly MVPA we found the intervention elicited an increase of 72 min/week, which is notably higher than a previous meta-analysis which reported a mean increase of 24 min/week from PA interventions implemented in primary care settings (Kettle et al., 2022). Similarly, a meta-analysis of behaviour interventions to increase fruit and vegetable intake reported a pooled mean increase of 1.1 servings per day (Thomson & Ravia, 2011), which was a lower magnitude of change compared to the increase of 3.6 servings following the present intervention. Notably, a meta-analysis of effective BCTs for promoting PA and healthy eating in overweight and obese adults highlighted the use of goal setting and self-monitoring of behaviour as strong predictors of positive short and long-term health behaviour change (Samdal et al., 2017). Congruently, our intervention implemented these components in addition to five other BCTs, which may have contributed to the observed effect sizes of change.

Strengths and Limitations

A strength of this study is our findings add valuable contribution to a small global literature base pertaining to interventions that include components for each healthy eating, PA, and sleep hygiene. The magnitude of effect sizes for positive health change observed in the intervention may be at least partly attributable to; (a) the implementation of seven BCTs including collaborative goal setting, (b) the personalised multiple-component nutrition, PA and sleep approach, (c) the multimodal intra-intervention communication administered via face-to-face consultations, a telephone call, and regular educational emails, and (d) the potential underlying motivation of airline pilots to improve their health to maintain their aviation medical license.

Potential limitations of this study need to be considered in the interpretation of our findings. Firstly, pilots voluntarily participated in the study via self-selection, thus those who enrolled may have exhibited higher readiness and motivation for health behaviour change than the general population, which may limit the generalizability of our findings. Secondly, for feasibility of implementation and to minimize participant burden, self-report measures for health behaviours were utilised which inherently possess inferior validity to more invasive objective methods. Accordingly, future research including measures such as a food frequency questionnaire or photo meal logging for dietary behaviours and actigraphy coupled with heart rate monitoring (e.g., smart watches) for PA and sleep monitoring would be valuable contributions to increase the validity of findings. Third, although the sex characteristics of our sample are congruent with the general airline pilot population (Wilson et al., 2022a), the lack of female participants limits the generalizability of our findings to female populations. Thus, future research should evaluate the effects of the intervention among an ample sample size of females. Finally, the intervention was delivered by an experienced health coach, which presents a barrier to intervention adoption at scale. Future research should evaluate the delivery of interventions using similar procedures via cost-effective and scalable methods, such as online modes of delivery (i.e., smartphone application).

Conclusion

The personalised 16-week healthy eating, sleep hygiene, and PA intervention implemented in this study elicited significant positive changes associated with *moderate* to *large* effects sizes in all main outcome measures at 4-months follow-up, relative to the wait-list control group. Our findings suggest that achievement of these three guidelines promote physical and mental health among overweight airline pilots and these outcomes may be transferrable to other populations. However, there is a need for future research to examine whether the observed effects are longitudinally maintained following the intervention.

CHAPTER EIGHT

A Contactless App-Based Intervention Improves Health Behaviors in Airline Pilots: A Randomized Trial

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Prelude

As demonstrated in Chapter Five, Chapter Six, and Chapter Seven, the implementation of a personalised nutrition, physical activity and sleep hygiene intervention elicits *moderate* to *large* positive effects for improving subjective and objective cardiometabolic health parameters among airline pilots. However, the face-to-face, health care professional delivered nature of the intervention inherently poses barriers to scalability. Accordingly, Chapter Eight investigates the effectiveness of a remotely delivered, automated smartphone-based app personalised nutrition, physical activity, and sleep hygiene intervention for improving subjective and objective cardiometabolic health parameters among airline pilots.

Abstract

There is a need for enhanced preventive health care among airline pilots to mitigate the prevalence of cardiometabolic health risk factors. A randomized, waitlist-controlled trial was utilized to evaluate the effectiveness of a smartphone-based app intervention for improving health behaviors and cardiometabolic health parameters. A total of 186 airline pilots (age, 43.2±9.1y; male, 64%) were recruited and participated in the trial during 2022. A personalized 16-week smartphone-based app multicomponent physical activity (PA), healthy eating, and sleep hygiene intervention. Outcome measures of objective health (Cooper's 12-minute exercise test, resting heart rate, push-ups, plank isometric hold, body mass), subjective health (self-rated health, perceived psychological stress and fatigue), and health behaviors (weekly PA, sleep quality and duration, fruit and vegetable intake) were collected at baseline and post-intervention. The wait-list control completed the same measures. Significant interactions for time × group from baseline to 16-weeks were found for all outcome measures (p<0.001). Significant between group differences for positive health changes in favor of the intervention group were found at post-intervention for all outcome measures (p<0.05, d=0.4-1.0) except for self-rated health, body mass, and Pittsburgh Sleep Quality Index score. Our findings demonstrate an app-based health behavior intervention can elicit positive cardiometabolic health changes among airline pilots over 16-weeks, associated with *trivial* to *large* effect sizes. The trial protocol was prospectively registered at The Australian New Zealand Clinical Trials Registry (ACTRN12622000288729).

Key Words: nutrition; physical activity; sleep; fruit and vegetable intake; moderate-to-vigorous physical activity; digital health

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CHAPTER NINE

General Discussion

This thesis set out to enhance the understanding of modifiable health risk factor prevalence among airline pilots. Furthermore, the thesis aimed to evaluate the implementation of evidence-based strategies for promoting positive health and wellness and non-communicable disease (NCD) risk factor mitigation among airline pilots. While occupational health risks of airline pilots such as fatigue and sleep disruption have received prior attention by researchers, there is a lack of focus on characterization of wider modifiable health risk factors. Further, there is a research void regarding evaluation of intervention strategies to mitigate health risk factors among this occupational group. This thesis aimed to provide novel contributions toward the two following overarching research questions:

1) What is the prevalence of modifiable cardiometabolic health risk factors among airline pilots?
2) What are effective strategies for enhancing health and reducing cardiometabolic health risk factors among airline pilots?

The first question is addressed by systematically evaluating the global literature pertaining to health risk factor prevalence among airline pilots and further conducting an original cross-sectional comparison of health risk factor prevalence and distribution between airline pilots and the general population in New Zealand (NZ). The second question is addressed by evaluating the effectiveness of a three-component personalised sleep hygiene, healthy eating, and physical activity lifestyle intervention via face-to-face and online modalities for enhancing cardiometabolic health parameters among airline pilots.

This chapter begins with a summary of the main findings and discussion of each of the thesis studies and key outcomes. Subsequently, the practical implications of this thesis' contributions to the scientific body of knowledge are discussed, followed by limitations and directions for future research. The chapter will end with an overall conclusion.

Key Outcomes

The key outcomes from this thesis include:

1) Notable cardiometabolic health risk factor prevalence was revealed among airline pilots globally for overweight and obesity, physical inactivity, insufficient fruit and vegetable intake, elevated blood pressure, and elevated psychological fatigue.

2) Evaluation of the global literature indicates a lack of high-quality research among airline pilots (i.e., lacking clinical trials, limited high quality methodology, and heterogeneity among studies).

3) Compared to the general population, a relatively higher health risk factor prevalence among airline pilots in NZ was discovered for insufficient physical activity, short sleep duration, positive self-rated health, and more pilots were "at risk" of hypertension.

4) Novel "world-first" clinical controlled trial during a COVID-19 lockdown findings revealed the implementation of a lifestyle health behaviour intervention significantly improved physical and mental health and may improve quality of life during an unprecedented global pandemic.

5) Clinical controlled trial findings revealed health behaviour and weight management improvement at 12-months post-intervention follow-up, demonstrating a brief lifestyle medicine intervention can support sustained health behaviour change longitudinally.

6) We conducted the first controlled clinical trial research evaluating the effectiveness of a multicomponent health behaviour lifestyle intervention for improving health parameters among airline pilots. This research utilised objective outcome measures which had not been previously reported among the literature pertaining to airline pilots, including body composition, weight management, cardiorespiratory fitness, and blood pressure management.

7) Findings across our multiple controlled clinical trials suggest face-to-face health assessments with intervention support are the most effective strategy for promoting health change associated with *moderate* to *large* effects, followed by online intervention delivery via a smartphone-based app, which produced *trivial* to *large* effects. Further, face-to-face health assessments with no intervention were effective in facilitating health improvements of *small* effects.

8) Brief lifestyle health behaviour interventions can be a powerful stimulus for facilitating acute and chronic health behaviour change and risk factor mitigation among airline pilots.

9) The multicomponent interventions and multimodal outcome measure evaluation approach utilised in the clinical trials provided valuable understanding of the intervention effects on multiple health domains (i.e., physiological and psychological health).

10) The scientific body of knowledge pertaining to airline pilots is dominated by male participants. Small samples of females featured in research studies are often excluded from data analyses due to insufficient comparative sample size with males. Curiously, female airline pilot health risk factor prevalence characteristics appear to be notably lower than males when reported, thus the current literature base should not be generalized to female pilots and targeted future research toward this population is warranted.

The Prevalence of Cardiometabolic Health Risk Factors Among Airline Pilots

Cardiometabolic NCDs such as cardiovascular disease, stroke, type 2 diabetes, collectively represent a predominant cause of mortality and their primary risk factors are a leading public health concern that produce significant and growing economic costs globally (Miranda et al., 2019). One aim of this thesis was to provide contributions toward characterization of cardiometabolic health risk factor prevalence among airline pilots globally and within NZ. Preceding this thesis, the scientific body of knowledge pertaining to health risk factor prevalence among airline pilots was fragmented and lacked synthesis, clarity, and adequate quantification of modifiable health risk factors among NZ airline pilots had not been established.

Study One (Wilson et al., 2022b) provided the first comprehensive synthesis of published research worldwide pertaining to physiological, behavioural, and psychological cardiometabolic health risk factors among airline pilots. This research revealed airline pilots globally had a similar prevalence for most health risk factors compared to general population estimates, yet higher sleep duration, lower smoking and obesity rates, less physical activity, and a higher overall rate of combined overweight and obesity. Study Two (Wilson et al., 2022a) generated the largest existing cross-sectional study of cardiometabolic health risk factor prevalence among NZ airline pilots, establishing age and sex standardized comparisons with the NZ general population. This research discovered similar risk factor prevalence in NZ pilots as established in Study One (Wilson et al., 2022b) among airline pilots globally, yet contrastingly found the NZ general population slept longer, were more physically active, had a higher prevalence of positive self-rated health, and had a lower proportion of individuals who were 'at risk' for hypertension compared with NZ pilots.

These findings challenge past assumptions and common annotations among the literature that airline pilots are typically healthier than the general population due to factors such as the healthy worker affect, socioeconomic status, and being subject to regular aviation medical examinations (Sykes et al., 2012). Our research accompanies recent advancement in literature detecting adverse health outcomes affecting airline pilots in the modern environment (Cahill et al., 2021; O'Hagan et al., 2017; Palmeira & Marqueze, 2016; Reis et al., 2013; Venus, 2021; Wilson et al., 2022b). The findings ascertained from Study One (Wilson et al., 2022b) and Study Two (Wilson et al., 2022a) of this thesis indicate substantial prevalence > 50% for overweight and obesity, physical inactivity, insufficient fruit and vegetable intake, elevated fatigue, and regular alcohol intake among airline pilots. Furthermore, approximately a quarter of the airline pilot population are not attaining enough sleep, present poor self-rated health and mild depressive symptoms, have hypertension, and a substantial additional proportion of the population are suffering from elevated blood pressure. The evident prevalence of physiological, behavioural, and psychological cardiometabolic health risk factors among airline pilots highlights the need for innovative strategies to mitigate NCD development, congruent with the World Health Organization global strategic targets to reduce premature deaths from NCDs and the United Nations Sustainable Development Goal 2030 of good health and well-being (Bennett et al., 2020).

Health Promotion and Health Risk Factor Mitigation Among Airline Pilots

Airlines adhere to regulatory authority policies pertaining to annual medical examinations of pilots that serve as identification of potential incapacitating health conditions, assessment of the pilots' medical fitness to fly, and govern aviation licensing accordingly (International Civil Aviation Authority, 2012). Furthermore, civil aviation regulators are required to apply safety management principles to the pilot medical assessment process, evaluate data on areas of increased health risk, and implement appropriate health promotion for pilots to reduce future medical risks to flight safety, as outlined in the International Civil Aviation Organization's Annex 1 (International Civil Aviation Authority, 2012). Nonetheless, preventative medicine interventions pertaining to foundational lifestyle behaviours including nutrition and physical activity are not routinely implemented, as the curative medical model (Babatunde et al., 2021) represents the dominant practices of aviation medical care (International Civil Aviation Authority, 2012). Indeed, despite the growing evidence base pertaining to benefits of lifestyle preventive medicine, uptake in a global context among the general population and aviation alike remains low, primarily due to factors associated with financial prioritization (Levine et al., 2019). Unaddressed modifiable health risks of disease and disability can result in substantial direct and indirect health care costs longitudinally (Bolnick et al., 2020), thus impactful and cost-efficient health promotion interventions may translate to significant economic value over time (Masters et al., 2017). Increasing uptake of preventive services requires multifaceted strategies, including but not limited to organisational leadership, education, evidence driven measurement metrics, and evidence of return on investment (Levine et al., 2019).

Multicomponent healthy eating, sleep hygiene, and physical activity interventions can elicit significant NCD risk factor reduction and promote positive physical and mental health outcomes in airline pilots with elevated health risk, as demonstrated in Study Four (Wilson et al., 2021a), Study Five (Wilson et al., 2021b), Study Six (Wilson et al., 2022c), and Study Seven. It is therefore evidently desirable to enhance the implementation of strategies to promote healthy dietary behaviours, physical activity engagement, and sleep quality and quantity in clinical aviation medicine practices to promote pilot health, wellness, NCD risk reduction, and to support flight operation safety.

As discussed in Study Three, various aspects of health behaviour promotion intervention design influence the effectiveness and economic feasibility of implementation in clinical practice. As evidenced by Study Four (Wilson et al., 2021a), Study Five (Wilson et al., 2021b), and Study Six (Wilson et al., 2022c), interventions that include a) face-to-face consultations with a trained health care professional, b) an individualized approach, c) integration of numerous behaviour change techniques, and d) include on-going care, are associated with acute and chronic efficacy for attaining *moderate* to *large* effect sizes for healthy adaptations in airline pilots.

Subsequently, interventions of this nature require considerable time investment, may be costly, and require trained individuals to deliver care, thus exemplifying commonly expressed barriers to practical utility and scalability of health behaviour interventions (Sohn et al., 2020). To mitigate these barriers, Study Seven evaluated the effectiveness of a smartphone-based app multicomponent physical activity, healthy eating, and sleep hygiene intervention that utilised a systematic and automized methodology to allocate personalised health behaviour programming in the absence of a human health coaching structure. Consequently, the smartphone-based app intervention elicited significant improvements in cardiometabolic health parameters associated with *small* to *large* effect sizes. As digital health interventions that do not require the resource and expertise requirements of health care professional delivery offer the potential for cost-effective scalability, these findings offer promising insights for future research to build upon.

With raised awareness globally in recent years of the presence of workplace stress and mental health issues, compounded by the emergence of the COVID-19 pandemic, implementation of workplace wellness programmes and employee assistance programmes incorporating wellbeing initiatives have advanced in prevalence (Baicker, 2021). However, in the attempt to simultaneously minimise expenditure and maximise scale, organisations are often inclined to implement workplace wellness initiative that are associated with a “tick-box culture” (Sims et al., 2020). For example, intervention approaches that are reactive in nature to contemporary occupational health policy requirements, and content driven exercises that offer a one-size-fits-all approach often fail to address unique personal needs of different employees. Correspondingly, a recent systematic review reported the majority of workplace diet and lifestyle interventions focused on delivery of basic educational information and generic counselling, with a smaller proportion of studies implementing personalised behaviour change coaching (Gea Cabrera et al., 2021). Of note, the interventions that involved personalised coaching were associated with significantly greater impact than non-personalised approaches (Gea Cabrera et al., 2021). It is well established that education is a necessary component for behaviour change, yet knowledge provision alone is often not enough to motivate behaviour change (Arlinghaus & Johnston, 2017). Workplace health initiatives that simply use information delivery and non-personalised approaches may fall short of achieving intended outcomes to improve health of employees as they provide content alone without support in the ongoing process of understanding and resolving existing barriers to behaviour change.

In contrast, the findings from the clinical trials in this thesis demonstrate that a face-to-face personalised intervention involving collaborative goal setting with consideration to participants' barriers and facilitators to health behaviour change can effectively promote short-term (4-months) positive physical and mental health changes. Furthermore, sustained positive behaviour changes following the intervention (12-months) were evident. We found the intervention delivery involving two face-to-face sessions (pre and post intervention consultations) with a health care professional yielded superior changes in health outcomes compared with a similar digital app-based intervention that did not involve a human coaching element. Therefore, interventions that involve direct interactions with a health care provider are likely to yield favourable return on investment for health promotion initiatives. These findings provide valuable insights for organisations wanting to care for their people and should be considered in the design of health interventions targeting the improvement of cardiometabolic health among airline pilots. Furthermore, these findings may be generalizable to wider adult working populations with elevated cardiometabolic risk factor prevalence.

A novel health challenge that airline pilots were subject to worldwide during the timeframe of conducting this thesis was the rise of the unprecedented COVID-19 pandemic. The confinement of individuals to their homes during enforced pandemic lockdowns promote sedentary behaviour (Hobbs et al., 2015) and have a direct impact on lifestyle, and consequently influences sleeping, eating, and PA behavioural patterns (Naja & Hamadeh, 2020). As discussed in Study Four (Wilson et al., 2021a), prospective cohort studies have reported negative effects of COVID-19 lockdowns on sleep (Gualano et al., 2020), physical activity (Stockwell et al., 2021), and dietary behaviours (Bennett et al., 2021) among the general population, yet numerous studies have contrastingly observed positive effects during COVID-19 lockdown periods for these same health behaviours (Bennett et al., 2021; Leone et al., 2020; Stockwell et al., 2021). Interestingly, these findings suggest that adverse effects from COVID-19 lockdowns on health outcomes may be mitigated through utilisation of effective behavioural countermeasures. In Study Four (Wilson et al., 2021a) and Study Five (Wilson et al., 2021b), a group of airline pilots that served as a control group and had no intervention support, experienced a significant increase in body mass, blood pressure and reduced mental health during a 12-month study during the first year of the pandemic, yet in parallel, the intervention group significantly improved among these health parameters. These findings suggest when given an appropriate stimulus, health behaviours were susceptible to favourable changes during the COVID-19 pandemic and health behaviour improvements subsequently enhanced physical and mental health and positively influenced quality of life during an unprecedented global pandemic (Ingram et al., 2020; Wilson et al., 2021a; Wilson et al., 2021b).

In the context of problem-solving the barriers to implement preventive medicine service delivery in aviation medicine, the findings from this thesis offer insights that may inform future policies and practices. Firstly, the existing infrastructure of standard aviation medical care administered annually by aviation medical professionals is an established platform that has potential to incorporate effective preventive health care delivery in pursuit of ensuring pilot medical competence to support flight safety (International Civil Aviation Authority, 2012). Secondly, if evidence-based training regarding preventive medicine practices and policies is provided to aviation doctors and registered nurses, they provide appropriate modes of health behaviour intervention administration to airline pilots. Third, the evidence-driven evaluative metrics utilised to measure outcomes among this thesis's studies have been trialled and are cost-effective for implementation in practice. Furthermore, the methodology obtained from Study Four (Wilson et al., 2021a), Study Five (Wilson et al., 2021b), Study Six (Wilson et al., 2022c), and Study Seven provide an evidence-based framework for health behaviour interventions which can be systematically adopted by aviation health care professionals to deliver preventive medicine care.

Practical Implications

The results of the research studies presented in this thesis have important implications for aviation health care professionals and researchers. This thesis' studies provided insight regarding the prevalence of modifiable health risk factors and the efficacy of lifestyle interventions for promoting health, which may inform practices relating to disease prevention, health promotion, and public health policymaking. The following recommendations have been assembled from the scientific contributions of this thesis:

1) The findings from this thesis demonstrate the pervasiveness of modifiable cardiometabolic health risks including excessive bodyweight, raised blood pressure, insufficient physical activity, short sleep, lacking fruit and vegetable intake, and psychological fatigue among the airline pilot population. The reported prevalence of physiological, behavioural and psychological cardiometabolic health risk factors among airline pilots globally denotes similar trends to the general population. Indeed, the World Health Organization advocates a global agenda for prevention and control of NCDs due to their immense toll on adverse human and economic outcomes (Bennett et al., 2020). This data warrants the implementation of appropriate health promotion for airline pilots to mitigate cardiometabolic health risk to reduce future medical risks to flight safety.

2) The findings presented in this thesis's clinical trials indicate that higher attainment rates of health guidelines for lifestyle behaviours nutrition, physical activity, and sleep support cardiometabolic health risk factor reduction and may protect from adverse outcomes to health associated with occupational demands. Consequently, an implication for airline organisations is to provide health behaviour strategies to promote these health behaviours alongside efforts to support health and wellbeing of airline pilots. These efforts may potentially therefore enhance physical and mental

health, which may subsequently produce positive effects on work performance, resilience, pilot career longevity, and support flight operation safety.

3) The health behaviour intervention methodology articulated in Study Four (Wilson et al., 2021a), Study Five (Wilson et al., 2021b), Study Six (Wilson et al., 2022c), and Study Seven provide a practical evidence-based framework covering key descriptors (i.e. the what, why, how, when, and where) for programme implementation into clinical practice by aviation medical professionals.

4) The integration of behaviour change techniques (BCT) within health behaviour interventions including collaborative goal setting, action planning, problem solving, information about health consequences, self-monitoring, feedback on behaviours, and reviewing of outcomes are associated with intervention efficacy and can be largely automated in practice via digital health platforms such as mobile apps. The integration of BCTs within health programme design appears integral to support motivation for participation in health behaviour change, and programme longitudinal engagement and adherence.

5) Face to face personalised intervention delivery from a health care professional produces favourable acute and chronic health change effects and appears to yield superior health outcomes than a personalised digital health intervention that does not contain a human personal support component. These findings are congruent with existing literature (Santarossa et al., 2018) that suggests human support as an integral health behaviour intervention component to promote patient accountability and intervention adherence and efficacy.

6) The WattBike (Woodway USA, Waukesha, WI, USA) electro-magnetically and air-braked cycle ergometer, is a reliable instrument that is sensitive to change over time for the assessment of cardiorespiratory fitness among airline pilots. The WattBike is a space efficient apparatus which provides valid and reliable cardiorespiratory fitness test protocols integrated within the digital display on the machine. These features of the WattBike enable health care professionals to utilise the device without having to undergo specialized training and can be feasibly incorporated into the aviation

medical clinic. Consequently, the authors advocate the uptake of WattBike machines in airline aviation medical practices for the assessment of cardiorespiratory fitness, which is an independent health risk factor for NCDs (Kaminsky et al., 2019), and further for the evaluation of health intervention efficacy.

7) Waist circumference (WC) is an independent cardiometabolic health risk factor and predictor of morbidity, yet this measurement is not routinely incorporated in aviation medicine practice due to its lack of inclusion in established cardiovascular risk predication models. As demonstrated in Study Six (Wilson et al., 2022c), WC changes observed as a result of the intervention were congruent with changes in other metabolic parameters including body mass, body fat percentage, and skin fold assessments. WC is cost-effective and valuable in the evaluation of cardiometabolic health, feasible for implementation in clinical settings, and adds clinical value above BMI, which can't assess central obesity or low-risk obesity phenotypes (Ross et al., 2020). Thus, aviation medical professionals should consider incorporation of routine WC measurement for the assessment of cardiometabolic health risk and evaluation of clinical interventions to promote cardiometabolic health.

Limitations

Within the thesis, each manuscript has acknowledged study-specific limitations (Chapters 2 to 8), however, some limitations across the project are evident. Undertaking research among airline pilots with the overarching aims of quantification of population health risk factor prevalence and evaluating the acute and chronic effectiveness of applied multicomponent health behaviour interventions is a complex task. While the studies were carefully designed and efforts were made to utilise preferential scientific methodologies within a sufficient participant sample size, there are various methodological aspects that limit the generalizability of findings and should be considered by readers in the synthesis of outcomes. This section intends to acknowledge these limitations of the studies conducted in this thesis.

Sample sizes of our original research articles were sufficient for achieving adequate power to distinguish statistically significant effects in the key outcome variables, yet participation in all studies were voluntary via self-selection. Invitation to participate in our research was extended to all pilots within the airline, yet those who voluntarily participated may have been inherently more actively interested in their health or had stronger motivation to engage in healthy change compared to those within the population who chose not to participate. Furthermore, the magnitude of intervention effects observed in our clinical trials may have been supported by the participants who were willing to engage in the intervention. Indeed, Barreto and colleagues (Barreto et al., 2013) suggested those who volunteer to participate in exercise-related studies are more likely to be fitter and healthier than non-volunteers. Furthermore, the transtheoretical model of behaviour change suggest individuals who are contemplating or are determined to engage in health promoting behaviour change are more likely to volunteer in associated research than those who are in the pre-contemplation stage (O'Hea et al., 2004). Therefore, according to these perspectives of health behaviour readiness and volunteer bias, our research theoretically and potentially may have not captured those at greatest health risk among the population. However, due to the lack of legal infrastructure existing to enforce mandatory engagement with health behaviour promoting strategies, this remains a challenge broadly for research and clinical practice, and future research should explore innovative strategies for engaging diverse and at-risk populations.

Outcome measures utilised among our original research studies were only those that had been previously validated and evaluated for acceptable reliability among existing literature, however numerous self-report subjective instruments were selected due to factors such as economic and implementation feasibility, and prioritization of larger sample sizes for the studies. Further, due to the extensive quantity of outcome measure instruments incorporated with data collection in the studies of this thesis, instrument selection was also influenced by considerations of participant burden and maximizing data collection adherence. For assessment of dietary behaviour, physical activity levels, and sleep quality and quantity, self-recall measurements were utilised, which are easy to implement in a time efficient and scalable manner, yet are inherently limited by the ability, awareness, and accuracy of the participants' recall (Stull et al., 2009). Although demonstrating adequate validity and reliability for use in this thesis' research context, self-recall instruments are less precise than alternative objective measurement options available, as comprehensively discussed in Study Three. However, implementation of such objective measurement is costly, time intensive, and challenging to implement among large sample sizes, within longitudinal investigations, and among multicomponent research endeavors as carried out in the cross-sectional and clinical trials within this thesis.

As the studies of this thesis focused broadly on a multifaceted approach to investigating various health parameters pertaining to cardiometabolic health risk and wider markers of physiological fitness, limited depth of investigation on each parameter were conducted. In the examination of sleep, we evaluated the average duration of sleep per night as the parameter of interest, which is the most widely reported sleep metric among the scientific body (Chattu et al., 2019). However, further important sleep architectural factors have not been examined, such as sleep quality, efficiency, and latency. Pertaining to nutrition, although fruit and vegetable intake which featured in our investigations is among the most widely studied and established nutritional risk factors for NCD development (Ezzati & Riboli, 2013), dietary behaviour characteristics that support health and NCD risk reduction are far more complex than this, as discussed in Study Three. Finally, as the emergence of the global COVID-19 pandemic occurred while conducting the work of this thesis, the associated unprecedented environmental, occupational, and lifestyle perturbations (Suau-Sanchez et al., 2020) airline pilots experienced during this time may have influenced health risk factor prevalence and participation characteristics of the population.

Future Research Directions

Based on the findings and limitations of the work of this thesis, there are several directions for future research to expand on the related scientific body of knowledge pertaining to cardiometabolic health parameters among airline pilots. The broad scope of this thesis precluded focused investigation of any one health risk factor or health behaviour; therefore, the present thesis contributions provide a foundation for future targeted scientific developments.

As identified in Study One (Wilson et al., 2022b), more detailed surveillance of health risk factor prevalence is required internationally among airline pilots due to the current lack of quality evidence. There is a dearth of literature pertaining to evaluation of dietary behaviours among airline pilots. Important nutritional characteristics including energy balance, the overall quality and quantity of dietary patterns, and the impact of flight duty periods on dietary behaviours among airline pilots are largely unexplored. As discussed in Study Three, the occupational demands of airline pilots present numerous challenges toward healthy dietary patterns in this population, yet to the authors' knowledge, no research has effectively quantified the dietary intake of pilots utilising high quality objective methodology. Accordingly, there is a need for future research to comprehensively evaluate dietary behaviour characteristics among airline pilots during both on-duty and off-duty periods, utilising objective measures such as extensive food diary logging.

To date, physical activity levels and sedentary behaviours have not been thoroughly investigated among airline pilots globally. The limited existing body of knowledge pertaining to physical activity in airline pilots has relied on assessment via self-recall questionnaires, inhibiting strong conclusions to be drawn due to the inherent limitations in validity and reliability of these instruments (Brener et al., 2003). The sedentary nature of the job as an airline pilot has been expressed among various sources as a contributor to work related stress and as an occupational health risk (Cahill et al., 2021; Sykes et al., 2012; Wilson et al., 2022b), yet scientific data has not been reported regarding quantification of sedentary behaviour among airline pilots habitually, nor during work duty periods. Future research should utilise objective measures of physical activity, such as actigraphy during on-duty and off-duty periods to accurately quantify sedentary behaviour and physical activity intensity characteristics such as time spent attaining light, moderate, and vigorous physical activity. The resulting data would be beneficial for strengthening epidemiological understanding of insufficient physical activity prevalence and for informing targeted intervention strategies for airline pilots relative to occupational behaviour characteristics.

Due to the sizable participation rates in our clinical trials and cross-sectional study, economic resourcing constraints precluded the inclusion of cardiometabolic parameters such as HbA1c and blood cholesterol levels. Given these clinical measures are routinely incorporated in the cardiovascular risk assessment of airline pilots > 35 years old as indicated by the International Civil Aviation Organization (International Civil Aviation Authority, 2012), these measures are relevant to informing clinical aviation practice and future health behaviour clinical trial research should incorporate these measures to enhance the understanding of intervention effects on the overall cardiometabolic health profile of airline pilots. Indeed, diet and physical activity interventions have demonstrated efficacy for improving glycemic control and promoting a favorable blood lipid profile in the general population (Varady & Jones, 2005), thus highlighting the relevance of investigating this in future research.

Longitudinal studies are particularly needed in the context of health behaviour change maintenance and sustained NCD risk mitigation. Standard practice in aviation occupational health involves regular annual or biannual aviation medical examinations of airline pilots, which is involved with the ongoing commercial flying license validation and renewal process. This routine occupational health practice provides an established and logical opportunity for integration of preventive medicine interventions to promote cardiometabolic health and NCD risk factor mitigation. As evidenced by the clinical trials in this thesis, the implementation of a face-to-face health assessment by a health care professional with the inclusion of collaborative goal setting and health behaviour intervention support can promote acute (four months) and chronic (twelve months) cardiometabolic health benefits, however it is unclear the intervention efficacy beyond 12-months. Thus, future research should explore implementation of a multicomponent health behaviour intervention integrated within the aviation medical examination appointment, followed by progress evaluation and programme refreshing during subsequent aviation medical examinations as a structure of on-going preventive medicine care. This proposition presents a structure for future research to measure longitudinal effectiveness of this on-going care approach.

Considering this thesis' findings of notable cardiometabolic health risk factor prevalence among the airline pilot population, coupled with the effectiveness of a multicomponent health behaviour intervention for mitigating these risk factors, it would be valuable for future research to investigate the health literacy and education of evidence-based lifestyle medicine practices to promote positive health outcomes among this population. Given the positive correlation between educated awareness and longitudinal decision-making ability (Kim et al., 2018), future research should investigate the effectiveness of multicomponent health behaviour interventions for enhancing health knowledge and literacy of airline pilots.

The clinical trials in this thesis focused on individualized lifestyle health behaviour intervention delivery in a non-socially facilitated context, apart from interactions with the health care professional. Recent research has suggested that individuals who participate in multicomponent health behaviour change interventions and simultaneously engage with a conducive social network can achieve significantly greater health change, compared with individuals who do not seek social support (Greaney et al., 2018). Thus, future research should evaluate the effectiveness of health behaviour interventions among airline pilots that integrate elements of social support, such as intervention group peer engagement via face-to-face or digital platforms (i.e., mobile app or social media). These findings would provide valuable insight for informing aviation medicine practices and policies by determining whether interventions with social support promote better health outcome effects and sustainability than non-socially facilitated programmes.

Past research has suggested that human personal support constructs appear to be among the most important components to support accountability, adherence, and effectiveness of health behaviour interventions (Santarossa et al., 2018). Among the clinical trials of this thesis, we found both face-to-face delivery from a health care professional and an automated digital app-based intervention both can yield significant cardiometabolic health improvements, yet the former appeared notably more effective. Therefore, future research is warranted to evaluate whether a digital person-to-person component (i.e., online consultations with a health care professional, or via artificial intelligence) can produce comparable efficacy to face-to-face in person support from a health care professional. These findings would be of value to inform cost-effective and scalable interventions strategies for future public health and aviation medicine practices and policies.

Finally, the research methodology applied in this thesis was quantitative in nature and future research relating to understanding airline pilot cardiometabolic health implementing qualitative designs such as semi-structured interviews would provide valuable insights. Future qualitative research should investigate the perceived barriers and facilitators to health behaviour change among airline pilots to tailor personalised health services more effectively. Further, exploration of the behavioural and environmental occupational demands and challenges from the airline pilots' perspective may provide beneficial insights for the future design of targeted interventions to optimally facilitate health behaviour change among this unique occupational group.

Conclusion

This thesis provides original research pertaining to the cardiometabolic health status of airline pilots, strategies to improve cardiometabolic health within this occupational group, and consequent applications for aviation occupational medicine and research. The data produced in this thesis can be used by aviation health professionals and practitioners, policymakers, researchers, and airline pilots to support better understanding of evident health risk prevalence among pilots and evidence-based strategies to mitigate health risk and promote positive health through lifestyle medicine. The major findings in this thesis were that substantial cardiometabolic health risk factor prevalence > 50% was present among airline pilots globally for overweight and obesity, physical inactivity, insufficient fruit and vegetable intake, elevated blood pressure, and high psychological fatigue. Furthermore, the implementation of a four-month multicomponent healthy eating, physical activity and sleep hygiene intervention can elicit significant acute and chronic improvements in cardiometabolic health parameters among airline pilots, and these findings may be generalisable to other populations with similar health risk factor prevalence. Health behaviour lifestyle interventions that support the attainment of evidence-based guidelines for health are an appropriate aviation occupational health practice for promoting positive acute health changes and mitigating the risk of NCD pathogenesis. Adopters of these recommendations may utilise the tested methodological framework of the clinical trials implemented in this thesis to support health intervention efficacy.

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Appendices

The following appendices include:

- Appendix A: Ethics approval letters
- Appendix B: Co-authorship forms for Manuscripts 1-7
- Appendix C: Graphical abstracts for Chapters 2-8
- Appendix D: Sleep Hygiene Checklist
- Appendix E: Top Ten Tips for Healthy Eating
- Appendix F: Supplementary file for Chapter Eight
- Appendix G: The published journal manuscripts in print (Chapters 2-3 and 5-7)

Appendix A

Ethics approval letters

The University of Waikato
Private Bag 3105
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Hamilton, New Zealand

Human Research Ethics Committee
Julie Barbour
Telephone: +64 7 837 9336
Email:humanethics@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

12 November

Daniel Wilson
HSHP
By email: Daniel.wilson@airnz.co.nz

Dear Daniel

HREC(Health)2019#35 : Airline pilot morbidity: A population-based comparison study with general population

Thank you for submitting your amended application HREC(Health)2019#35 for ethical approval.

We are now pleased to provide formal approval for your project where you will request permission to access data collected for (bi-)annual medical certificates by NZ, and collect further wellbeing data from pilots.

Please contact the committee by email (humanethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,

Julie Barbour PhD
Chairperson
University of Waikato Human Research Ethics Committee

The University of Waikato
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Gate 1, Knighton Road
Hamilton, New Zealand

Human Research Ethics Committee
Roger Moltzen
Telephone: +64 7 838 4528
Email:humanethics@waikato.ac.nz

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

3 June 2020

Daniel Wilson
Te Huataki Waiora, School of Health
DHECS
By email: daniel.wilson@toiohomai.ac.nz

Dear Daniel

HREC(Health)2020#07: Are lifestyle health and wellbeing interventions effective for enhancing health metrics in airline pilots?

Thank you for submitting your amended application HREC(Health)2020#07 for ethical approval.

We are now pleased to provide formal approval for your project.

Please contact the committee by email (humanethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,

Emeritus Professor Roger Moltzen MNZM
Chairperson
University of Waikato Human Research Ethics Committee

Appendix B

Co-authorship forms

THE UNIVERSITY OF
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Co-Authorship Form

Postgraduate Studies Office
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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 2 - Wilson, D., Driller, M., Johnston, B., & Gill, N. (2022). The prevalence of cardiometabolic health risk factors among airline pilots: A systematic review. International Journal of Environmental Research and Public Health. 19(8) 4848. https://doi.org/10.3390/ijerph19084848 [Impact Factor: 4.614]

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Matthew Driller	Supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Ben Johnston	Provided feedback on the drafting of the paper and reviewed it prior to publishing.

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Nicholas Gill		14-08-2022
Matthew Driller		12-08-2022
Ben Johnston		12-08-2022

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Chapter 3 - Wilson, D., Driller, M., Johnston, B., & Gill, N. (2022). The prevalence and distribution of health risk factors in airline pilots: A cross-sectional comparison with the general population. Australian and New Zealand Journal of Public Health. Advance online publication. https://doi.org/10.1111/1753-6405.13231 [Impact Factor: 3.755]

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Matthew Driller	Supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Ben Johnston	Provided feedback on the drafting of the paper and reviewed it prior to publishing.

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Chapter 4 - Wilson, D., Driller, M., Johnston, B., & Gill, N. (Under review). Healthy nutrition, physical activity, and sleep hygiene as preventive medicine for airline pilots: A narrative review.

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 5 - Wilson, D., Driller, M., Johnston, B., & Gill, N. (2020). The effectiveness of a 17-week lifestyle intervention on health behaviors among airline pilots during COVID-19. Journal of Sport and Health Science. 10(3) 333-340. https://doi.org/10.1016/j.jshs.2020.11.007 [Impact Factor: 13.077]

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
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Chapter 6 - Wilson, D., Driller, M., Winwood, P., Johnston, B., & Gill, N. (2021). The effects of a brief lifestyle intervention on the health of overweight airline pilots during COVID-19: A 12-month follow-up study. Nutrients. 13(12) 4288. https://doi.org/10.3390/nu13124288 [Impact Factor: 6.706]

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	85%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Matthew Driller	Supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Ben Johnston	Provided feedback on the drafting of the paper and reviewed it prior to publishing.
Paul Winwood	Supported data analysis, provided feedback on the drafting of the paper and reviewed it prior to publishing.

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Nicholas Gill		14-08-2022
Matthew Driller		12-08-2022
Ben Johnston		12-08-2022
Paul Winwood		12-08-2022

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Chapter 7 - Wilson, D., Driller, M., Winwood, P., Clissold, T., Johnston, B., & Gill, N. (2022). The Effectiveness of a Combined Healthy Eating, Physical Activity, and Sleep Hygiene Lifestyle Intervention on Health and Fitness of Overweight Airline Pilots: A Controlled Trial. Nutrients. 14(9) 1988. https://doi.org/10.3390/nu14091988 [Impact Factor: 6.706]

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Matthew Driller	Supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
Ben Johnston	Provided feedback on the drafting of the paper and reviewed it prior to publishing.
Paul Winwood	Supported data analysis, provided feedback on the drafting of the paper and reviewed it prior to publishing.
Tracey Clissold	Provided feedback on the drafting of the paper and reviewed it prior to publishing.

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Chapter 8 - Wilson, D., Driller, M., Johnston, B., & Gill, N. (Under review). A smartphone-based app intervention improves physical activity, nutrition and sleep habits in airline pilots: A randomized control trial.

Nature of contribution by PhD candidate	Research conceptualization, development of study design, data collection and analysis, manuscript preparation and journal submission.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Nicholas Gill	Contributed to research conceptualization and study design, supported data collection, supervised the research process, feedback on the drafting on the paper and reviewed it prior to publishing.
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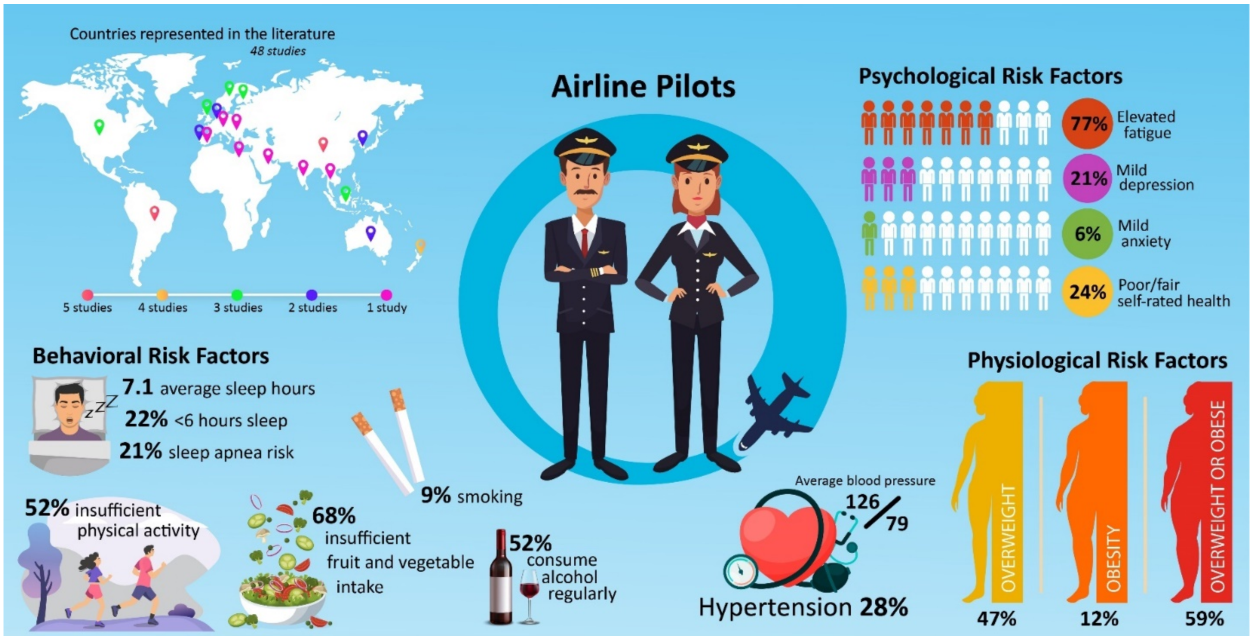
Name	Signature	Date
Nicholas Gill		14-08-2022
Matthew Driller		12-08-2022
Ben Johnston		12-08-2022

Appendix C

Chapter Two Graphical Abstract



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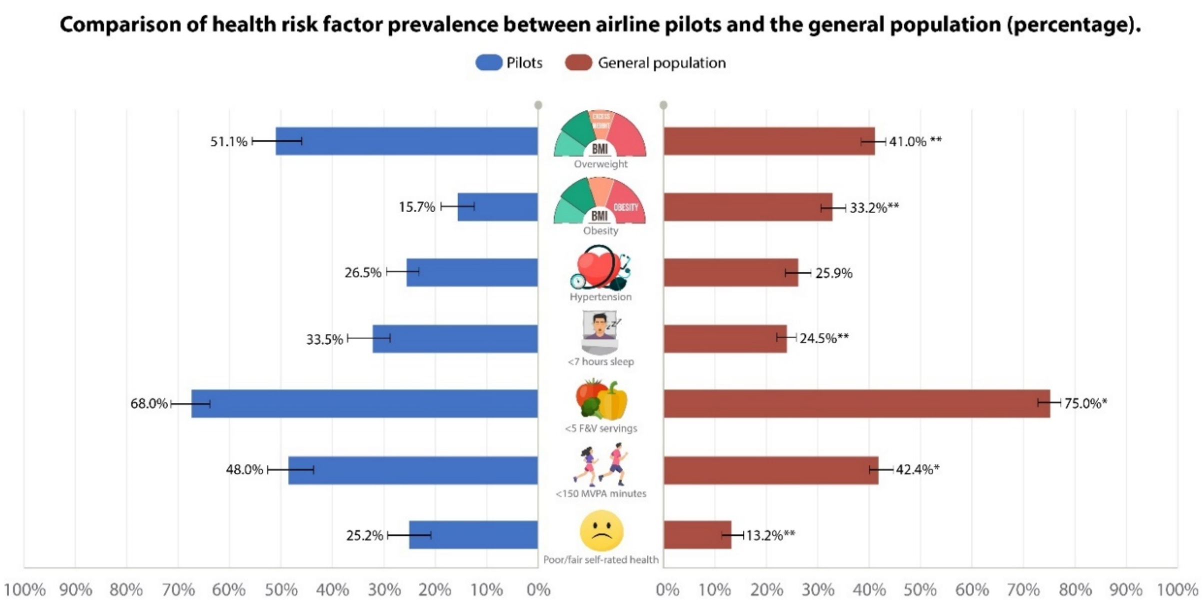

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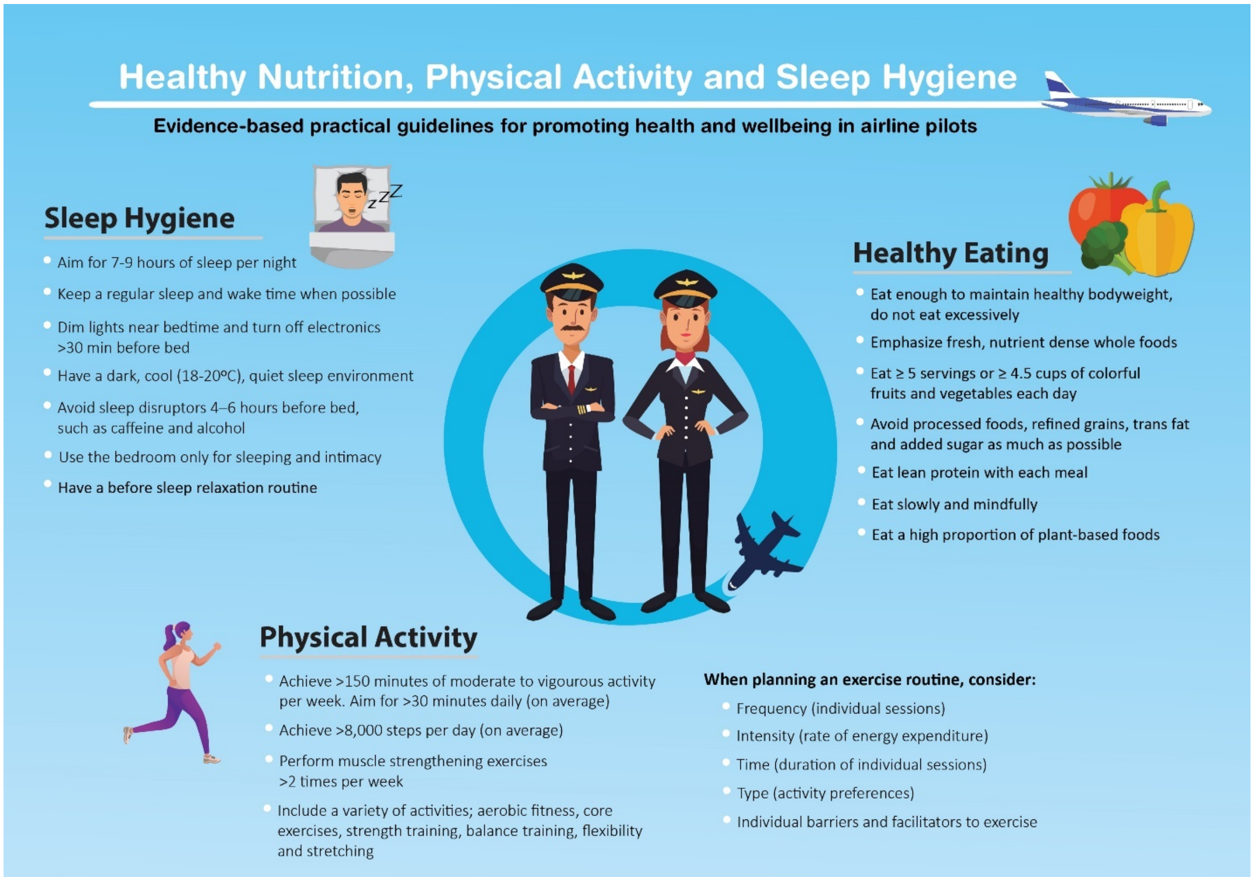

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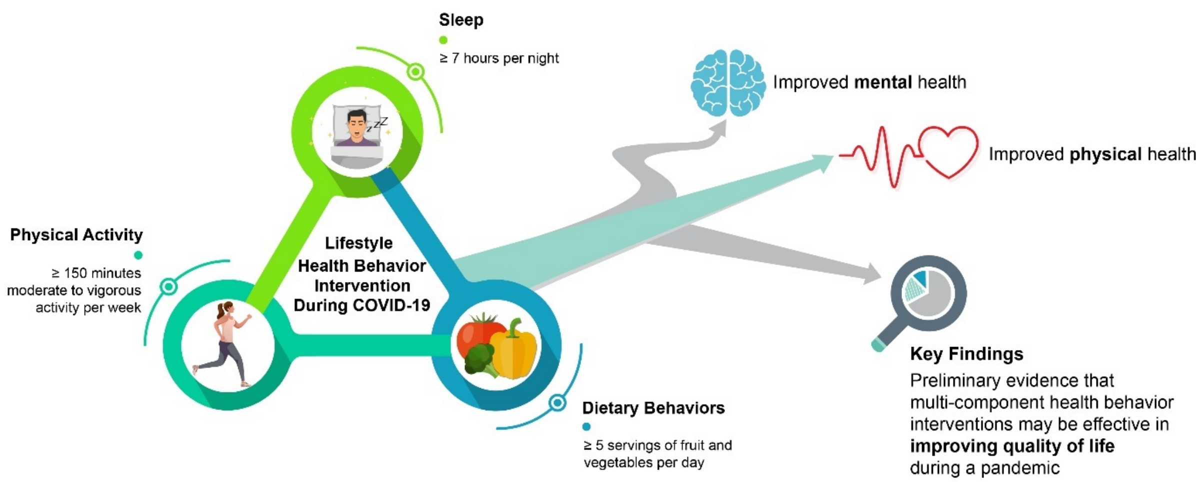

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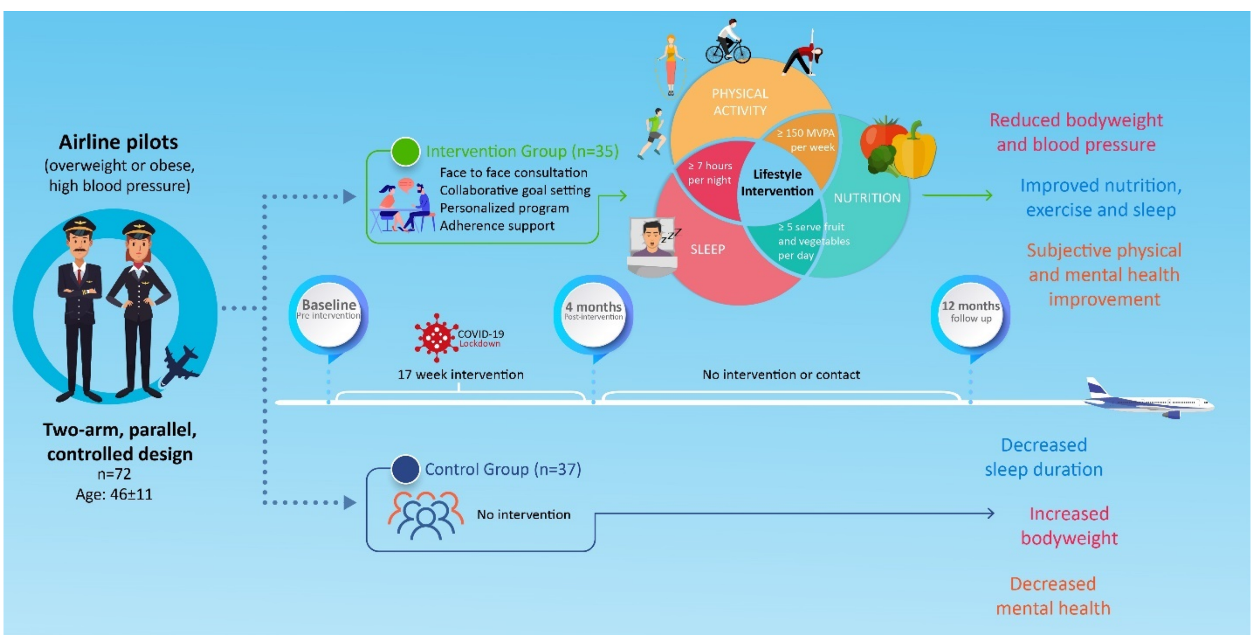

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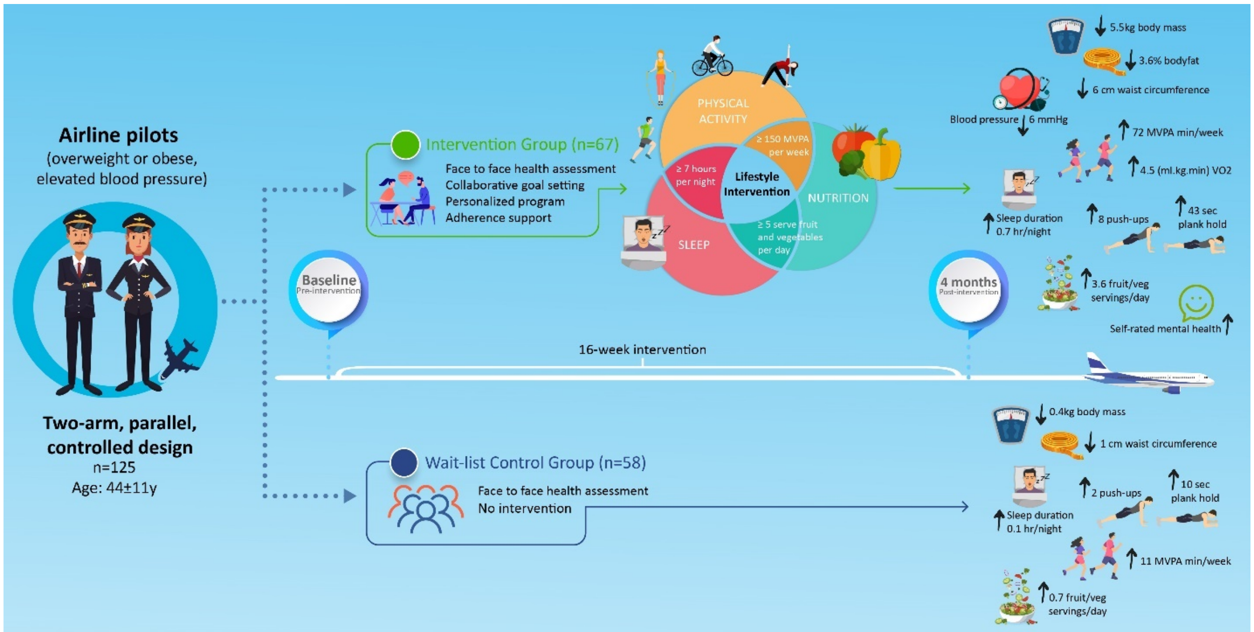
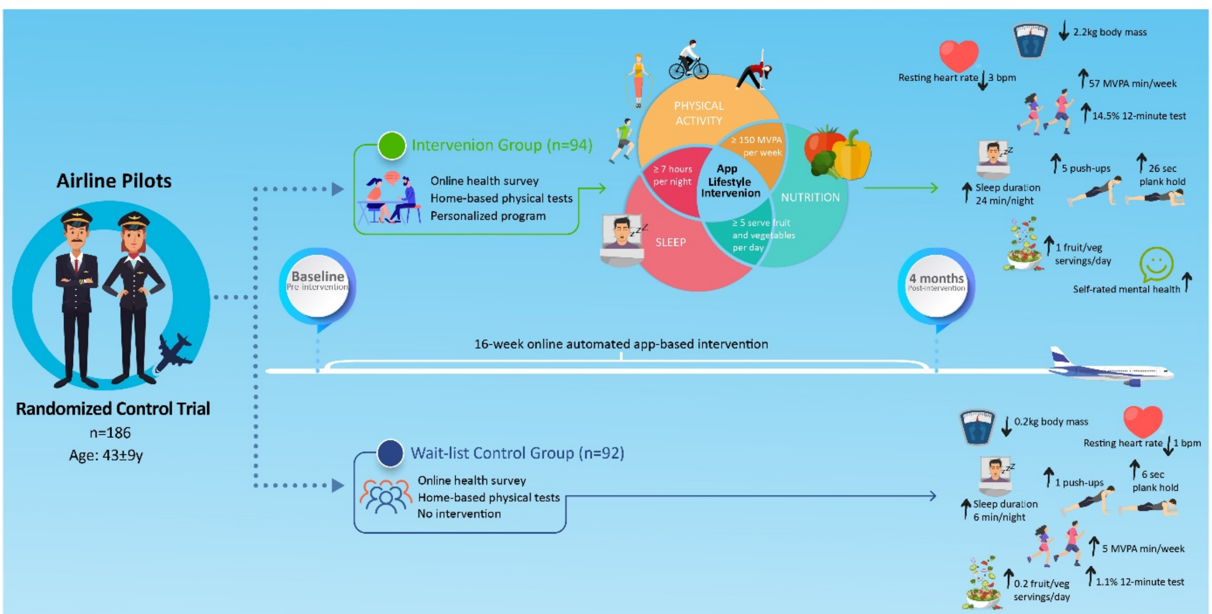


Chapter Eight Graphical Abstract



Appendix D

Sleep Hygiene Checklist

Sleep Hygiene Checklist: Strategies for Enhancing Sleep	*YES Achieving*	*NOT Achieving*
1. Sleep at least 7 hours		
2. Sleep routine or depower hour		
3. Regular sleep and wake time		
4. Dim lights near bedtime and turn off electronics > 30 min before bed		
5. Avoid sleep disruptors 4-6 hours before bed e.g., caffeine, large meals, alcohol		
6. Have a dark, cool, quiet sleep environment		
7. Exercise every day, not too close to bedtime		
8. Use the bedroom only for sleeping and intimacy		
9. Do a brain dump on paper before bed		
10. Early morning light exposure		

Appendix E

Top Ten Tips for Healthy Eating

A system of habits to support a healthier you.

1. Emphasize whole foods

Choose unprocessed natural foods.

As food processing increases, nutrient density decreases. The more ingredients that are listed on a food, the more processed the food will likely be.

2. Reduce sugar where possible

Limit foods with added sugar (cookies, cakes, sugar sweetened beverages etc.) where you can. Read labels to avoid hidden sugars (sauces, cereals, dairy products etc.). Aim for less than 10% of daily energy from sugar or under 5% for better health.

3. Eat a rainbow of foods

Eat a variety of fruit and vegetables each day. Try those with rich colors of red, blue, green and orange. The more color in your day the more antioxidant, vitamins, and minerals you will be getting.

4. Reduce white.

Try to avoid the energy dense white foods like pasta, rice, bread, and potato. Use MyFitnessPal to understand other options. For example, 2 cups of broccoli with a curry is a healthier meal and some would say tastier than 2 cups of rice, and far fewer calories! Also consider having more vegetables that grow above the ground than those that grow below the ground.

5. Eat lean protein with each meal

Protein foods such as lean meat, chicken, fish, eggs, low fat dairy foods, bean, nuts, seeds, legumes and lentils aid in muscle repair and support lean body mass.

6. Caution with your portions

Do not heap food on your plate (except vegetables). Use the hand portion sizing guide to make good meal size decisions. Think twice before having second helpings.

7. Eat slowly and mindfully

Set aside adequate time for your meal so you're not rushed and chew your food well. While eating try to avoid watching TV or eating on the go. Pay attention to your food. Eat until you feel 80% full.

8. Think about your drinks

Drink 2 liters of fluids a day. Choose mainly water. Unsweetened fruit juice contains natural sugar so limit to one glass a day (200 ml/one third pint). Alcohol is high in calories; limit to one unit a day for women and two for men.

9. Choose good fats

Choose fats that enhance your recovery and immune system not those that break it down. Some good sources of are nuts and seeds, nut butters, avocado, fatty fish, olive oil, and flaxseed oils.

10. Setup your healthy environment

If a food is in your house or possession, either you or someone you love, will eat it. If you remove the temptation of unhealthy foods from your surroundings and add more healthy options, you will set yourself up for success.

Appendix F

Supplementary file for Chapter Eight

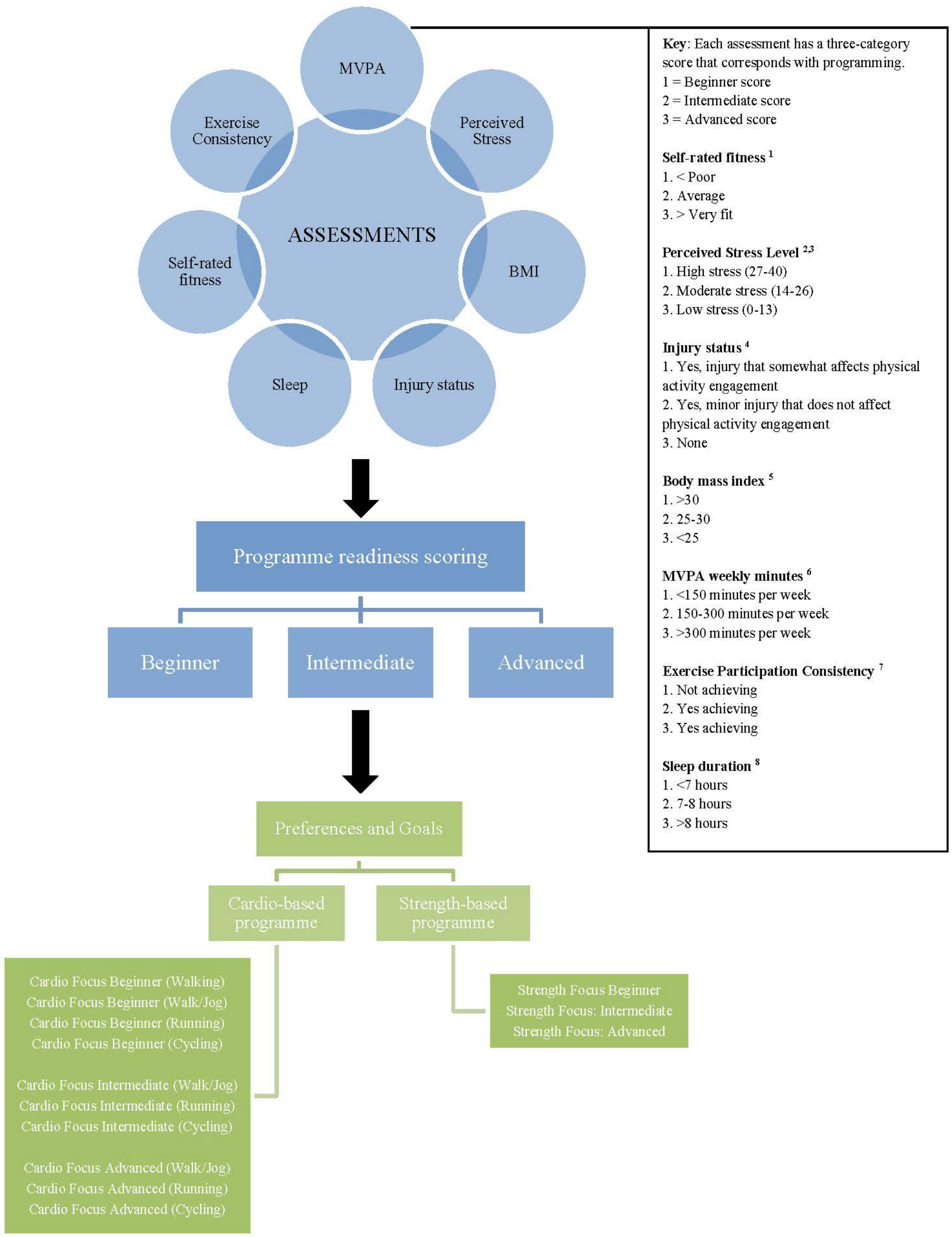


Figure 1: Physical activity programme allocation algorithm process overview flow chart.

Evidence-based physical activity programme readiness allocation algorithm (PRAA)

PRAA Scoring and Determination of Physical Activity Programme Intensity Level

For each of the seven outcomes, a score of 1, 2, or 3 corresponded to score contribution for either a beginner, intermediate or advanced programme, respectively. The programme intensity that received the highest sum score derived across the seven assessment outcomes determined the final programme intensity allocation. If multiple programme scores were tied, the lower intensity programme option was allocated.

PRAA Component 1: Self-rated Fitness

Self-rated physical fitness has demonstrated strong correlations with measures of cardiorespiratory fitness [1]. One question "How would you rate your physical fitness right now?" was coded by participants as either "Poor", "Average", or "Very fit", which corresponded as scores 1 (beginner), 2 (intermediate), or 3 (advanced, respectively.

PRAA Component 2: Perceived Stress Level

Psychological stress and physical activity are considered to be reciprocally related, and evidence suggests excessive stress levels are associated with impaired physical activity engagement [3]. Perceived stress levels were measured utilizing the Perceived Stress Scale, a 10-item self-report questionnaire for assessment of psychological stress [2]. Perceived Stress Scale scores of 27-40, 14-26, and 0-13 [2] were coded as 1 (beginner), 2 (intermediate), or 3 (advanced), respectively.

PRAA Component 3: Physical Injury Status

Prior to intervention allocation, participants were excluded from study inclusion if significant injuries were present that had not been examined by a medical professional and/or if medical clearance was deemed necessary prior to engagement in a physical activity programme after completion of the 2020 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) [4]. After passing preceding eligible requirements, participants were asked to select one following answer that best represents their current injury status. Response "Yes, injury that somewhat affects physical activity engagement", "Yes, minor injury that does not affect physical activity engagement", and "No injuries" were coded as 1 (beginner), 2 (intermediate), or 3 (advanced), respectively.

PRAA Component 4: Body Mass Index (BMI)

Evidence suggests a significant negative correlation between obesity and cardiorespiratory fitness exists [9]. Well established BMI categories were calculated [5] as $\geq$30 kg/m^2, 25-29.9 kg/m^2, and <25 kg/m^2, which were coded as 1 (beginner), 2 (intermediate), or 3 (advanced), respectively.

PRAA Component 5: Weekly Moderate to Vigorous Physical Activity (MVPA)

World Health Organization 2020 guidelines on physical activity and sedentary behaviour advocate adults should undertake 150–300 minutes of moderate-intensity, or 75–150 min of vigorous-intensity physical activity, or some equivalent combination of moderate-intensity and vigorous-intensity aerobic physical activity per week [6]. Accordingly, participants who achieved baseline MVPA per week of <150 minutes, 150-300 minutes, or >300 minutes were coded as 1 (beginner), 2 (intermediate), or 3 (advanced), respectively.

PRAA Component 6: Exercise Participation Consistency

Exercise participation consistency is associated with greater MVPA and cardiorespiratory fitness [7,10]. Exercise participation consistency was defined as performing planned, structured physical activity at least 30 minutes at moderate intensity on at least 3 d·wk−1 for at least the last 3 months [7]. Participants who did not achieve this criterion were coded as 1 (beginner) and for those that achieved this criteria, a score was contributed to both 2 (intermediate) and 3 (advanced).

PRAA Component 7: Average Sleep Duration Per Night

Short sleep is associated with poor health outcomes, including cardiorespiratory fitness. Sleep duration guidelines proposed for adults from 18 to 64 years is 7–9 hours per night [8]. Accordingly, average sleep duration per night of <7 hours, 7-8 hours, and >8 hours were coded as 1 (beginner), 2 (intermediate), or 3 (advanced), respectively.

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Appendix G

Published Manuscripts in Printed Form

Chapter Two Publication Print

International Journal of *Environmental Research and Public Health*

MDPI

Review

The Prevalence of Cardiometabolic Health Risk Factors among Airline Pilots: A Systematic Review

Daniel Wilson [1,2], Matthew Driller [3,*], Ben Johnston [4] and Nicholas Gill [1,5]

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Abstract: Background: The occupational demands of professional airline pilots such as shift work, work schedule irregularities, sleep disruption, fatigue, physical inactivity, and psychological stress may promote adverse outcomes to cardiometabolic health. This review investigates the prevalence of cardiometabolic health risk factors for airline pilots. Methods: An electronic search was conducted utilizing PubMed, MEDLINE (via OvidSP), CINAHL, PsycINFO, SPORTDiscus, CENTRAL, and Web of Science for publications between 1990 and February 2022. The methodological quality of included studies was assessed using two quality assessment tools for cross-sectional and clinical trial studies. The prevalence of physiological, behavioral, and psychological risk factors was reported using descriptive analysis. Results: A total of 48 studies derived from 20 different countries, reviewing a total pooled sample of 36,958 airline pilots. Compared with general population estimates, pilots had a similar prevalence for health risk factors, yet higher sleep duration, lower smoking and obesity rates, less physical activity, and a higher overall rate of body mass index >25. Conclusions: The research reported substantial prevalence >50% for overweight and obesity, insufficient physical activity, elevated fatigue, and regular alcohol intake among pilots. However, the heterogeneity in methodology and the lack of quality and quantity in the current literature limit the strength of conclusions that can be established. Enhanced monitoring and future research are essential to inform aviation health practices and policies (Systematic Review Registration: PROSPERO CRD42022308287).

Keywords: aviation medicine; occupational health; morbidity; noncommunicable disease risk; risk factors; modifiable risk

Citation: Wilson, D.; Driller, M.; Johnston, B.; Gill, N. The Prevalence of Cardiometabolic Health Risk Factors among Airline Pilots: A Systematic Review. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4848. https://doi.org/10.3390/ijerph19084848

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1. Introduction

Cardiometabolic noncommunicable diseases (NCDs) such as cardiovascular disease (CVD), stroke, type 2 diabetes (T2D), and their primary risk factors are a leading public health concern that produce significant and growing economic costs globally [1]. The leading cause of mortality worldwide is CVD [2], which has been reported as the most frequent cause of permanent groundings among Korean airline pilots [3]. Cardiovascular and cerebrovascular incidents have also been reported among the most prevalent causes of flight incapacitation in the United Kingdom [4].

Airline pilots experience unique occupational demands which may promote adverse outcomes to cardiometabolic health, including shift work, work schedule irregularities, sleep disruption, fatigue, the sedentary nature of the job, and stress demands associated with flight safety [3,5–8]. Cardiometabolic diseases are associated with numerous modifiable risk factors across physiological, behavioral, and psychological domains [1]. Central and systemic obesity, hypertension, dyslipidemia, hyperglycemia, insulin resistance, and adipose dysfunction are among prevalent physical risk factors associated with increased risk of CVD and T2D [1,9]. Modifiable behavioral risk factors [10] such as unhealthy diet, physical inactivity, excessive alcohol consumption, and tobacco smoking, along with psychological risk factors including high fatigue [11] and depression [12], are each independently established as risk factors for cardiometabolic diseases.

To date, no systematic reviews have been published pertaining to the evaluation of modifiable health risk factor prevalence among airline pilots. Estimations of health risk prevalence are important for monitoring of trends and to inform risk reduction interventions; hence, the aim of the current review was to critically analyze the global literature to quantify the prevalence of modifiable cardiometabolic health risk factors among commercial airline pilots. The findings from this review may be valuable to inform aviation health practices and policies for supporting pilot health, enhancing flight operation safety, and identifying deficiencies within the literature base to inform future research.

2. Materials and Methods

2.1. Protocol

This systematic review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) [13]. The protocol of this systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO, CRD42022308287).

2.2. Literature Search

An electronic search was conducted utilizing PubMed, MEDLINE (via OvidSP), CINAHL, PsycINFO, SPORTDiscus, CENTRAL, and Web of Science. A broad search strategy was implemented to gather literature published between 1 January 1990 and 28 February 2022. Key terms incorporated in the search string were relating to airline pilots and cardiometabolic health risk prevalence (see Table 1). The search was limited to peer-reviewed publications in English. Eligible publications were extracted, and their reference lists were manually checked for potentially relevant studies. The reference lists of existing review articles pertaining to aviation medicine were also cross-checked for relevant articles.

Table 1. Search terms blocks were combined for text and word search in PubMed and adapted to the remaining databases: 1 and 2; 1 and 3; 1, 2, and 3.

1. Airline Pilots	2. Cardiometabolic Risk Markers	3. MeSH
Pilots OR "airline pilot *" OR "commercial pilot *" OR "professional pilot *" OR "civil pilot *" OR "civilian pilot *" OR "aviation pilot *" OR "commercial airline *" OR aircrew OR "cockpit crew *" NOT military * NOT army NOT "pilot study" NOT piloted NOT "pilot project" NOT "pilot research"	"Health risk *" OR "risk factor *" OR cardiometabolic OR cardio-metabolic OR cardiovascular OR "cardiometabolic risk" OR "metabolic syndrome" OR "syndrome x" OR diabetes OR hypertension OR weight OR overweight OR obesity OR "body composition" OR adiposity OR "physical activity" OR exercise OR sleep OR circadian OR apnoea OR apnea OR nutrition OR diet OR eating OR fruit * OR vegetable * OR stress OR lipids OR cholesterol OR glucose OR insulin OR "insulin resistance" OR "insulin sensitivity" OR "waist circumference" OR fat OR "blood pressure" OR hypertension OR "C-reactive protein" OR "inflammatory markers" OR inflammation OR "microvascular dysfunction" OR fatigue OR medical OR depression OR stress OR distress OR anxiety OR alcohol OR smok * OR microalbumin * OR "endothelial dysfunction"	MeSH terms: "risk factors" [mesh] OR "health risk behaviors" [mesh] OR "health status indicators" [mesh] OR "risk assessment" [mesh]

Note: * indicates use of truncation.

2.3. Eligibility Criteria

Publications were identified for inclusion on the basis of population, literature type, publication date, and cardiometabolic health risk eligibility. The population criteria for inclusion were fixed-wing pilots (airline, commercial, civilian), and no restrictions were placed on fleet type (short-haul, long-haul, mixed-fleet). Articles were excluded if they included pilots with <1 year experience of being a pilot, as well as those who worked part-time, were a helicopter pilot, or worked in noncivil aviation roles (Air Force, military, army, or private), and if they were published before 1990. Literature sources that met inclusion were peer-reviewed original articles (retrospective, prospective, cross-sectional, case–control, cohort, and experimental), and other sources were excluded, e.g., literature reviews, commentaries, and editorials. To be eligible for inclusion, publications had to report on at least one of the following cardiometabolic health risk markers: blood pressure (BP), body composition (body mass, body mass index [BMI], waist circumference, waist-to-hip ratio, body fat percentage, lean mass percentage, visceral adiposity), glycemic control (fasting or postprandial glucose, HbA1c), insulin (fasting, insulin sensitivity, or insulin resistance), inflammation (C-reactive protein, inflammatory markers), blood lipid panel (total cholesterol (TC), low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides (TG)), microalbuminuria, endothelial or microvascular dysfunction, alcohol consumption, smoking, dietary behaviors (fruit and vegetable intake, high-energy-dense intake, high-saturated-fat intake, high sugar intake, or low-fiber), physical activity (sedentary behavior, moderate-to-vigorous physical activity (MVPA), or daily steps), cardiorespiratory fitness (submaximal or maximal oxygen consumption [VO_2]), sleep (hours per night, sleep quality), psychosocial stress (stress, depression, anxiety, and fatigue), and self-rated health.

To avoid including studies involving work duty-induced inflation of cardiometabolic risk prevalence, studies pertaining to outcome measures recorded preceding (<24 h), during, or acutely following (<48 h) long-haul flights were excluded. Where available, nonflight duty baseline data from these studies were utilized. Studies reporting data exclusively on pilot subpopulations (e.g., diabetic or obese pilots) were excluded. A hand search of recent issues of prominent aviation journals was conducted to screen for any recently published articles that were not yet indexed and apparent on the systematic search.

2.4. Screening Process

The lead author conducted the initial literature search, and results were downloaded and imported into Endnote citation software (Endnote x9, Clarivate Analytics, Philadelphia, PA, USA) for collation and duplicate removal. Thereafter, articles were exported to Microsoft Excel (Microsoft® Excel version 16.54) for further removal of duplicates and subsequent eligibility screening. Initial title and abstract screening was conducted by one author and cross-checked by a second reviewer. Subsequently, potentially eligible articles from the initial screening progressed to full-text evaluation of eligibility for inclusion. Discrepancies in outcomes between the reviewers were resolved via discussion and consultation with a third reviewer.

2.5. Methodological Quality Assessment

The methodological quality of publications included for this review was independently assessed by two reviewers. The risk-of-bias quality assessment checklist (adapted from Hoy and colleagues [14]) was utilized for evaluation of cross-sectional studies, which consisted of four external validity items and six internal validity items. Clinical trials were evaluated utilizing the risk-of-bias tool from Cochrane [15]. The summative quality assessment for each publication was expressed as being of low quality (high risk of bias), moderate quality (high risk of bias), or high quality (low risk of bias). Consistent with the Grades of Recommendation, Assessment, Development, and Evaluation and Cochrane approaches, total scores for the cross-sectional study assessment were grouped as the following thresholds: very high risk of bias (0–4 points), high risk of bias (5–6 points), or low risk of bias (7–10 points). Clinical trials were rated as 'high', 'low', or 'unclear' for seven items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and outcome-specific evaluations of risk of bias.

2.6. Data Extraction

The study country, aim, design, participant characteristics, outcomes of interest, and instruments for included publications were extracted (Appendix A). If necessary, additional publication information was sought from trial registries, article supplementary materials, or direct contact with article authors. Study data were independently extracted and coded by one reviewer, and a second reviewer independently extracted and coded 20% of the included studies for process cross-evaluation. Any discrepancies between reviewers were resolved via discussion and consultation with a third reviewer if necessary. For clinical trials included in our analysis, descriptive data were extracted from their reported baseline data, and post-intervention data were not included. For between-group studies that only reported subgroup descriptive statistics (e.g., interventional and control), we computed the combined population mean using Cochran's formula [16].

2.7. Analysis of Data

The prevalence of cardiometabolic health risks was reported using descriptive analysis. Available data were sought and extracted from included publications for descriptive analysis, including one or multiple of the following available statistical metrics: mean descriptive statistics, prevalence proportions, incidence rates, standardized incidence ratios, prevalence ratios, odds ratios, risk ratios, or scoring outcomes derived from relevant self-report instruments. The meta-analysis estimates for proportions and descriptive statistics for cardiometabolic health risk factors were calculated by weighing the studies according to their sample size within pooled samples. A 95% confidence interval was presented alongside pooled prevalence statistics. Meta-analyses were not conducted for some cardiometabolic risk factors due to a low number of studies reporting the parameter of interest ($n < 4$) or due to methodological heterogeneity. Data were entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into statistical software SPSS v28 for Windows (IBM, New York, NY, USA), where meta-analysis interpretation was performed.

3. Results

3.1. Study Selection

The search strategy produced 6138 unique results, 107 of which were deemed potentially eligible at primary screening. After full-text reviews, 48 passed eligibility evaluation for inclusion. A PRISMA flowchart depicting stages of the selection process is illustrated in Figure 1.

3.2. Study Characteristics

The 48 studies involved a total of 36,958 participants, included in 46 cross-sectional studies and three clinical trials (Figure 2). The characteristics of the included studies are summarized in Appendix A. Across all studies, males represented 96% of participants. The mean age of participants was 40 $\pm$ 11 years according to 35/48 studies which reported the mean age. The most prevalent age range reported in the remaining studies was 35–45 years. Twenty-five studies reported self-report subjective data, 14 utilized a combination of self-report subjective and objective data, and five reported only objective data. The included studies were conducted in 20 different countries or regions, including Brazil (five), China (five), New Zealand (four), Finland (three), Indonesia (three), Sweden (three), the United Kingdom (three), the United States (three), Korea (two), the Netherlands (two), Portugal (two), and one study each from Arab states, Australia, Europe, Germany, India, Oceania, Saudi Arabia, Spain, and Thailand. Four studies involved participants from numerous countries.

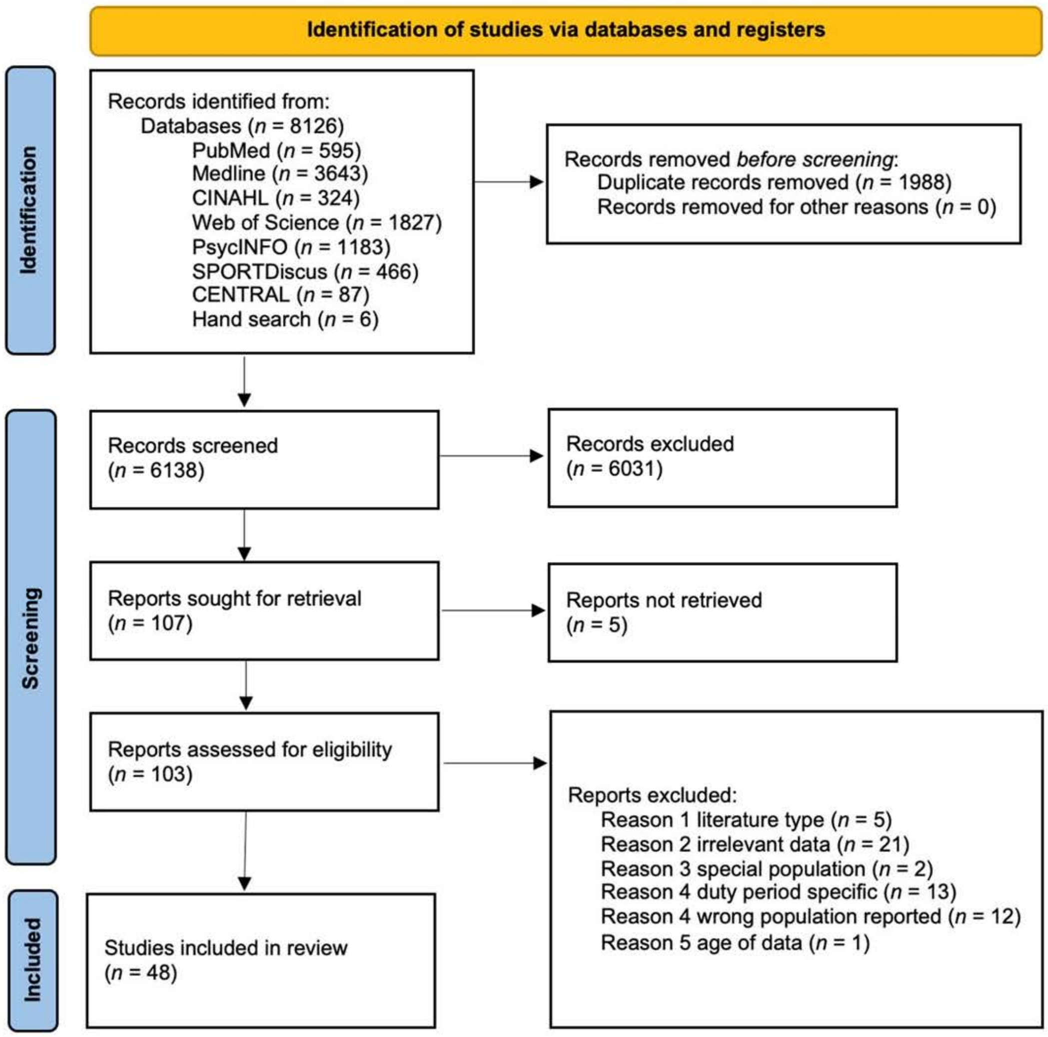

Figure 1. PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

3.3. Quality of Reviewed Articles

The results of the risk-of-bias assessment are displayed in Tables 2 and 3. Of the 48 publications included in the review, four were considered of low methodological quality with a high risk of bias and 13 were considered of high methodological quality with a low risk of bias. Weak external validity was apparent for most cross-sectional studies, with a paucity of random sampling (n = 39) and high nonresponse bias (n = 33) as leading factors. Lacking reliability and validity of outcome measures (n = 17) and inappropriate observed prevalence period (n = 14) were prominent factors of poor internal validity among cross-sectional studies. The three clinical trials reviewed ranged from low to moderate quality, all exhibiting high risk of bias for allocation concealment and blinding of participants.

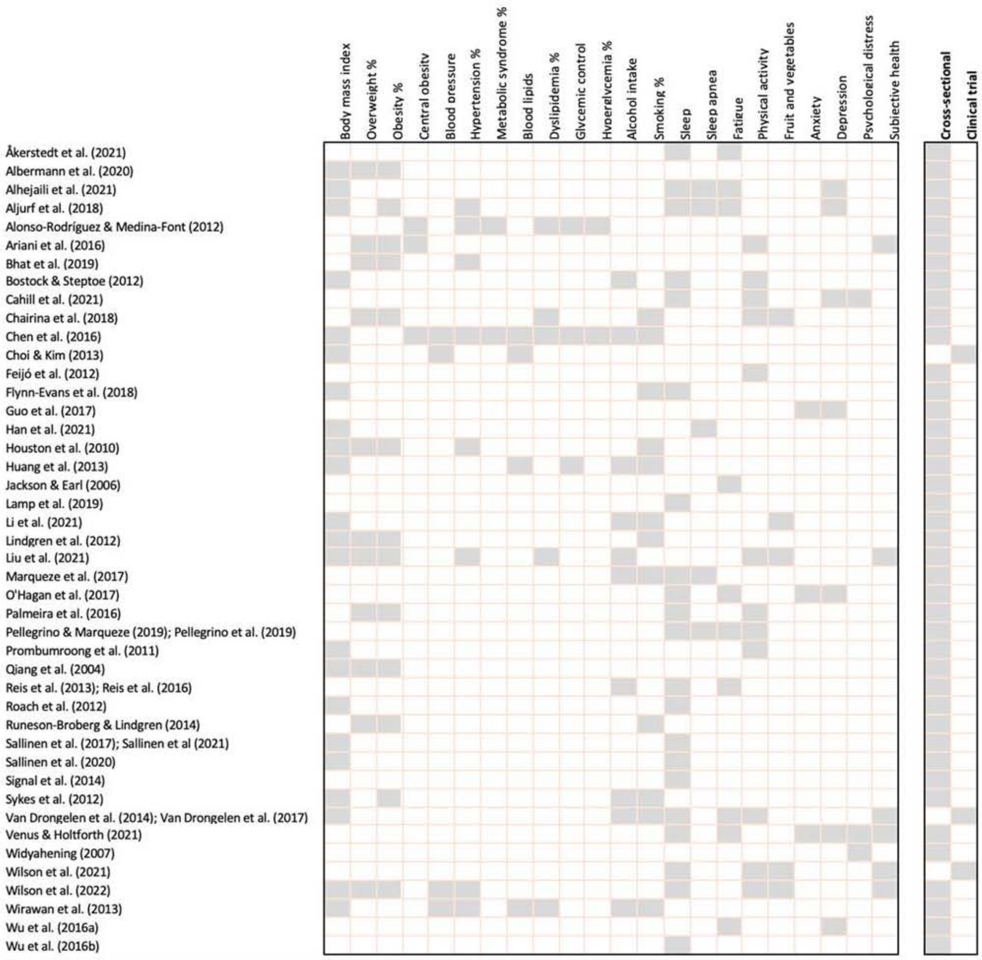

Figure 2. Cardiometabolic risk markers and airline pilot outcome summary for each study.

Table 2. Methodological quality scores of cross-sectional studies.

Author (Year)	External Validity				Internal Validity						
	1	2	3	4	5	6	7	8	9	10	Quality
Åkerstedt et al. (2021) [17]	N	N	N	Y	Y	Y	Y	Y	Y	Y	(3) High
Albermann et al. (2020) [18]	Y	Y	N	Y	Y	Y	N	Y	Y	Y	(2) High
Alhejaili et al. (2021) [19]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Aljurf et al. (2018) [20]	Y	N	N	N	Y	Y	Y	Y	Y	Y	(3) High
Alonso-Rodríguez and Medina-Font (2012) [21]	Y	Y	N	Y	Y	Y	Y	N	Y	Y	(2) High
Ariani et al. (2017) [22]	N	N	N	N	N	Y	N	Y	Y	Y	(6) Med
Bhat et al. (2019) [23]	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High
Bostock and Steptoe (2012) [24]	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Cahill et al. (2021) [25]	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Chairina et al. (2018) [26]	N	N	N	N	Y	N	N	N	Y	Y	(7) Low
Chen et al. (2016) [27]	Y	N	N	N	Y	Y	Y	Y	N	Y	(4) Med
Feijó et al. (2012) [28]	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High

Table 2. *Cont.*

Author (Year)	External Validity				Internal Validity						
	1	2	3	4	5	6	7	8	9	10	Quality
Flynn-Evans et al. (2018) [29]	N	N	N	Y	Y	Y	N	Y	Y	Y	(4) Med
Guo et al. (2017) [30]	Y	N	N	N	Y	Y	Y	Y	N	Y	(4) Med
Han et al. (2020) [31]	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Houston et al. (2010) [32]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	(1) High
Huang et al. (2012) [33]	N	Y	N	Y	Y	Y	N	N	N	Y	(5) Med
Jackson and Earl (2006) [34]	N	N	N	N	Y	Y	N	Y	N	Y	(6) Med
Lamp et al. (2019) [35]	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Li et al. (2021) [36]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Lindgren et al. (2012) [37]	Y	Y	N	N	Y	Y	N	Y	N	Y	(4) Med
Liu et al. (2021) [38]	N	Y	N	Y	Y	Y	N	Y	N	Y	(4) Med
Marqueze et al. (2017) [39]	Y	Y	N	N	Y	Y	Y	Y	Y	Y	(2) High
O'Hagen et al. (2016) [40]	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Palmeira et al. (2016) [41]	Y	Y	Y	N	Y	Y	N	Y	Y	Y	(2) High
Pellegrino and Marqueze (2018) [42]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Pellegrino et al. (2018) [43]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Prombumroong et al. (2011) [44]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Qiang et al. (2004) [45]	N	Y	N	Y	Y	Y	Y	Y	Y	Y	(2) High
Reis et al. (2013) [46]; Reis et al. (2016) [47]	Y	N	N	N	Y	Y	N	Y	Y	Y	(4) Med
Roach et al. (2012) [48]	N	N	N	N	Y	Y	Y	Y	N	Y	(5) Med
Runeson-Broberg and Lindgren (2013) [49]	Y	Y	N	N	Y	Y	N	Y	N	Y	(4) Med
Sallinen et al. (2017) [50]	Y	N	Y	Y	Y	N	Y	N	N	N	(5) Med
Sallinen et al. (2020) [51]	Y	N	N	Y	Y	N	Y	N	Y	N	(5) Med
Sallinen et al. (2021) [52]	N	N	N	N	Y	Y	N	Y	Y	Y	(5) Med
Signal et al. (2014) [53]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Sykes et al. (2012) [6]	Y	Y	N	N	Y	Y	N	Y	Y	Y	(3) High
Venus and Holtforth (2021) [54]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Widyahening (2007) [55]	N	N	N	N	Y	N	N	Y	N	Y	(7) Low
Wilson et al. (2022) [56]	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	(1) High
Wirawan et al. (2013) [57]	Y	Y	N	N	Y	Y	N	N	N	Y	(5) Med
Wu et al. (2016a) [58]	N	N	N	N	Y	Y	Y	Y	Y	Y	(4) Med
Wu et al. (2016b) [59]	Y	N	N	N	Y	Y	Y	Y	Y	Y	(3) High

Note: High = high quality (low risk of bias); Low = low quality (high risk of bias); Med = medium quality (moderate risk of bias); N, no; Y, yes; 1—Was the study's target population a close representation of the national population in relation to relevant variables, age, sex, and occupation? 2—Was the sampling frame a true or close representation of the target population? 3—Was some form of random selection used to select the sample OR was a census undertaken? 4—Was the likelihood of nonresponse bias minimal? 5—Were data collected directly from the subjects (as opposed to a proxy)? 6—Was an acceptable case definition used in the study? 7—Was the study instrument that measured the parameter of interest (e.g., prevalence of lower-back pain) shown to have reliability and validity (if necessary)? 8—Was the same mode of data collection used for all subjects? 9—Was the length of the shortest prevalence period for the parameter of interest appropriate? 10—Were the numerator(s) and denominator(s) for the parameter of interest appropriate?

Table 3. Risk-of-bias assessment of clinical trials.

Author (Year)	1	2	3	4	5	6	7
Choi and Kim 2013 [3]	High	High	High	High	Unclear	Low	Low
Van Drongelen et al. 2014 [60]; Van Drongelen et al. 2016 [61]	Low	High	High	High	Low	Low	High
Wilson et al. 2021 [62]	High	High	High	Low	Low	Low	Low

Note: 1 = random sequence; 2 = allocation concealment; 3 = blinding of participants; 4 = blinding of outcomes; 5 = incomplete outcome data; 6 = selective reporting; 7 = other; High = high risk of bias; Low = low risk of bias; Unclear = not possible to rate risk of bias.

3.4. Physiological Cardiometabolic Risk Factors among Pilots

Twenty-eight studies investigated physiological cardiometabolic risk factors. From the 22 studies reporting BMI, 12 were objectively measured and 10 were based on self-report data. The overall objectively measured BMI (n = 20,279) pooled mean was 26.1 $\pm$ 3.0 kg/m^2 and the overall subjective BMI (n = 3710) pooled mean was 24.7 $\pm$ 3.1 kg/m^2. For females, one study (n = 661) reported an objectively measured BMI of 23.9 kg/m^2 (20.0–27.7), and another (n = 32) reported a subjective BMI as 22.7 kg/m^2.

Eleven studies investigated the prevalence of overweight and obesity; five (n = 19,171) were objectively measured and six (n = 3309) were based on self-reporting from participants. The pooled mean for objective measures of overweight and obesity were 47.5% (47.4–47.5%) and 11.6% (11.6–11.7%), respectively. One study reported obesity only, revealing a prevalence of 20% [6]. The pooled mean for subjective measures of overweight and obesity was 43.6% (43.3–43.9%) and 12.4% (11.9–12.9%), respectively. The overall pooled prevalence of overweight plus obesity was 59.1% (59.0–59.2%) for objective measures and 56.0% (55.5–56.5%) for subjective measures. The combined pooled prevalence from subjective and objective measures for overweight, obesity, and overweight plus obesity was 46.8% (46.7–46.9), 11.7% (11.6–11.8%), and 58.6% (58.5–58.7%), respectively. One study [32] (n = 661) reported the prevalence of overweight and obesity for females as 28% and 6%, respectively. The prevalence of metabolic syndrome was reported by two studies, ranging from 15% [21] to 38% [27]. Furthermore, these studies reported objectively measured central obesity (>102 cm) prevalence as 18% [21] and 64% [27]. Only one study investigated C-reactive protein levels, reporting a mean hs-CRP serum level of 1.68 ± 1.79 (mg/L) [21].

Four studies (n = 16,327) reported the prevalence of hypertension (BP ≥ 140/90 mmHg) from objective measurement as 29% [32], 28% [27], 26% [56], and 11% [23], with a pooled prevalence of 27.6% (27.5–27.7%). Furthermore, one study (n = 303) reported the prevalence of elevated BP (≥130/85 mmHg) as 38% [21]. Derived from four studies [3,27,56,57], the objectively measured pooled mean systolic blood pressure (SBP) was 126 ± 14 mmHg, and the objectively measured pooled mean diastolic blood pressure (DBP) was 79 ± 9 mmHg. The prevalence of self-reported known hypertension of participants in three studies was 13% [20], 7% [38], and 6% [57]. One study reported the prevalence of objective hypertension for females as 14% [32].

HDL cholesterol and triglycerides were reported in four studies [3,27,33,57] (n = 1640), revealing pooled means of 1.3 ± 0.9 mmol/L and 19 ± 1.6 mmol/L, respectively. Additionally, three studies reported the prevalence of low HDL as 8% [21], 46% [27], and 57% [26] and of elevated triglycerides as 24% [21], 28% [27], and 29% [26]. The pooled mean of three studies [3,33,57] (n = 1337) reporting TC was 5.3 ± 1.0 mmol/L, and an LDL cholesterol mean of 3.3 ± 0.9 mmol/L was derived from two studies [3,33] (n = 742). The prevalence of self-reported known dyslipidemia of participants in two studies was 10% [57] and 19% [38]. Only two studies investigated hyperglycemia, reporting the prevalence as 31% [21] (≥100 mg/dL) and 30% [27] (≥5.6 mmol/L).

3.5. Behavioral Cardiometabolic Risk Factors among Pilots

Thirty-one studies included the evaluation of behavioral cardiometabolic risk factors. Alcohol intake was investigated in 10 samples of airline pilots [6,24,27,33,36,38,39,46,47,57,60,61]; one study utilized a validated questionnaire [36], and five studies [27,33,36,38,39] (n = 2538) ascertained "regular alcohol intake" on the basis of a participant self-recall question, producing a pooled prevalence of 52% (51.3–53.1). Twelve studies [6,26,27,29,32,33,36,37,39,49,57,60] (n = 19,116) reported smoking prevalence, yet no studies evaluated quantity or frequency of smoking. The pooled prevalence was 9.4% (9.3–9.5%). One study reported the prevalence of smoking for females as 6% [32].

From the 20 studies evaluating sleep, seven studies objectively measured sleep hours with actigraphy (n = 1764) [29,35,48,50–53,59], and six used self-recall methods (n = 2224) [17,24,39,56,59,62]. The pooled means for objective and self-recall sleep hours per night were 7.2 ± 1.1 and 7.0 ± 0.6, respectively. Three studies reported the prevalence of <6 h of sleep per night as 23% [43], 20% [61], and 22% [20]. Furthermore, other studies reported that <6 h of sleep per night was associated with obesity [41] and poor sleep quality [42] within participants. The prevalence of excessive sleepiness assessed by the Epworth Sleepiness Scale (score ≥ 10) was reported by five studies [19,20,39,42,46], exhibiting a pooled prevalence of 44.5% (44.1–44.8%). Among four studies reporting high obstructive sleep apnea (OSA) risk ascertained from the Berlin Questionnaire, the prevalence was 5% [19], 20% [39], 21% [42], and 29% [20], providing a pooled mean of 21.4% (21.3–21.5%).

The prevalence of self-reported insufficient physical activity (<150 min MVPA per week) was reported in five studies (n = 2233) providing a pooled prevalence of 51.5% (51.3–51.7%) [22,26,42,56,62]. Additionally, <150 min MVPA per week was found to be associated with obesity in one study which reported a prevalence ratio of 1.08 (0.98–1.19) [41]. One study reported the mean days per week of moderate physical activity and strenuous physical activity as 3.3 $\pm$ 1.9 and 2.0 $\pm$ 1.4, respectively. Another study reported the mean walking minutes and MVPA minutes per week as 110 $\pm$ 117 and 145 $\pm$ 72, respectively.

Three studies (n = 955) reported the prevalence of subjective insufficient daily fruit intake as 33% (<200 g/day) [38], 60% [56], and 65% (<2 servings/day) [62] and of insufficient daily vegetable intake as 19% (<300 g/day) [38], 47% [62], and 48% [56] (<3 servings/day). From these studies, two reported the prevalence of combined insufficient fruit and vegetable intake as 68% [56] and 84% [62]. One study reported the mean number of snacks per duty as 4 $\pm$ 3 [60].

3.6. Psychological Cardiometabolic Risk Factors among Pilots

Sixteen studies included an evaluation of psychological cardiometabolic risk factors. Among 10 studies investigating the prevalence of psychological fatigue, four studies (n = 2987) utilized the Fatigue Severity Scale (FSS), two of which reported a psychological fatigue prevalence (FSS $\geq$ 4 mean score) of 77% [54] and 89% [46,47]. Another two studies reported the severe psychological fatigue prevalence (FSS $\geq$ 36 total score) as 33% [19] and 68% [20]. The prevalence of elevated psychological fatigue in the remaining studies (n = 2719) was reported as 5% [58], 27% [42,43], 30% [60,61], and 75% [34], each produced with different methodology.

Seven studies subjectively measured the prevalence of depression, with a pooled mean of 21% (20.8–21.6) for mild depression derived from five studies [19,25,30,54,58] (n = 3411) utilizing the Patient Health Questionnaire (PHQ-9; score $\geq$ 10). One study reported a depression prevalence of 35% [20] according to the Hospital Anxiety and Depression Scale (score > 8), whereas another study reported depression or anxiety within the last 12 months as 54.4% [40]. One study reported mild depression (PHQ-9 score $\geq$ 10) prevalence in females as 11% [58]. Two studies (n = 2527) reported the prevalence of mild anxiety derived from the Generalized Anxiety Disorder-7 (GAD-7; score > 10) scale, noting 4% [30] and 7% [54]. The prevalence of below-average or poor subjective self-rated health was reported in three studies (n = 1282) as 8% [38], 25% [56], and 39% [22], each derived from different methodology.

4. Discussion

To our knowledge, this is the first comprehensive synthesis of published research pertaining to physiological, behavioral, and psychological cardiometabolic health risk factors among this unique occupational group. Our findings provide stakeholders including aviation medical professionals, policymakers, researchers, clinicians, and occupational health authorities with a scientific synthesis of the magnitude of prevalence of cardiometabolic health risk factors among commercial pilots. These findings may be beneficial to inform developments in aviation health practices and policies to support pilot health and wellness, to mitigate risks of occupational morbidity, medical conditions causing loss of license, and medical incapacity, and to support flight safety [5].

Findings from the review suggest similar health risk factor prevalence to the general population, yet higher sleep duration, less physical activity, lower smoking rates, higher regular alcohol consumption, less obesity, and a higher overall rate of body mass index >25 among pilots. We discovered, within the literature reviewed, a dominance of self-reported data, with most studies exhibiting moderate to high risk of methodological bias. Indeed, there are limited high-quality studies within the field, warranting the need for future research to address the gaps within and strengthen the body of knowledge.

4.1. Prevalence of Physiological Cardiometabolic Risk Factors among Pilots

As described by the International Civil Aviation Organization (ICAO) aviation medical regulations, cardiometabolic health risk data are acquired routinely during aviation medical examinations for pilots >35 years old for CVD risk assessment, which include BMI, BP, resting heart rate, blood lipids, and HbA1c [5]. In 2015, the global prevalence of overweight, obesity, and overweight plus obesity in the general population was reported as 38.7%, 16.4%, and 55.1%, respectively [63]. This general population estimate is relative to the country, age, and sex characteristics represented in the present review of studies conducted among pilots. Past research has reported a lower prevalence of overweight and obesity in pilots compared to the general population [6,64,65]. Indeed, the present review found that pilots had a 4.7% lower prevalence of obesity than the general population [63]. As obesity is a major risk factor for diseases such as CVD and T2D [66], the lower rate of obesity within pilots may promote a lower pilot population cardiometabolic disease relative risk compared to the general population.

Interestingly, with overweight and obesity pooled together, we discovered that pilots had an overall 3.5% higher rate of overweight plus obesity compared to the general population (58.6% and 55.1%, respectively). This finding suggests that past reports of lower rates of overweight and obesity within pilots [6,64,65] compared to the general population may be archaic, and future research should investigate the underlying causal mechanisms that contribute to overweight and obesity rates among pilots. A noteworthy consideration for interpretation of this information is the lack of random sampling and potential response bias within studies on pilots compared to the general population, which adds a notable limitation to the validity of prevalence comparisons between populations.

Most countries represented within the present review were high-income countries. In 2010, the global hypertension prevalence was estimated as 31.1% (30.0–32.2%), while that among high-income countries was estimated as 28.5% (27.3–29.7%) [67]. We found four studies reporting the prevalence of hypertension within pilots, ranging from 11% to 29% [23,27,32,56], with a pooled prevalence slightly lower than the general population at 27.6%. Airline pilots undergo regular medical examinations evaluating BP [5], and this regular active monitoring may promote the observed lower hypertension prevalence. However, one study reported a 38% [21] prevalence of pilots exhibiting elevated BP (≥130/85 mmHg); thus, it would be valuable for future epidemiological research to report the prevalence of elevated BP, accompanying hypertension rates in order to better inform researchers on the distribution of BP ranges across the pilot population.

Prospective epidemiological studies have consistently reported that unfavorable blood lipid profiles are associated with increased incidence of metabolic syndrome (MS) and NCDs such as CVD [68]. We found three studies reporting the prevalence of markers of dyslipidemia in pilots, with prevalence of low HDL ranging from 8% to 57% and of elevated TG ranging from 24% to 29% [21,26,27], whereas MS prevalence ranged from 15% [21] to 38% [27]. These evident variances in prevalence rates based on the small sample of studies ($n = 3$) [21,26,27] illustrate the need for further research to be conducted regarding quantification of these risk factors in pilots to reach valid inferences of their prevalence.

The global prevalence of diabetes is rising, and it has been estimated that 49.7% of people living with diabetes are undiagnosed [69]. Investigation of impaired glucose tolerance and hyperglycemia is scarce in the airline pilot literature, with only two studies reporting the prevalence of hyperglycemia (30.4–31.3%) [21,27] and scant research reporting on the prevalence of elevated HbA1c, which is the leading diagnostic criteria for T2D [69]. This dearth of information may be attributable to past barriers for diabetic pilots to operate commercials flights due to the risk of incapacitation from hypoglycemia while flying, yet recent advances in insulin therapies, monitoring techniques, and modes of administration have given rise to policy developments reducing barriers for diabetic pilots to operate commercial flights [70]. Seemingly, there is a need for more research attention on glycemic control and identifying the prevalence of elevated risk markers for T2D among airline pilots.

4.2. Prevalence of Behavioral Cardiometabolic Risk Factors among Pilots

From the 31 studies we found reporting on behavioral risk factors, sleep was the most frequently reported risk factor (n = 21). Sleep disruption is an inherent risk for pilots as occupational characteristics such as extended duty periods, work schedules, crossing time zones, and sleep restrictions cause perturbance of sleep routine consistency [71]. Recent research has indicated that sleep difficulty is frequently expressed as a primary source of work induced stress among pilots [25]. The present review found the mean pooled sleep hours per night to range from 7.0 h to 7.1 h, indicating that the population mean falls within the lower range of sleep guidelines for health in adults, which has been reported as the attainment of 7–9 h [72]. We found three studies reporting the prevalence of short sleep (<6 h) ranging from 20% to 23% [20,59,61], which is comparably lower than a USA-based study noting a prevalence of $\leq$6 h sleep as 29% among the general population in 2012 [73]. Indeed, due to the influence of fatigue on flight safety, pilots are often subject to fatigue management training via aviation medical management [71,74], facilitating the implementation of adaptive coping strategies to mitigate fatigue which may support the attainment of sleep guidelines within the population.

Past research has reported lower sex- and age-adjusted prevalence for smoking and higher levels of physical exercise among aircrews compared to the general population [65]. Indeed, we found a pooled smoking prevalence of 9% among pilots, which is considerably lower than a 2015 prevalence estimate of 25% for smoking among the global male general population [75]. Interestingly, for physical activity, we found a pooled prevalence of 51.5% for insufficient physical activity among pilots, which is markedly higher than a recent global prevalence estimate of 32% (30–33%) in 2016 among the general population within high-income countries [76]. However, our findings were only derived from four studies using self-recall data and small samples, making comparisons with the general population of scant validity. Future research utilizing objective outcome measures is important to further evaluate the accuracy of current findings.

Alcohol use is a leading risk factor for global disease burden, with the global prevalence of current drinking estimated as 47% in 2017 [77]. According to five studies we found, the pooled mean for regular alcohol intake among pilots was 52%. However, the lack of quantity and the low-quality methodology among studies minimize the validity of prevalence estimation. Furthermore, pilots may be inherently biased to misrepresent their true alcohol intake to aviation medical professionals or researchers due to aviation regulations prohibiting alcohol consumption within 8 h of acting as a crew member and existing alcohol testing mandates [78].

Dietary behaviors are a leading risk factor for obesity and cardiometabolic diseases such as CVD and T2D [79]. Previous studies have conveyed occupational factors such as inconsistent mealtimes, physical inactivity on duty, suboptimal airport and airline catering options, and shift work as factors that may be detrimental to healthy dietary patterns among pilots [6,7,21]. There is a dearth of literature pertaining to the quantification of dietary behaviors among pilots, with only two studies identified in this review reporting the prevalence of pilots who were not achieving daily fruit and vegetable intake guidelines of $\geq$5 servings ranging from 68–84% [56,62]. Although lacking validity, this estimate is comparable to the estimated global prevalence estimate of 79% derived from the World Health Survey 2002–2004 [80], relative to the country and sex characteristics represented in the present review.

4.3. Prevalence of Psychological Cardiometabolic Risk Factors among Pilots

High levels of psychological fatigue are associated with elevated risk of CVD and excess mortality within the general population [11] and are detrimental to a pilot's ability to safely operate the aircraft or perform safety-related duties [5]. We found the prevalence of elevated psychological fatigue to range from 5% to 77% [19,42,43,46,47,54,58,60,61] And of severe psychological fatigue to range from 33% to 68% [19,20]. The heterogeneity of methodology among studies within pilots inhibits valid comparisons with the general population. Nonetheless, with numerous studies reporting noteworthy rates of elevated psychological fatigue during nonduty periods, this warrants further research regarding the development of innovative interventions to better facilitate fatigue mitigation in this occupational group.

Major depressive disorder is associated with elevated cardiometabolic risk factors and poor health outcomes [12]. Depression and mental health issues among pilots have been proposed as contributing factors in numerous flight incidents resulting in mass casualties [40]. Thus, psychological risk factors are pertinent to pilot health and wellness and, in turn, flight operation safety. We discovered a pooled mean of 21% for mild depression [19,25,30,54,58] among pilots. Comparatively, a prevalence of 21% for mild depression was reported within a general population sample using congruent methodology, delineating a similar prevalence between populations.

4.4. Study Strengths

To the authors' knowledge there is no published scientific synthesis of cardiometabolic health risk factor data for airline pilots. The studies included in the systematic review were derived from 20 different countries from around the globe. Therefore, the findings are not localized to a certain region and are relevant data pertaining to the global airline pilot population. This review revealed insights that diverge from previous assumptions regarding cardiometabolic health among airline pilots, thus providing useful data which may inform public health practice and the development of targeted initiatives to support occupational health and safety.

4.5. Study Limitations

As this review sought to identify baseline nonwork duty-related prevalence of cardiometabolic health risk factors, we did not examine risk factor quantification during or immediately following flight duty periods, as these work characteristics often elicit acute inflated risk prevalence for factors such as psychological fatigue, sleep disruption, and other psychological distress-related parameters [39,52]. Thus, the present review did not capture the magnitude of work duty-induced perturbations to behavioral and psychological cardiometabolic health risks.

Furthermore, as we sought to identify the prevalence of cardiometabolic health risks among the overall airline pilot population, we did not stratify outcomes by fleet division, such as short-haul, long-haul, or mixed-fleet. The comparison of health risk prevalence between fleet divisions may be an appropriate scope for a future systematic review, which would add to the literature for understanding the magnitude of health risk difference between pilot rosters.

Due to the heterogeneity of publication dates among the literature featured in our review, the global general population prevalence comparison studies utilized may not optimally align with timepoints from studies among pilots and should be considered by readers with our presented population comparisons. Additionally, the heterogeneity of measurements of cardiometabolic parameters among the airline pilot studies reviewed and the general population estimates should be considered in the interpretation of our findings.

Lastly, the low quantity of robust studies limits the generalizability of the current findings reported within the literature. Future high-quality epidemiological research utilizing validated measurements will be valuable to increase the probability of attaining reliable conclusions pertaining to the health risk prevalence within the pilot population. To provide further meaningful insight into pilot cardiometabolic health risk and to address gaps in the literature, research attention pertaining to the assessment of glycemic control (i.e., HbA1c) and blood lipids, objectively measured health behaviors (dietary behaviors, physical activity, alcohol intake), and wider assessment of depressive symptoms among the airline pilot population would provide valuable contributions to advance the body of knowledge.

5. Conclusions

The findings of this review provide synthesis on the prevalence and magnitude of cardiometabolic health risk factors among airline pilots. A wide range of prevalence rates were reported for many investigated health risk parameters in the literature, with pervasiveness of overweight and obesity, insufficient physical activity, elevated psychological fatigue, insufficient fruit and vegetable intake, and regular alcohol consumption among pilots. The inherent bias, dominance of self-report data, and heterogeneity of methodology mean that it was not possible to establish strong conclusions. Future research utilizing objective measures and robust random sampling strategies are advocated to strengthen the validity of prevalence estimates and enhance the generalizability of findings.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interests.

Appendix A

Table A1. Summary of characteristics of studies that investigated cardiometabolic health risk parameters among airline pilots.

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Åkerstedt et al. (2021) [17]	Investigate associations among schedule, fatigue, and sleep	Cross-sectional; subjective; Sweden	n = 89; 76%; 38 ± 9 years	Fatigue (KSS) = 4.2 ± 1.8; sleep = 6.8 ± 1.4 h; sleep, duty time, and early starts are important predictors of fatigue in the 24 h window and that the number of very early starts and short sleep have cumulative effects on fatigue across a 7 day work period	Karolinska Sleepiness Scale; sleep duration self-report
Albermann et al. (2020) [18]	Evaluate the prevalence of lower-back pain compared with the general population	Cross-sectional; subjective; Germany	n = 698; 92%; 40 ± 9 years	BMI = 24.4 ± 2.7; overweight = 35% and obesity = 3.2%; chronic lower-back pain = 83%; time spent sitting during work = 90%	BMI (self-report); Oswestry Lower-Back Pain Disability Index
Alhejaili et al. (2021) [19]	Evaluate the presence of obstructive sleep apnea in pilots	Cross-sectional; subjective and objective; Saudi Arabia	n = 39; 100%; 43 ± 10 years	BMI = 24.5 ± 2.4; insomnia prevalence (AIS ≥ 6) = 31%; high risk of obstructive apnea = 5%; abnormal sleepiness = 23%; mild depression = 26%; moderate severity depression = 10%; suboptimal sleep quality = 39%; severe fatigue = 33%; VAFS abnormal fatigue = 23%	BMI; Athens insomnia scale (AIS); Berlin Questionnaire; Epworth Sleepiness Scale (ESS); Pittsburgh Sleep Quality Index (PSQI); Fatigue Severity Scale (FSS); Visual Analog Fatigue Scale (VAFS); Patient Health Questionnaire (PHQ-9)
Aljurf et al. (2018) [20]	Evaluate the prevalence of fatigue, depression, sleepiness, and the risk of obstructive sleep apnea	Cross-sectional; subjective; Arab states	n = 328; 99%; 41 ± 10 years	BMI = 27.6 ± 5.0; BMI ≥ 30 = 24%; Sleep <6 h = 22%; known hypertension = 13%; severe fatigue (FSS ≥ 36) = 68%; reported mistakes being made in the cockpit because of fatigue = 67%; ESS excessive sleepiness = 34%; high risk of OSA = 29%; depression (HADS ≥ 8) = 35%	Fatigue Severity Scale (FSS); Berlin Questionnaire; Epworth Sleepiness Scale (ESS); Hospital Anxiety and Depression Scale (HADS)
Alonso-Rodríguez and Medina-Font (2012) [21]	Evaluate C-reactive protein levels and the prevalence of metabolic syndrome	Cross-sectional; objective; Spain	n = 1009; 100%; 42 ± 11 years	elevated BP = 38%; hyperglycemia = 31%; elevated serum triglycerides = 24%; abdominal obesity = 18%; low HDL cholesterol = 8%; hs-CRP serum levels = 1.7 ± 1.8 mg/L; high hs-CRP incidence increased with age; metabolic syndrome (MS) prevalence = 15%; MS in pilots <35 years old = 4%; MS in pilots 35–50 years old = 14%; MS in pilots >50 years old = 29%; hs-CRP was significantly higher in pilots with MS than those without MS	Venous blood test; waist circumference; blood pressure; not all instruments specified
Ariani et al. (2016) [22]	Evaluate physical exercise habits and associated factors	Cross-sectional; subjective; Indonesia	n = 332; 100%; 20–29 years = 39%, 30–39 years = 23%, 40–49 years = 21%, 50–65 years = 16%	<150 MVPA min per week = 56%; overweight = 28% and obesity = 53%; central obesity = 46%; low or average SLS score (≤24) = 39%	BMI (self-report); Satisfaction with Life Scale (SLS); not all instruments specified
Bhat et al. (2019) [23]	Examine the prevalence of hypertension and obesity and their relationship	Cross-sectional; objective; India	n =1185; 89%; 35 ± 14 years	Overweight = 39% and obesity = 7%; hypertension = 11%	BMI; blood pressure

Table A1. *Cont.*

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Bostock and Steptoe (2012) [24]	Investigate work schedule influence on diurnal cortisol rhythm	Cross-sectional; subjective; the United Kingdom	n = 30; 100%; 20–29 years = 15%, 30–39 years = 41%, 40–49 years = 30%, 50–65 years = 15%	BMI = 25.6 ± 2.5; sleep = 8.2 ± 1 h; consumed alcohol on nonwork days = 52%; exercised >10 min on nonwork days = 28%	BMI (self-report); not all instruments specified
Cahill et al. (2021) [25]	Investigate the relationship among work-related stress, wellbeing, and coping mechanisms	Cross-sectional; subjective; international	n = 821; 88%; <25 years = 5%, 25–35 years = 27%, 36–45 years = 31%, 46–55 years = 26%, 56–65 years = 12%	Mild depression = 40%; moderate-severity depression = 4%; severe depression = 2%; regular exercise (≥3 times per week) = 25%; perceived regular sleep difficulties = 81%; regular work stress digestive symptoms = 59%; regular work stress induced psychosocial distress = 37%	Patient Health Questionnaire-9 (PHQ-9); Oldenburg Burnout
Chairina et al. (2018) [26]	Identify the risk factors associated with dyslipidemia	Cross-sectional; subjective and objective; Indonesia	n = 128; 100%; not reported	Overweight = 20% and obesity = 65%; <150 MVPA min per week = 71%; inappropriate or excessive food intake = 66%; smoking = 45%; dyslipidemia = 62%; elevated TG = 29%; elevated LDL = 47%; low HDL = 57%	Instruments not specified
Chen et al. (2016) [27]	Evaluate metabolic syndrome and periodontal disease status	Cross-sectional; objective; China	n = 303; 100%; 35 ± 8 years	BMI = 23.6 ± 2.6; smoking = 33%; regular alcohol drinker = 20%; metabolic syndrome =3 8%; elevated waist circumference = 64%, 87.6 ± 8.5 (cm); low HDL-C levels = 46%, 1.2 ± 1.9 (mmol/L); elevated fasting plasma glucose = 30%, 5.4 ± 0.6 (mmol/L); high systolic BP = 28%, 124 ± 11 (mmHg); elevated TG levels = 28%, 1.5 ± 0.8 (mmol/L); high diastolic pressure = 17%, 79 ± 7 (mmHg)	Venous blood test; saliva test; periodontal examination; blood pressure; waist circumference; BMI; Community Periodontal Index
Choi and Kim (2013) [3]	Evaluate the effects of physical examination and diet consultation on risk factors for CVD	Clinical trial; subjective and objective; Korea	n = 326; 100%; 30–39 years = 47%, 40–49 years = 33%, 50–59 years = 20%	TC > 220 mg/dL = 18%; TC (mg/dL) = 236 ± 13; HDL (mg/dL) = 51 ± 11; LDL (mg/dL) = 155 ± 16; TG (mg/dL) = 154 ± 81; BMI = 24.5 ± 2.1; weight (kg) = 73 ± 8; SBP (mmHg) = 118 ± 12; DBP (mmHg) = 76 ± 9	BMI; venous blood test; blood pressure
Feijó et al. (2012) [28]	Evaluate the prevalence of common mental disorders and related factors	Cross-sectional; subjective; Brazil	n = 807; 92%; 46 years	Regular physical activity practice = 61%; common mental disorders = 7%	Self-Reporting Questionnaire—20 items
Flynn-Evans et al. (2018) [29]	Investigate work schedule effects on neurobehavioral performance and sleep	Cross-sectional; subjective and objective; USA	n = 44; 91%; 31 ± 7 years	BMI = 24.2 ± 2.6; sleep = 6.8 ± 0.9 h; sleep latency 18%; sleep efficiency = 83%; smoking habit = 5%	Sleep diary; Psychomotor Vigilance Task; Samn–Perelli fatigue scale; actigraphy
Guo et al. (2017) [30]	Investigate the effects of emotional intelligence on depression and anxiety	Cross-sectional; subjective; China	n = 319; 100%; 31 ± 6 years	Mild depression = 24%; moderate depression = 1%; mild anxiety = 4%; moderate anxiety = 0.3%	Trait Meta Mood Scale; Proactive Coping Scale; The Patient Health Questionnaire (PHQ-9); Generalized Anxiety Disorder-7 (GAD-7)
Han et al. (2021) [31]	Investigate the occurrence of obstructive sleep apnea	Cross-sectional; subjective and objective; Korea	n = 103; 100%; 44 ± 8 years	BMI = 24.6 ± 2.1; neck circumference = 38 ± 2 (cm); OSA high risk = 32%	BMI; Epworth Sleepiness Scale (ESS); Berlin questionnaire; neck circumference; polysomnography; apnea–hypopnea index; oxygen desaturation index; respiratory disturbance index

Table A1. *Cont.*

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Houston et al. (2010) [32]	Identify the 10 year absolute CVD risk of pilots using a cardiovascular disease risk prediction model	Cross-sectional; subjective and objective; the United Kingdom	*n* = 14,379; 95%; not reported	BMI = 26.0 (male) and 23.9 (female); overweight = 47% (male) and 28% (female); obesity = 12% (male) and 6% (female); smoking = 8% (male) and 6% (female); hypertension = 29% (male) and 14% (female); population 10 year absolute CVD risk = 8% ± 7%; 10 year absolute CVD risk >20% (high risk) was 9% for males and 0% for females	BMI; blood pressure; not all instruments specified
Huang et al. (2013) [33]	Evaluate distribution of APOE gene polymorphism, dyslipidemia, and overweight	Cross-sectional; subjective and objective; China	*n* = 416; 100%; 39 ± 11 years	BMI = 24.2 ± 2.5; fasting glucose = 5.2 ± 0.6 (mmol/L); smoking = 54%; regular alcohol intake = 32%; total cholesterol = 4.6 ± 0.9 (mmol/L); LDL (mmol/L) = 2.8 ± 0.8; HDL = 1.3 ± 0.3 (mmol/L); TG = 1.6 ± 0.9 (mmol/L)	BMI; venous blood test; not all instruments specified
Jackson and Earl (2006) [34]	Evaluate fatigue prevalence	Cross-sectional; subjective; the United Kingdom	*n* = 162; 94%; 38 ± 9 years, range 21–59 years	Global CFS fatigue score = 18 ± 5; severe fatigue on the CFS = 75%; "fatigue worse than 2 years ago" = 81%; "feel tired with impaired judgement while flying?" = 80%; "concerned with the level of fatigue you experience?" = 78%	Chronic Fatigue Scale (CFS)
Lamp et al. (2019) [35]	Evaluate sleep timing and duration	Cross-sectional; subjective and objective; USA	*n* = 92; 84%; 51 ± 9 years	Sleep = 8.2 ± 1.7h	Actigraphy
Li et al. (2021) [36]	Investigate the prevalence of functional gastrointestinal disorders and associated triggers	Cross-sectional; subjective; China	*n* = 212; 100%; 34 ± 7 years	BMI = 23.8 ± 2.4, range 19–29; regular alcohol = 31%; smoking = 49%; functional gastrointestinal disorder prevalence = 39%	BMI (self-report); semi-quantitative food frequency questionnaire (SQFFQ)
Lindgren et al. (2012) [37]	Investigate associations among digestive symptoms and diet, insomnia, and lifestyle factors	Cross-sectional; subjective; Sweden	*n* = 354; 91%; 49 ± 6 years	Male BMI = 25.2; female BMI = 22.7; overall overweight = 41% and obesity = 4%; smoking = 5%	BMI (self-report); not all instruments specified
Liu et al. (2021) [38]	Investigate health-related quality of life and its related factors	Cross-sectional; subjective; China	*n* = 373; 100%; 35 ± 8 years	BMI = 23.8 ± 2.2; hypertension = 7%; dyslipidemia = 19%; overweight = 46% and obesity = 3%; smoking = 39%; regular alcohol intake = 38%; physical activity days per week = 2 (range 1–3); vegetable intake ≤300 g per day = 19%; fruit intake ≤200 g per day = 33%; self-rated health (very poor or poor) = 13%; self-rated quality of life (very poor or poor) = 8%; self-rated energy and fatigue (very poor or poor) = 6%	BMI (self-report); WHOQOL-BREF; not all instruments specified
Marqueze et al. (2017) [39]	Evaluate factors associated with unintentional sleep at work of airline pilots	Cross-sectional; subjective; Brazil	*n* = 1234; 97%; 39 ± 10 years	Smoking = 7%; regular alcohol = 75%; moderate alcohol intake = 24%; harmful use of alcohol = 1%; sleep 6.9 ± 1.2 h; unintentional sleep while on duty = 58%; sleep quality "fairly or very bad" = 11%; OSA high risk = 20%; excessive sleepiness = 42%	Alcohol Use Disorders Identification Test; Karolinska Sleep Questionnaire; Berlin questionnaire; Epworth Sleepiness Scale; Work Ability Index

Table A1. *Cont.*

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
O'Hagan et al. (2017) [40]	Investigate the differences in self-reported depression or anxiety	Cross-sectional; subjective; Europe	*n* = 701; 95%; not reported	Depression or anxiety in the past 12 months prevalence = 54%; working >41 h per week, sleep disruption, elevated fatigue, and being female were factors associated with higher probability of reporting feeling depressed or anxious in the last 12 months	Internally validated questionnaire
Palmeira et al. (2016) [41]	Identify the prevalence and associated factors of overweight and obesity	Cross-sectional; subjective; Brazil	*n* = 1198; 100%; 39 ± 10 years, range 21–67 years	Overweight = 54% and obesity = 15%; factors associated with obesity included ≤150 min of weekly physical activity, ≤6 h of sleep during days off, sleepiness, and time of being a pilot were associated with obesity	BMI (self-report); Karolinska Sleep Questionnaire
Pellegrino and Marqueze (2019) [42]; Pellegrino et al. (2019) [43]	Investigate the association of work organization and sleep aspects with work ability	Cross-sectional; subjective; Brazil	*n* =1234; 97%; 39 ± 10 years	<150 MVPA min per week = 50%; perceived insufficient sleep = 32%; excessive sleepiness = 43%; perceived of high fatigue = 27%; OSA high risk = 21%; poor sleep quality = 48%; poor sleep quality was associated with shift characteristics, being insufficiently physically active, and sleeping <6 h on days off.	Karolinska Sleepiness Scale; Berlin questionnaire; Epworth Sleepiness Scale; Yoshitake questionnaire; Work Ability Index; Job Stress Scale; Need for Recovery Scale
Prombumroong et al. (2011) [44]	Evaluate the prevalence of lower-back pain and associated factors	Cross-sectional; subjective; Thailand	*n* = 684; 100%; 40 ± 10 years	BMI = 24.3 ± 2.8; no regular exercise = 64%; lower-back pain in the last 12 months = 56%	BMI (self-report); Job Content Questionnaire Thai version (JCQ Thai version); Nordic questionnaire for lower-back pain
Qiang et al. (2004) [45]	Evaluate the association of body mass index with cardiovascular disease	Cross-sectional and prospective; subjective and objective; USA	*n* =3019; 100%; range 45–54 years	BMI = 27.2 ± 3.4; overweight = 55% and obesity = 7%; pilots who were overweight and obese had 6% and 22% higher CVD risk, respectively	BMI; blood pressure
Reis et al. (2013) [46]; Reis et al. (2016) [47]	Evaluate the prevalence of fatigue and compare the differences among fatigue, sleep, and labor specificities	Cross-sectional; subjective; Portugal	*n* = 456; 97%; 39 ± 8 years	Total fatigue prevalence (FSS ≥ 4) = 89%; JSS ≥ 4 = 35.0%; excessive sleepiness = 59%; alcohol intake >3 times per week = 1%	Internally validated questionnaire; Fatigue Severity Scale (FSS); Epworth Sleepiness Scale (ESS); Jenkins Sleep Scale (JSS)
Roach et al. (2012) [48]	Evaluate the impact of work schedule on the sleep and fatigue	Cross-sectional; subjective and objective; Australia	*n* = 19; 100%; 54 ± 2 years	BMI = 25.0 ± 2.4; sleep hours = 7.2 h	Samn–Perelli Fatigue Checklist; actigraphy; not all instruments specified
Runeson-Broberg and Lindgren (2014) [49]	Assess the prevalence of musculoskeletal symptoms	Cross-sectional; subjective; Sweden	*n* = 354; 91%; 31–40 years = 9%, 41–50 years = 61%, 51–60 years = 29%, 61+ years = 2%	Overweight = 41% and obesity = 4%; smokers = 5%	BMI (self-report); Nordic questionnaire for analyzing musculoskeletal symptoms
Sallinen et al. (2017) [50]; Sallinen et al. (2021) [52]	Evaluate and compare sleep patterns, sleepiness, and management strategies	Cross-sectional; subjective and objective; Finland	*n* = 477; 100%; 43 ± 7 years	BMI = 25.1 ± 2.9; sleep = 7 h 27 min ± 51 min	Actigraphy; Karolinska Sleepiness Scale; BMI (self-report)
Sallinen et al. (2020) [51]	Compare sleepiness ratings of airline pilot and truck drivers	Cross-sectional; subjective and objective; Finland	*n* = 33; 100%; 44 ± 7 years	Sleep = 7 h 48 min ± 56 min; BMI = 25.6 ± 3.6; KSS = 4.0	Actigraphy; Karolinska Sleepiness Scale; BMI (self-report); not all instruments specified
Signal et al. (2014) [53]	Evaluate the uptake and effectiveness of fatigue mitigation guidance material	Cross-sectional; objective; New Zealand	*n* = 52; 100%; 55 years	Sleep hours = 7.0 ± 1.2 h; sleep efficiency = 88 ± 5%	Actigraphy
Sykes et al. (2012) [6]	Compare the prevalence of medical conditions and risk factors with the general population	Cross-sectional; subjective and objective; New Zealand	*n* = 595; 97%; not reported	BMI = 27.1; obesity prevalence = 20%; smoking = 2%; alcoholic drink per week = 5.4	Instruments not specified

Table A1. *Cont.*

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Van Drongelen et al. (2014) [60]; Van Drongelen et al. (2017) [61]	Investigate the effects of an mHealth intervention to mitigate fatigue and determine risk factors for fatigue	Clinical trial; subjective; the Netherlands	n = 502; 93%; 41 ± 8 years	BMI = 24.1 ± 2.3; alcohol intake several days per week = 67%; smoking = 11.2%; CIS = 62 ± 22; moderate physical activity (days p/w) = 3.3 ± 1.9; strenuous physical activity (days p/w) = 2.0 ± 1.4; number of snacks per duty = 4.6 ± 3.6; sleep quality (1–20 scale) = 7.5 ± 3.9; sleep duration <6 h = 20%; health perception (1–5 scale, higher value denotes better health) = 3.4 ± 0.8; CIS fatigue prevalence = 30%	BMI (self-report); Checklist Individual Strength (CIS); Need for Recovery scale; Dutch Questionnaire on the Experience and Evaluation of Work; Jenkins Sleep Scale; Pittsburgh Sleep Quality Index; Short Form 36-item (SF-36) Health Survey
Venus and Holtforth (2021) [54]	Evaluate work schedule effects on fatigue risks on flight duty, stress, sleep problems, fatigue severity, wellbeing, and mental health	Cross-sectional; subjective; International	n = 406; 92%; 41 ± 11 years	PHQ stress = 5.0 ± 3.5; WHO5 PR (wellbeing) = 55 ± 20; PHQ-8 = 5.7 ± 4.4; SRQ-20 (common mental disorders) = 3.9 ± 4.0; Fatigue Severity Scale = 4.5 ± 1.0; Jenkins Sleep Scale = 2.0 ± 1.1; high fatigue = 33% and severe fatigue = 42%; PHQ8 ≥10 = 19%; GAD-7 = 3.9 ± 3.8; GAD7 ≥10 = 7.2%	Fatigue Severity Scale; Jenkins Sleep Scale; WHO5; Self-Reporting Questionnaire-20 (SRQ20); Patient Health Questionnaire (PHQ-8); Generalized Anxiety Disorder-7 (GAD-7)
Widyahening (2007) [55]	Identify the effect of work stressors and other factors on mental–emotional disturbances among airline pilots	Cross-sectional; subjective; Indonesia	n = 109; 100%; <40 years = 65%, >40 years = 56%	Mental–emotional disturbance = 39%; poor physical conditions, high work stressors, and household tension were associated with mental–emotional disturbance	Symptom Checklist 90 (SCL90) questionnaire
Wilson et al. (2021) [62]	Evaluate the efficacy of an intervention for enhancing health behaviors	Clinical trial; subjective; New Zealand	n = 79; 82%; 42 ± 12 years	Sleep = 7.2 ± 0.5 h; PSQI global score = 5.4 ± 2.7; weekly walking min = 110 ± 117; weekly MVPA min = 145 ± 72; <150 MVPA min per week = 49%; fruit and vegetable intake (servings/day) = 3.6 ± 0.9; <2 fruit (servings/day) = 65%; <3 vegetables (servings/day) = 47%; <5 fruit and vegetables (servings/day) = 84%; physical health score (SF-12v2) = 48 ± 7; mental health score (SF-12v2) = 51 ± 5	Pittsburgh Sleep Quality Index (PSQI); International Physical Activity Questionnaire (IPAQ) Short Form; Short Health Form 12v2 (SF-12v2); dietary recall
Wilson et al. (2022) [56]	Explore the prevalence and distribution of health risk factors in airline pilots and compare these with the general population	Cross-sectional; subjective and objective; New Zealand	n = 504; 91%; 46 ± 10 years	BMI = 26.6; overweight = 51%; obesity = 16%; SBP = 131 ± 13; DBP = 81 ± 9; hypertension = 27%; sleep <7 h = 34%; sleep = 7 h 11 min; weekly MVPA = 141 ± 87; insufficient physical activity = 48%; physical health score (SF-12v2) = 47 ± 6; mental health score (SF-12v2) = 49 ± 8; fruit and vegetable intake (servings/day) = 3.7 ± 1.7; <2 fruit (servings/day) = 60%; <3 vegetables (servings/day) = 48%; <5 fruit and vegetables (servings/day) = 68%; poor or fair self-rated health = 25%	International Physical Activity Questionnaire (IPAQ) Short Form; Short Health Form 12v2 (SF-12v2); dietary recall

Table A1. *Cont.*

Study (Year)	Aim of Study	Design; Data; Country	Sample; % Male; Age	Key Findings	Instruments
Wirawan et al. (2013) [57]	Investigate the prevalence of excessive CVD risk score	Cross-sectional; subjective and objective; Oceania	n = 595; 100%; 46 ± 12 years	BMI = 26.5 ± 4.0; smoking = 2%; alcohol consumption 5 ± 6 u/week; known hypertension = 6%; SBP = 128 ± 15; DBP = 78 ± 10; hyperlipidemia history = 10%; TC = 5.3 ± 1.1; HDL = 1.3 ± 0.5; TG = 1.1 ± 0.8; cholesterol–HDL ratio = 3.9 ± 1.4; pilots who were found to have 5 year CVD risk score of 10–15% or higher = 3.5%	Instruments not specified
Wu et al. (2016a) [58]	Investigate the prevalence of depression	Cross-sectional; subjective; international	n = 1826; 86%; not reported	13% of males and 11% of females met depression threshold; 4.1% reported suicidal thoughts within the past two weeks; 5% reported experiencing fatigue daily	Patient Health Questionnaire 9 (PHQ-9)
Wu et al. (2016b) [59]	Characterize sleep behaviors	Cross-sectional; objective; international	n = 332; 100%; 52 years, range 23–64 years	Sleep = 7.6 h (self-report) and 6.8 h (objective); sleep ≤ 6 h = 23%; sleep > 9 h = 1%	Actigraphy and self-report

Note: AIS = Athens Insomnia Scale; BMI = body mass index; BP = blood pressure; CIS = Checklist Individual Strength; CRP = C-reactive protein; CSF = Chronic Fatigue Scale; CVD = cardiovascular disease; DBP = diastolic blood pressure; ESS = Epworth Sleepiness Scale; FSS = Fatigue Severity Scale; GAD-7 = Generalized Anxiety Disorder-7; HADS = Hospital Anxiety and Depression Scale; HDL = high-density lipoprotein; IPAQ = International Physical Activity Questionnaire; JSS = Jenkins Sleep Scale; KSS = Karolinska Sleepiness Scale; LDL = low-density lipoprotein; mmHg = millimeters of mercury; MS = metabolic syndrome; MVPA = moderate-to-vigorous physical activity; OSA = obstructive sleep apnea; PHQ-8 = Patient Health Questionnaire 8; PHQ-9 = Patient Health Questionnaire 9; PSQI = Pittsburgh Sleep Quality Index; SBP = systolic blood pressure; SCL90 = Symptom Checklist 90; SF-36 = Short Form 36-item Health Survey; SLS = Satisfaction with Life Scale; SRQ20 = Self-Reporting Questionnaire-20; TG = triglycerides; VAFS = Visual Analog Fatigue Scale; WHOQOL-BREF = World Health Organization Quality of Life Brief Form.

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Chapter Three Publication Print

The prevalence and distribution of health risk factors in airline pilots: a cross-sectional comparison with the general population

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Abstract

Objective: To explore the prevalence and distribution of health risk factors in airline pilots and compare these with the general population.

Methods: Health risk measures: age, sex, weight, height, body mass index (BMI), blood pressure, sleep, physical activity (PA) and fruit and vegetable intake (FV) were analysed to determine the prevalence and distribution of health risk.

Results: Obesity prevalence and BMI was lower in pilots (p=<0.001, -17.5%, d=-0.41, and p=<0.05, -1.8, d=-0.37, respectively), yet overall overweight and obesity prevalence did not differ between groups (p=0.20). No difference was observed between groups for hypertension (p=0.79, h=-0.01), yet a higher proportion of pilots were 'at risk' for hypertension (p=<0.001, h=-0.34). The general population had longer sleep duration (p=<0.001, d=0.12), achieved more total PA minutes (p=<0.001, d=0.75), and had a higher prevalence of positive self-rated health (p=<0.001, h=0.31). More pilots achieved >5 servings of FV daily (p=0.002, h=0.16).

Conclusion: Pilots had lower obesity prevalence, higher FV, yet lower positive self-health ratings and total PA minutes, and shorter sleep duration overall.

Implications for public health: The results indicate notable health risk factor prevalence in airline pilots and the general population. Based on present findings, aviation health researchers should further examine targeted, cost-effective intervention methods for promoting healthy bodyweight, managing blood pressure, and enhancing health behaviours to mitigate the risks of occupational morbidity, medical conditions causing loss of licence, medical incapacity, and to support flight safety.

Key words: morbidity, non-communicable disease risk, health behaviour, overweight and obesity, hypertension, occupational health, diet, physical activity, sleep, subjective health

Generally, pilots are considered to have better health status than the general population,[1,2] however, work characteristics of professional airline pilots may present unique risks which may negatively impact health.[3-6] Pilots are subject to circadian disruption from shift work and irregular flight schedules, perceived fatigue, cosmic ionizing radiation exposure, irregular mealtimes, mental stress demands associated with flight safety, the sedentary nature of the job, and noise, vibration and air quality of the cabin environment.[1,3,7,8] Some evidence has indicated an elevated incidence for melanoma and kidney disease compared to the general population.[1,4] Further, noteworthy risk prevalence has been reported for back pain,[9] obesity,[2,5] metabolic syndrome,[10] physical inactivity,[8,11] poor sleep,[11,12] and depressive symptoms in pilots.[13]

In contrast, protective factors associated with being an airline pilot, such as socioeconomic status, the healthy worker effect and being subject to regular medical examinations, are thought to mitigate some health risks.[1,2] Indeed, based on some previous investigations,[1,2] pilots are generally considered to have a lower prevalence of non-communicable diseases (NCDs) and a lower risk for most health conditions than the general population. However, to date, there is a limited literature base pertaining to the quantification of behavioural risk factors in airline pilots and the distribution of health risk factors among different age groups.

Non-communicable diseases such as cardiovascular disease, cancer, chronic respiratory diseases and diabetes are the leading cause of mortality worldwide,[14] highlighting the importance of community integration of measures to counteract NCDs. With global strategic targets to reduce premature deaths from NCDs,[14] surveillance and quantification of health risks associated with NCD pathogenesis are vital to inform health initiatives to prevent, manage or treat NCDs.

The global obesity prevalence nearly doubled from 7% in 1980 to 13% in 2015.[15] Obesity is a complex, multifactorial and largely preventable physiological state that adversely affects nearly all functions of the body and comprises a significant public health threat

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and NCD risk.[15] Chronic high blood pressure is associated with numerous cardiovascular system pathologies and is a leading risk factor for global disease burden, with the worldwide prevalence of hypertension estimated as 31.1% in 2010.[16]

Sleep, nutrition and physical activity are each modifiable behavioural risk factors of chronic disease.[17] Obtaining adequate sleep, habitually consuming healthy dietary patterns and engaging in sufficient physical activity have a positive effect on physical and mental health,[8,17] significantly lower all-cause mortality and likely attenuate numerous NCD pathogenic processes.[18-20] Global prevalence of physical inactivity in 2016 was estimated as 27.5%, with an elevated rate of 42.3% in high-income Western countries.[21] Eighty-eight per cent of countries were estimated to be on average consuming insufficient vegetable intake in 2013,[22] and global figures indicated a decline in the average total number of hours of sleep obtained per night by adults.[23]

To date, the literature base pertaining to causal mechanisms between occupational factors and health outcomes in pilots is weak, and there is limited research quantifying the variance in health risk factor prevalence between pilots and the general population in New Zealand. The aim of this study is to explore the prevalence and distribution of NCD risk factors within airline pilots and compare these characteristics with an age and ethnicity matched general population representative sample.

Methodology

Design

A between-group, retrospective cross-sectional study was performed to evaluate the prevalence and distribution of health risk among airline pilots and the general population. This study examined health risk variables: age, sex, weight, body mass index (BMI), blood pressure, sleep duration, fruit and vegetable intake, physical activity levels and self-rated health. The outcome measures selected for this study were congruent with the 2018/19 New Zealand Health Survey (NZHS),[24] which was used to represent general population health risk data for comparison with pilots. This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand (reference number 2019#35).

Participants

The pilot population consisted of commercial pilots from an international airline. Five hundred and four pilots volunteered to participate in the study (see Table 1). Pilots were invited to participate in the study at the time of completing their routine aviation medical examinations between 5 November 2019 and April 2021. Participants were from a combination of short-haul and long-haul rosters (n=261 and 243, respectively). Inclusion criteria were pilots who had a valid commercial flying license and worked on a permanent basis. All participants provided written informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wish to do so. Age, sex and ethnicity adjusted means, confidence intervals, and prevalence rates for health measures in the general population (n=2,033) were derived from the 2018/19 NZHS dataset, a National annual health survey that utilises a geographic sampling strategy with weights representative of the resident population, which is detailed elsewhere.[24] Data were collected for the 2018/19 NZHS between 1 July 2018 to 30 June 2019. The NZHS micro-dataset was provided by Statistics New Zealand for analysis in this study.

Procedures

At the time of their aviation medical appointment, pilots were invited to participate in the study by completing an electronic health questionnaire via an iPad (Apple, California, CA, USA) and providing consent to allow the researchers to access their anonymised aviation medical cardiovascular risk factor data. The electronic survey was constructed in Qualtrics software (Qualtrics, Provo, UT, USA) and consisted of questions about demographic information and health risk factor measures for sleep, nutrition, physical activity, and self-rated health. To support anonymity and dataset blinding during data analysis, participants were provided with a unique identification code on their informed consent form and were instructed to input it into their electronic survey instead of their name. Objective health risk measures for bodyweight and blood pressure were recorded by a clinical aviation medical professional during the pilot's aviation medical examination. All data from the NZHS were collected during interviews conducted at the respondent's home, which were carried out by a specialist survey provider contracted by the Ministry of Health.[24]

Outcome measures

Age at the date of response was calculated using date of birth. Measurements of height for pilots were recorded with a SECA 206 height measure and bodyweight was measured using SECA 813 electronic flat scales (SECA, Hamburg, Deutschland). In the NZHS, measurements for weight were recorded using Tanita HD-351 electronic weighing scales (Tanita, Tokyo, Japan) and height was recorded using laser height measurement.[25] For bodyweight measurement, scales were placed on a hard, flat surface and participants were wearing clothes and were asked to stand in the centre of the scales with their arms loosely by their sides and weight distributed on both feet. Two weight measurements were made to the nearest 0.1 kg. If the two measurements differed by more than 1%, a third measurement was made. The final weight measurement for each participant was calculated by averaging the two closest measurements. Data on height and weight were used to calculate body mass index (BMI), which was used to identify the proportion of participants who were underweight, a normal weight, overweight, or obese, as determined by scores of <18.5, 18.5–24.9, 25–29.9, and >30 (kg/m²), respectively.[2,24]

Table 1: Demographic characteristics of the study populations.

Parameters	All subjects (n=2,537)	Pilots (n=504)	NZHS (n=2,033)
Sex (f/m)	44/2,547	44/460	0/2,033
Age (y)	46 ± 11	46 ± 10	46 ± 12
Caucasian (f/m)	44/2,481	44/448	0/2,033
Māori (f/m)	0/3	0/3	0/0
Indian (f/m)	0/7	0/7	0/0
Asian (f/m)	2/1	2/1	0/0

Notes:
Mean ± SD reported for age, total values are reported for all other variables.
Abbreviations: SD = standard deviation. f = female. m = male. NZHS = New Zealand Health Survey.

Measurements of blood pressure in pilots were conducted according to a standardised aviation medicine protocol.[26] Two blood pressure readings were measured with an OMRON HEM-757 device in a sitting position with the arm supported and held at the level of the atria. If the two initial readings were <140/<90, the lowest reading was recorded. If levels were >140/>90, two further readings at intervals of several minutes were taken. Measurements of blood pressure in the NZHS were made using standardised protocol[25] using an OMRON HEM-907 device, which automatically records heart rate, and systolic and diastolic blood pressure three times, with a one-minute pause between measurements. Blood pressure ranges were classified 'normal', 'at risk', and 'hypertension' as determined by values (systolic/diastolic) <120/<80, 120–139/80–89, and >140 and/or >90, respectively.[27]

Physical activity levels were assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF), a validated self-report measurement tool of moderate-to-vigorous physical activity (MVPA) that has been widely used in large cohort studies including the NZHS.[25] The IPAQ-SF estimates physical activity achievement by quantifying weekly walking, and moderate and vigorous physical activity duration and frequency. IPAQ-SF outcome measures derived were total weekly minutes of moderate and vigorous physical activity (MVPA) in bouts of ≥10 min, excluding walking, and total weekly minutes of walking in bouts of ≥10 min. Responses were capped at 3h/day and 21 h/week as recommended by IPAQ Guidelines.[28] Physical activity guidelines for health are >150 minutes moderate-intensity, or 75 minutes vigorous-intensity, or an equivalent combination MVPA per week.[29] Responses from the IPAQ were used to identify proportions of participants who were either obtaining little or no physical activity (<30 min MVPA), insufficient physical activity (30–149 min MVPA), sufficient physical activity (150–299 min MVPA), or exceeding guidelines (>300 min MVPA).

Fruit and vegetable intake was measured using two questions with acceptable validity and reliability derived from the New Zealand Health Survey.[25] The questions asked participants to report on average, over the past week how many servings of fruit and vegetables they had eaten per day. Showcards were used to help improve respondent engagement and the accuracy of their responses.[30] Responses to these questions were used to determine the proportion of participants who achieved daily intake health guidelines of ≥2 fruit servings, ≥3 vegetable servings, and ≥5 fruit and vegetable servings combined.[18]

Average self-reported sleep duration was measured via one question which asked how much sleep the respondent usually got in a 24-hour period, during the last month. Responses from this question were used to identify the proportion of participants who achieved health guidelines of ≥7 hours of sleep per night.[19]

Prospective cohort research suggests self-report health to be strongly associated with mortality risk and provides clinical and epidemiological value.[31] Subjective self-rated health was measured using the questions derived from the Short Health Form 12v2 (SF-12v2), a short version of the SF-36 that has demonstrated a high correlation with SF-36 scores[32] and good test-retest reliability and convergent validity to detect changes in mental and physical health in adults.[33] Responses were used to determine the responses for two discrete categories: a) poor or fair self-rated health; and b) good, very good or excellent self-rated health. All self-report health measures were congruent with those reported in the NZHS.

Statistical analysis

The NZHS data presented was age, sex and ethnicity adjusted to match the pilot population data. We reported absolute numbers, percentages, 95% confidence intervals (CIs), or means with standard deviations (mean ± SD). We calculated the prevalence and Clopper-Pearson binominal 95% CIs (exact method) for health risk measures and derived comparative values of the general population from the NZHS dataset. Additionally, we calculated the distribution by age group for each health risk. Subjects were categorised into age groups: 25–34, 35–44, 45–54 and 55–64 years, which were congruent with the NZHS data reporting. Adult age groups 18–24 and ≥65 years were not included in this study due to no pilot respondents within these age groups. Age-specific incidence rates among pilots were compared with corresponding rates in the general population of the NZHS.

Mean values for all outcome measures for each pilot age group was compared with the mean value for the corresponding age-sex-ethnicity adjusted group of the general population using a factorial analysis of variance (ANOVA). Health risk prevalence comparisons of significance between populations were performed with a Chi-squared test. To evaluate magnitude of differences, effect sizes were produced using Cohen's *h* for proportions and Cohen's *d* for means.[34] The magnitude of each effect size was interpreted using thresholds of 0.2, 0.5 and 0.8 for *small*, *moderate* and *large*, respectively.[34] The α level was set at a *p*-value of less than 0.05.

Raw data from survey responses were extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into statistical software SPSS v24 for Windows (IBM, New York, NY, USA) and MedCalc Statistical Software v20 (MedCalc, Ostend, Belgium, https://www.med-calc.org). Listwise deletion was applied for individual datasets with missing values or participants who did not complete all electronic survey components.

Results

The pilot population was heavily skewed towards male sex (91.2%) and Caucasian ethnicity (97.4%), which excluded analysis of data on female pilots and non-Caucasian ethnicities due to inadequate sample size to detect meaningful inferences for these subgroups. Similar demographic trends have been published in previous studies within commercial pilots.[1,2] Therefore, from the 504 pilots who volunteered to participate in this study, 460 were included in the data analysis, which represents approximately 33% of the pilot population within the airline. From the 13,572 adult responses available in the NZHS 2018/19, data from 2,033 general population participants were included in our analysis after adjustment for age-sex-ethnic demographics of the pilot population. According to the NZ Census 2018,[35] this sample represents 0.25% of the male Caucasian population in NZ between the ages of 25–64 years. The NZHS recruited participants evenly among the age groups, whereas the age distribution of the airline pilots was more reflective of a working population, with fewer pilots in the youngest and oldest age groups.

The health risk characteristics among pilots and the general population are given in Table 1 and comparison of health risk prevalence between groups are presented in Table 2.

Table 2: Demographic and health risk characteristics among airline pilots and the general population.

	Airline pilots (n=460)				General population (n=2,033)							
	25-34y (n=68)	35-44y (n=134)	45-54y (n=153)	55-64y (n=105)	25-34y (n=433)	ES	35-44y (n=438)	ES	45-54y (n=527)	ES	55-64y (n=635)	ES
Objective measures												
Height (cm)	182 (181–184)	181 (180–182)	180 (179–181)	179 (178–180)	178 (178–179)**	0.60	179 (178–179)*	0.27	178 (177–178)**	0.45	176 (175–176)**	0.48
Weight (kg)	86 (82–90)	86 (84–88)	88 (86–90)	87 (85–89)	88 (86–89)	-0.07	90 (88–91)*	-0.21	91 (89–93)*	-0.19	90 (88–91)	-0.17
BMI (kg/m2)	25.9 (25–27)	26.3 (26–27)	27 (26–27)	27 (27–28)	28 (27–28)*	-0.33	28 (28–29)**	-0.35	29 (28–29)**	-0.38	29 (28–30)**	-0.40
Systolic BP (mmHg)	129 (126–132)	129 (127–131)	131 (129–133)	136 (133–138)	126 (125–127)	0.19	126 (125–127)*	0.23	130 (128–131)	0.08	135 (134–137)	0.02
Diastolic BP (mmHg)	76 (74–78)	80 (78–80)	83 (81–84)	84 (83–86)	74 (73–75)	0.17	76 (75–77)**	0.33	80 (79–81)*	0.24	80 (79–81)**	0.41
Average BP (mmHg)	102 (100–105)	104 (103–106)	107 (105–108)	110 (108–112)	100 (99–101)	0.20	101 (100–102)*	0.29	105 (104–106)	0.16	107 (106–109)	0.18
Subjective measures												
Sleep (hours)	7.3 (7.1–7.5)	7.1 (7.0–7.2)	6.9 (6.8–7.1)	7.0 (6.9–7.2)	7.4 (7.3–7.5)	-0.08	7.1 (7.0–7.2)	-0.06	7.2 (7.1–7.3)*	-0.19	7.1 (7.0–7.2)	-0.07
Total PA (min)	219 (194–245)	217 (199–235)	220 (201–239)	204 (185–224)	1,001 (899–1103)**	-0.78	919 (816–1022)**	-0.73	859 (775–943)**	-0.74	872 (799–945)**	-0.77
Health "Excellent" (n,%)	1 (1.5%)	2 (2%)	2 (1%)	2 (2%)	42 (10%)	-0.39	53 (12%)	-0.46	49 (9%)	-0.39	73 (12%)	-0.42
Health "Very good" (n,%)	17 (25%)	22 (16%)	13 (9%)	11 (11%)	196 (45%)	-0.43	164 (37%)	-0.48	217 (41%)	-0.80	221 (35%)	-0.60
Health "Good" (n,%)	39 (57%)	81 (60%)	95 (62%)	59 (56%)	142 (33%)	0.50	167 (38%)	0.45	191 (36%)	0.52	249 (39%)	0.34
Health "Fair" (n,%)	10 (15%)	25 (19%)	37 (24%)	29 (28%)	48 (11%)	0.11	46 (11%)	0.23	60 (11%)	0.34	66 (10%)	0.45
Health "Poor" (n,%)	1 (1.5%)	4 (3%)	6 (4%)	4 (4%)	5 (1%)	0.03	8 (2%)	0.08	10 (2%)	0.12	26 (4%)	-0.02

Notes:

Data are means with Copper-Pearson 95% CIs in parentheses or counts and percentages in parentheses.

** indicates statistical significance (p < 0.05). ** indicates statistical significance (p < 0.001).*

Abbreviations: n = sample size. BMI = Body Mass Index. PA = Physical Activity. Total PA = combined weekly walking, moderate and vigorous physical activity minutes. BP = Blood Pressure. Average BP = systolic/diastolic. ES = Effect Size (Cohen's d for means and Cohen's h for percentages).

On average, pilots were significantly taller (p=<0.05, d=0.45) and had a lower BMI across all age groups (p=<0.05, d=0.37). Further, pilots had shorter sleep duration in age group 45–54 (p=<0.05, d=-0.19), higher average blood pressure in age group 35–44 (p=<0.001, d=0.29), and lower total weekly PA minutes across all age groups (p=<0.001, d=0.74-0.78), see Table 1.

The prevalence and distribution of health risk factors between pilots and the general population across age groups are depicted in Figure 1. Both groups had an increase in the prevalence of overweight and obesity, hypertension, short sleep, and poor and fair self-rated health with increased age (Figure 1). Pilots had significantly lower (p=<0.001, d=-0.41) prevalence of obesity across all age groups (Figure 2). Overall, the difference between the prevalence of overweight and obesity was not statistically significant between the general population and pilots (p=0.20, 74.5% and 66.8%, respectively).

The prevalence of hypertension did not significantly differ between groups overall (p=0.79, h=-0.01). A significantly higher proportion of pilots were 'at risk' for hypertension (p=<0.001, h=-0.34). For the age group 35-44 years, pilots had significantly higher prevalence of hypertension (p=<0.001, h=0.16), whereas pilots aged 55–64 had a significantly lower prevalence (p=0.03, h=-0.11).

Overall self-report sleep duration was higher in the general population compared to pilots (p=<0.001, d=0.12, 7h 3.6min and 7h 11.4min, respectively). The proportion of participants who achieved >7 hours of sleep per night was higher in the general population compared to pilots overall (p=0.12, 75.5% and 66.5%, respectively) and was significantly higher for age groups 25–34, 45–54, and 55–64 (p=<0.05, h=0.32, 0.20, 0.14, respectively).

More pilots achieved >5 servings of self-report fruit and vegetables daily compared to the general population (p=0.002, h=0.16). Total self-report PA weekly minutes were significantly higher in the general population across all age groups (p=<0.001, d=0.74-0.78), yet there was no overall significant difference in the prevalence of achieving >150 min MVPA per week (p=0.22, h=0.11).

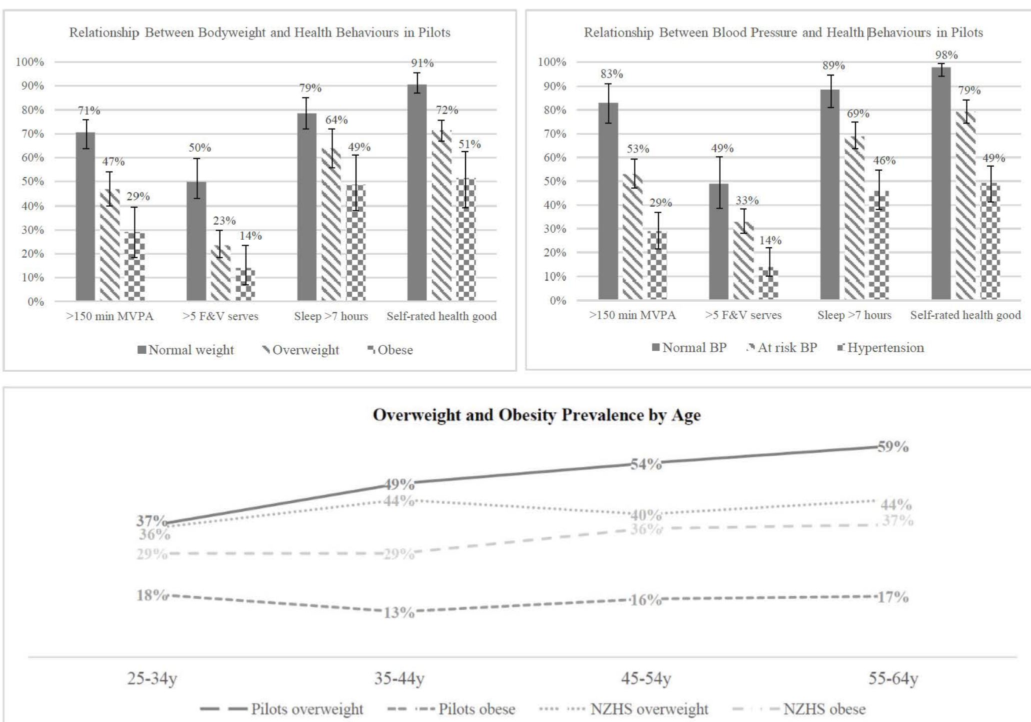
The prevalence of self-rated health being 'good', 'very good' or 'excellent' was significantly higher in the general population compared to pilots (p=<0.001, h=0.31), with the prevalence of 'poor' or 'fair' ratings increasing with age in both groups.

disease incidence than that of the general population. Previous studies have proposed potential protective factors that may contribute to the mitigation of adverse health outcomes in pilots, including the healthy worker effect, pilots being subject to regular medical examinations and socioeconomic status.[1,39]

To our knowledge, hypertension incidence has not been previously reported for NZ pilots. Within UK pilots, a significantly higher prevalence of hypertension was reported for males in age groups <25 and 35–44 years, with significantly lower rates in age groups 45–54 and 55–64, compared to the general population.[2] We found an overall pilot population hypertension prevalence of 26.5%, and higher rates of hypertension in pilots across ages 25–54 years compared to the general population, yet only the 35–44 age group was statistically significant. Comparatively, this incidence rate is lower than previously reported hypertension rates of 28.3% in Chinese pilots,[10] 28.7% in UK pilots[2] and 38% in Spanish pilots.[37] Conversely, a much lower hypertension rate of 4.1% was reported in a sample of Indian pilots.[36]

A limited number of studies have reported sleep duration, dietary behaviours and physical activity within airline pilots and there are no studies comparing these health behaviours of pilots with the general population. There is a dearth of literature pertaining to the distribution of sleep duration among different pilot age groups. We found 66.5% of pilots overall achieved ≥7 hours of sleep, which was 9% lower than the general population. Further, we observed sleep duration decreased with increased age in both groups, which is consistent with previously reported age-associated degradation of sleep quality and quantity.[40] Pilots had an average sleep duration of 7 hours and 4 minutes overall, with no difference to the general population for age groups below 45 years, however, a reduced sleep duration in age groups >45 years compared to groups younger than 45 was noted, which was significantly lower than the general population. Indeed, a previous study identified >64% of pilots achieve less than 7 hours of sleep per night on average during off-duty periods.[11] Whereas, another study objectively measured sleep and reported 23% of pilots averaged <6 hours of sleep habitually.[12] Sleep disruption is an inherent risk for pilots, who have occupationally induced perturbations to the natural circadian rhythm, including shift work, extended duty periods, travelling across time zones, sleep restrictions associated with short layovers, regularly changing work/rest schedules, and regular changes in the sleeping environment (for example, at home, onboard, and in hotels),[41,42] all of which may contribute to lower sleep duration in contrast to the general population. Furthermore, long-haul pilots often do not follow a normal

Figure 2: Health risk trends within airline pilots.



Notes:

Data are expressed as prevalence percentage of the overall population.

F&V = Fruit and Vegetable serves.

The "underweight" bodyweight category was omitted from Chart 1 due to insufficient sample size for this subgroup (n=4).

Discussion

To our knowledge, no previous studies have explored physical, health behaviour and self-report health risk factors together in an independent cross-sectional study among airline pilots, nor have any studies compared health behaviour characteristics in this occupational group with the general population. Some of our findings about demographic and health risks were identified that are consistent with past research in pilots. These included a high proportion of male pilots compared to females,[1,2] pilots having lower incidence of a BMI exceeding 25 (overweight and obesity),[1,2] and notable prevalence of risk factors for sleep,[11,12] nutrition,[8] and physical activity.[5,8] Our research adds preliminary quantification of the prevalence of hypertension in NZ pilots and behavioural health risk factors of sleep duration, fruit and vegetable intake and physical activity in pilots, which to date have been largely unexplored in the literature.

Studies have previously examined cardiovascular disease-related health risk factors within commercial pilots. Past research in NZ pilots identified the mean BMI as 27.1 and obesity incidence as "almost 20%".[1] Comparatively, we found an overall lower mean BMI of 26.6 and an obesity prevalence of 15.7%. Overall, we found pilots had a significantly lower prevalence of obesity than the general population. Similarly, a previous cross-sectional UK-based study reported significantly lower overweight and obesity in pilots (46.8% and 12.4%, respectively) compared to the general population (47% and 21%, respectively), with a significantly lower overall mean BMI in pilots.[2] The prevalence in other countries have been reported as 39%[36] and 53.7%[37] for overweight, and 7.3%[36] and 14.6%[37] for obesity in Indian and Spanish pilots, respectively.

In the present study, an evident trend across age groups were statistically significant higher rates of overweight and lower rates of obesity in pilots compared to the general population, which is congruent with previous research.[2] Thus, although the overall prevalence of overweight and obesity was not significantly different to the general population, fewer pilots were categorised as obese, which is associated with increased NCD risk compared to those who are <29 BMI.[38] Consequently, the pilot population may have a lower risk of obesity-related

Figure 1: Comparison of health risk prevalence in between airline pilots and the general population.

Notes:
Data are expressed as prevalence percentage of the overall population by age group.
F&V = Fruit and vegetable serves.
** indicates statistical significance (p < 0.05); ** indicates statistical significance (p < 0.001).*
Confidence intervals are presented for all data.

day/night sleep pattern with a single long sleep at night, as do the general population. For example, a long-haul pilot may have a pre-flight nap, potentially multiple short periods of sleep in the crew bunk during the flight (1 to 2 hours), and then a 4–5-hour post-arrival sleep, followed by an overnight sleep on subsequent layover nights and then repeating the process on the return leg. Thus, self-report questions pertaining to average sleep in a 24-hour period may be difficult to interpret for pilots and may influence the overall average sleep duration reported.

Occupational duties of airline pilots involve prolonged periods of sedentary time sitting in the cockpit and at airports.[1,5] Insufficient physical activity is a prevalent source of work-related stress,[13] and indeed, lower levels of physical activity are associated with daytime sleepiness and fatigue in pilots.[7] Our study is the first to explore the proportion of pilots attaining the World Health Organization's MVPA guidelines[29] compared with the general population. Fifty-one per cent of pilots achieved ≥150 min MVPA per week, compared to 57.6% in the general population, indicating nearly half of the overall population in both groups were not sufficiently physically active. These findings are similar, yet higher than a previously reported 42.3% global estimate of physical inactivity in high-income Western countries.[21] Three previous studies have reported weekly physical activity on average, to be <150 minutes of MVPA per week within pilot populations,[5,8,43] whereas two other studies reported days per week achieving ≥30 minutes of moderate activity as 3.2 to 3.4 days per week.[7,11] To date, the limited evidence base suggests low rates of physical activity in pilots, yet no research has critically examined the validity of self-report physical activity measurements compared to objective measures such as accelerometry in pilots.

Work-related characteristics of pilots including irregular and long duty periods, perceived fatigue, disrupted sleep and unhealthy food availability in the work environment may affect dietary behaviour.[1,3,13] Our study is the first to explore the proportion of pilots who achieve the widely advocated health behaviour of consuming ≥5 servings of fruit and vegetables per day for health risk reduction benefits.[18] A previous study in a small sample (n=79) of NZ based airline pilots reported an average of 3.6 servings of fruit and vegetable per day,[8] yet extremely few published studies have addressed dietary behaviours in pilots.

Table 3: The prevalence of health risk factors among airline pilots and the general population overall.

	Pilots (n=460)	NZHS (n=2,033)	*p* value	Effect size (Cohen's h)	OR (95% CI)
Bodyweight					
Underweight BMI	4/460 (0.9%)	11/2,033 (5.0%)	0.411	0.16	1.60 (0.50–5.06)
Normal weight	149/460 (32.4%)	515/2,033 (25.3%)	0.002	0.16	1.27 (1.03–1.57)
Overweight	235/460 (51.1%)	833/2,033 (41.0%)	<0.001	0.20	1.24 (1.03–1.48)
Obese	72/460 (15.7%)	674/2,033 (33.2%)	<0.001	-0.41	0.47 (0.36–0.61)
Blood pressure					
Normal	88/460 (19.1%)	745/2,033 (36.6%)	<0.001	-0.39	0.52 (0.40–0.66)
At risk	250/460 (54.3%)	758/2,033 (37.3%)	<0.001	0.34	1.45 (1.22–1.73)
Hypertension	122/460 (26.5%)	527/2,033 (25.9%)	0.791	0.01	1.02 (0.81–1.27)
Sleep					
<5 hours per night	0/460 (0.0%)	45/2,033 (2.2%)	0.001	-0.30	0.04 (0.00–0.78)
5-6 hours per night	3/460 (0.7%)	93/2,033 (4.6%)	<0.001	-0.26	0.14 (0.04–0.45)
6-7 hours per night	151/460 (32.8%)	360/2,033 (17.7%)	<0.001	0.35	1.85 (1.49–2.29)
7-8 hours per night	263/460 (57.2%)	697/2,033 (34.3%)	<0.001	0.46	1.66 (1.40–1.98)
8-9 hours per night	39/460 (8.5%)	666/2,033 (32.8)	<0.001	-0.63	0.25 (0.18–0.36)
>9 hours per night	4/460 (0.9%)	172/2,033 (8.5%)	<0.001	-0.40	0.10 (0.03–0.27)
Nutrition					
<2 fruit servings	277/460 (60.2%)	1,156/2,033 (56.9%)	0.189	0.07	1.05 (0.89–1.24)
>2 fruit servings	183/460 (39.8%)	877/2,033 (43.1%)	0.189	-0.07	0.92 (0.76–1.11)
<3 vegetable servings	220/460 (47.8%)	1,069/2,033 (52.6%)	0.065	-0.10	0.90 (0.76–1.08)
>3 vegetable servings	240/460 (52.2%)	964/2,033 (47.4%)	0.065	0.10	1.10 (0.92–1.30)
<5 fruit and vegetable servings	313/460 (68.0%)	1,524/2,033 (75.0%)	0.002	-0.16	0.90 (0.77–1.06)
>5 fruit and vegetable servings	147/460 (32%)	509/2,033 (25.0%)	0.002	0.16	1.27 (1.03–1.57)
Physical Activity					
Little or none	40/460 (8.7%)	193/2,033 (9.5%)	0.596	-0.03	0.91 (0.64–1.30)
Insufficient	181/460 (39.3%)	669/2,033 (32.9%)	0.008	0.13	1.19 (0.98–1.45)
Sufficient	208/460 (45.2%)	108/2,033 (5.3%)	<0.001	1.01	8.51 (6.60–10.96)
Heavy	31/460 (6.7%)	1,063/2,033 (52.3%)	<0.001	-1.09	0.12 (0.08–0.18)
Self-rated health					
Poor or fair	116/460 (25.2%)	269/2,033 (13.2%)	<0.001	0.31	1.90 (1.49–2.42)
Good, very good or excellent	344/460 (74.8%)	1,764/2,033 (86.8%)	<0.001	-0.31	0.86 (0.73–1.00)

Notes:
Data are proportion counts with percentage in parentheses.
NZHS = New Zealand Health Survey. BMI = Body mass index. OR = Odds ratio.

We found the proportion of pilots overall who achieved a daily intake of ≥5 servings of fruit and vegetable was significantly higher than the general population (p=0.002, 32% and 25%, respectively). Nevertheless, more than two-thirds of pilots and the general population were not achieving fruit and vegetable intake guidelines, highlighting the major prevalence of this behavioural risk factor. Similarly, a global epidemiological analysis reported 88% of countries they examined did not achieve vegetable intake guidelines.[22] Thus, evidence-driven interventions to encourage vegetable consumption are of public health importance.[22]

In our study, a relationship between health behaviours, overweight and obesity was evident, where overweight and obesity were associated with lower fruit and vegetable intake, less weekly MVPA and shorter sleep duration compared to pilots having a BMI of ≤25 (Figure 2). These findings are comparative to a previous study within Brazilian pilots, which identified factors associated with obesity were sleeping <6 hours on days off, <150 min of weekly physical exercise, number of years working as a pilot, and presence of daytime sleepiness.[5] Further, a cross-sectional investigation into health-related quality of life and its related factors among civilian pilots concluded physical activity and fruit and vegetable intake were positively correlated with quality of life.[6] Thus, targeted strategies to improve health behaviour in pilots may promote healthy weight, blood pressure management and quality of life, yielding positive NCD risk reduction effects.

Limitations of this study need to be considered regarding the interpretation of our findings. Firstly, as outcome measures were recorded for pilots in the aviation medicine clinic during their routine aviation medical examination, and data collected for the general population in their home residence, these environmental differences may have a potential influence on findings. In particular, in-clinic blood pressure measurement may be less accurate in the detection of true resting blood pressure values than measurement at home[44] and may account for the increase in blood pressure observed in pilots. Nevertheless, measurements were taken congruent with standardised aviation medicine blood pressure protocols,[26] which are established to mitigate the risk of false readings. Future research in pilots should investigate home blood pressure measurement readings compared to blood pressure recordings during aviation medical examinations to quantify whether significant environmental variance exists. Secondly, as pilot population data collection coincided with the emergence of the COVID-19 pandemic, the global novel pandemic environmental circumstances may have influenced some differences observed between study populations. Third, some self-selection bias may be present; those pilots who voluntarily participated may be more likely to have a greater active interest in their personal health than pilots who did not choose to participate. Finally, for feasibility reasons, self-report methods were used in this study. These methods have their own inherent limitations including reliance on participant recall ability and they are subject to over- or under-estimation responses.[45] To strengthen the validity of our findings and better inform targeted health promotion interventions for pilots, future research should examine dietary behaviours via direct or indirect measures of dietary recall, such as photo food logging, food frequency questionnaires and 24-hour recalls on both flying and non-flying days, to provide more comprehensive characterisation of dietary patterns in this occupational group. Further, quantification of sleep patterns and habitual physical activity levels should be explored using objective methods such as actigraphy.

Civil Aviation Regulators are required to apply safety management principles to the pilot medical assessment process, evaluate data on areas of increased health risk, and implement appropriate health promotion for pilots to reduce future medical risks to flight safety, as outlined in the International Civil Aviation Organization's Annex 1.[46] Based on present findings, we advocate aviation health and occupational safety professionals and researchers to further examine targeted, cost-effective intervention methods for promoting healthy bodyweight, managing blood pressure and enhancing health behaviours to mitigate risks of occupational morbidity, medical conditions causing loss of license, medical incapacity, and to support flight safety.

Conclusion

This study found pilots had a similar prevalence of NCD risk factors with the general population overall, yet a lower incidence of a BMI exceeding 30 (obesity) and a higher fruit and vegetable intake than the general population. We found preliminary evidence of those 'at risk' for hypertension, less total weekly physical activity, shorter sleep duration and lower self-rated health than the general population. Both pilots and the general population had an increase in the prevalence of overweight and obesity, hypertension, short sleep, and poor and fair self-rated health with increased age. Future research should investigate home blood pressure measurement and health behaviour quantification with objective measures to strengthen the validity of our study's findings.

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Original article

The effectiveness of a 17-week lifestyle intervention on health behaviors among airline pilots during COVID-19

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Abstract

Purpose: The aim of this study was to evaluate the efficacy of a 17-week, 3-component lifestyle intervention for enhancing health behaviors during the coronavirus disease 2019 (COVID-19) pandemic.
Methods: A parallel-group (intervention and control) study was conducted amongst 79 airline pilots over a 17-week period during the COVID-19 pandemic. The intervention group ($n = 38$) received a personalized sleep, dietary, and physical activity (PA) program. The control group ($n = 41$) received no intervention. Outcome measures for sleep, fruit and vegetable intake, PA, and subjective health were measured though an online survey before and after the 17-week period. The changes in outcome measures were used to determine the efficacy of the intervention.
Results: Significant main effects for time × group were found for International Physical Activity Questionnaire-walk ($p = 0.02$) and for all other outcome measures ($p < 0.01$). The intervention group significantly improved in sleep duration ($p < 0.01$; $d = 1.35$), Pittsburgh Sleep Quality Index score ($p < 0.01$; $d = 1.14$), moderate-to-vigorous PA ($p < 0.01$; $d = 1.44$), fruit and vegetable intake ($p < 0.01$; $d = 2.09$), Short Form 12v2 physical score ($p < 0.01$; $d = 1.52$), and Short Form 12v2 mental score ($p < 0.01$; $d = 2.09$). The control group showed significant negative change for sleep duration, Pittsburgh Sleep Quality Index score, and Short Form 12v2 mental score ($p < 0.01$).
Conclusion: Results provide preliminary evidence that a 3-component healthy sleep, eating, and PA intervention elicit improvements in health behaviors and perceived subjective health in pilots and may improve quality of life during an unprecedented global pandemic.

Keywords: COVID-19; Healthy eating; Lifestyle health; Moderate-to-vigorous physical activity; Sleep

1. Introduction

The global coronavirus disease 2019 (COVID-19) pandemic has rapidly spread, showing capability to infect the world's population.[1] Widespread infectious diseases such as COVID-19 are associated with adverse mental health consequences[2] and perturbations in physical activity (PA) behaviors due to environmental factors such as forced self-isolation.[3] The confinement of individuals to their homes may increase sedentary behavior[4] and has a direct impact on lifestyle, and, consequently, on sleeping, eating, and PA patterns.[5] Furthermore, psychological and emotional responses to the pandemic[6] may lead to dysfunctional dietary and sleep behaviors.[7,8] Numerous industries have experienced substantial operational perturbations emanating from COVID-19, including civil aviation.[9] Consequently, these conditions may have unexplored impacts on the health behaviors of airline pilots. Vocational requirements of airline pilots present health risks, such as circadian disruption due to shift work and flight schedules,[10] fatigue induced by flight schedules,[11] irregular meal times, mental stress demands associated with flight safety,[12] and the sedentary nature of the job.[13] Circadian disruption is detrimental to acute physiological[14] and psychological[15] health metrics and is associated with elevated risk for some chronic conditions such as cardiovascular disease.[16] Despite reduced workloads for airline pilots during COVID-19,[9] substantial industry disruption, uncertainty,[17] and financial

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concerns confounded by lockdown conditions may present adverse effects on the physical[3,18] and mental health[19] of pilots.

Obtaining adequate sleep, consuming enough fruits and vegetables, and engaging in sufficient PA are 3 lifestyle behaviors that significantly reduce all-cause mortality[20–22] and have a positive effect on physical and mental health.[23,24] Good sleep health facilitates the ability to maintain attentive wakefulness and is characterized by duration, quality, timing, and efficiency.[25] Sleep duration guidelines proposed for adults from 18 to 64 years is 7–9 h per night.[26] Fruit and vegetables supply dietary fiber, vitamins and minerals, phytochemicals, and anti-inflammatory agents.[27] Consumption of 400 g or more of fruit and vegetables per day, excluding starchy vegetables, is associated with protective effects against cardiovascular disease, some cancers,[28] depression,[29] and total mortality.[20] An inverse association between fruit and vegetable intake and mortality has been reported, with benefits observed in up to 7 daily portions.[30] Sufficient PA is defined as the achievement of 150 min/week or more of moderate-to-vigorous PA (MVPA), or 75 min/week or more of vigorous PA, or an accumulative equivalent combination of both, with added health benefits of 300 or more total MVPA minutes per week.[31]

Adequate sleep, healthy dietary behaviors, and sufficient PA also play an important role in strengthening the immune system and its antiviral defenses.[32,33] Lack of sleep, poor dietary habits, and physical inactivity are all independently associated with immunocompromising effects,[32,34,35] which impair host defenses against viral infection and may lead to individuals being at higher risk of more severe and complicated outcomes than those which are non-immunocompromised.[36] A lack of sleep,[37] dietary characteristics such as consuming a Western diet,[38] and insufficient PA are each associated with obesity,[39] which is suggested to be a profound risk factor for adverse health outcomes from COVID-19.[40]

Avoidance of health behaviors during a pandemic outbreak may lead to immunocompromise, increased susceptibility to viral propagation and elevated risk of severe symptoms.[36,41] Behavioral countermeasures for individuals are vital determinants to health resilience amongst exposure to unprecedented environmental events such as the COVID-19 pandemic.[5] Thus, evidence-driven interventions targeting the promotion of behaviors that enable individuals to protect themselves physically and psychologically during a pandemic are of public health importance.[5,42] No previous studies have examined change in health behaviors in airline pilots before and after a pandemic event like COVID-19, nor have any studies evaluated the effectiveness of a controlled lifestyle-based health intervention during such times. The aim of this study was to evaluate the effectiveness of a 3-component healthy eating, sleeping, and PA program in airline pilots during COVID-19 lockdown in New Zealand.

2. Methods

2.1. Design

A between-group, parallel controlled study with pre- and post-test was performed to evaluate the effectiveness of a 17-week, 3-component lifestyle intervention for enhancing health behaviors during a national COVID-19 pandemic response in New Zealand.

During the 17-week intervention period, the first 5 weeks preceded the New Zealand government's enforcement of a 4-tier response system to COVID-19.[1] Thereafter, 5 weeks were at alert Level 4 (March 25 to April 27, 2020), where all non-essential workers were instructed to stay home, and safe recreational activity was permitted only in the local area whilst maintaining social distancing of 2 m or more. Subsequently, 2.5 weeks were at alert Level 3 (April 27 to May 14, 2020), where some businesses could reopen; however, people were instructed to work from home unless that was not possible. Finally, 2 weeks were at alert Level 2 (May 14 to June 8, 2020), where gatherings of up to 100 people were allowed and sport and recreation activities were also allowed. On June 8, New Zealand returned to alert Level 1,[43] where within-community restrictions were removed yet international border restrictions remained. Around the globe in the weeks following the World Health Organization's characterization of COVID-19 as a pandemic on March 11, 2020, the airline industry experienced a decrease of approximately 60%–80% in capacity at major carriers.[9] Consequently, pilots experienced limited flying duties during the time when the intervention was conducted (Table 1). Pre-test occurred between February 14 and March 9, 2020, and post-test was conducted between June 8 and June 19, 2020. At pre- and post-test, participants completed an electronic survey measuring the following outcome variables: self-report PA levels, dietary behaviors, quality and quantity of sleep, and subjective health.

2.2. Participants

The study population consisted of commercial pilots from a large international airline. Seventy-nine pilots (aged = 42 ± 12 years, mean ± SD; 65 males, 14 females) participated in the study (Table 1). Participants were from a combination of short haul, long haul, and mixed fleet rosters (n = 32, 35, and 12, respectively). Inclusion criteria were pilots who had a valid commercial flying license and worked on a full-time basis. Control group participants consisted of volunteers who were pilots recruited at the time they completed their routine aviation medical examinations at the airline medical unit during the pre-test period (between February 14 and March 9, 2020). The intervention group volunteered to participate in the lifestyle intervention via self-selection. All volunteers participating in the study had responded to an invitation delivered to all pilots within the company via internal organization communication channels. In the control group, mixed-fleet pilots had the most flights, followed by long haul and short haul pilots (10 ± 9 flights, 7 ± 7 flights, and 6 ± 5 flights, respectively). In the intervention group, mixed-fleet pilots had the most flights, followed by short haul and long haul pilots (14 ± 1 flights, 9 ± 9 flights, and 6 ± 4 flights, respectively). All participants provided written informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wished to do so. In order to support anonymity and dataset blinding during

Table 1
Baseline demographic characteristics of participants (mean ± SD or *n*).

Parameters	All subjects ($n = 79$)	Intervention ($n = 38$)	Control ($n = 41$)
Sex (F/M)	14/65	8/30	6/35
Age (year)	42 ± 12	39 ± 10	44 ± 13
Short haul	32	22	10
Long haul	35	14	21
Mixed fleet	12	2	10
Flights during lockdown	7.8 ± 7.3	5.9 ± 7.5	7.2 ± 7.1

Abbreviations: F = female; M = male.

data analysis, participants were provided with a unique identification code on their informed consent form and were instructed to input it into their written survey instead of their name. This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand (reference number 2020#07).

2.3. Intervention group

Participants who registered their interest in participating in the intervention and agreed to attend a face-to-face consultation session at the airline medical unit were included in the intervention group. The intervention group received an initial one-on-one 60-min consultation session with an experienced health coach, followed by provision of an individualized health program, weekly educational content emails during the intervention and a mid-intervention phone call. The health advice provided was evidence based and derived from experts in the areas of PA, nutrition, and chronobiology.

Personalized goal setting was carried out for each participant in the intervention group, with relevant outcome, performance, and process goals[44] discussed pertaining to each of the 3 intervention components: (1) dietary behaviors, (2) PA, and (3) sleep habits. Moreover, individual perceived barriers to health change were assessed with methods outlined elsewhere[45] and were factored into the individualized program.

Sleep hygiene as an educational strategy has demonstrated improvements in self-report sleep quality in blue collar employees.[46] Stimulus control as a behavior technique has demonstrated positive outcomes on sleep parameters in insomniacs.[47] An evidence-based sleep health checklist was developed for utilization in this study (Appendix). The items in the checklist consisted of standard recommendations derived from previous sleep hygiene and stimulus control studies.[48,49] Application of the items in the sleep health checklist involved collaborative identification of the strategies that participants were achieving at baseline. Pilots completed the Pittsburgh Sleep Quality Index (PSQI) prior to attending their consultation. During the face-to-face consultation, the health coach discussed suboptimal PSQI component scores with the participant and identified individual sleep priorities. Thereafter, participants collaboratively set personalized sleep practice goals with support from the health coach. Personalized collaborative goal setting was implemented as a behavioral technique to support development of sleep habits that support restorative sleep.[44]

PA prescription was individualized based on participant perceived barriers and facilitators to exercise;[45] application of the frequency, intensity, time, and type principles;[50] and progression to attainment of sufficient MVPA to meet guidelines[31] in congruence with individual capabilities. The frequency and time of PA sessions were tailored to participant time availability. Intensity was tailored based on participant exercise experience, physical health, and goal orientation.[51] The type of PA was determined by the individual's modality preferences for cardiovascular (such as walking, running, or cycling) and strengthening (e.g., resistance equipment and/or bodyweight exercises) PA. The PA progression self-monitoring was indicated, and participants were advised to implement small, progressive changes in PA during the intervention (such as increased session duration, more repetitions, greater exercise intensity or more weekly bouts).[52] Healthy eating principles were emphasized through individualized advice and educational materials focused on adding color to the diet via consumption of fruit and vegetables;[27] choosing nutrient-dense foods;[53] limiting processed foods; enhancing whole-food consumption;[54] and reducing white carbohydrates, refined carbohydrates, and added sugar (e.g., energy-dense food).[55] Relative to participant baseline behaviors, collaborative individualized process behavior goals were established, for example, adding color to meals and replacing high glycemic index foods with low glycemic index options. The prescribed dose of fruit was 2 or more servings per day, and the prescribed dose of vegetables was 3 or more servings per day. A mid-intervention (during Week 8 ± 1) follow-up phone call lasting approximately 10 min consisted of a semi-structured interview emphasizing discussion of progress and compliance pertaining to individualized sleep, PA, and dietary goals established during the pre-test consultation. Advice was provided when necessary and was consistent with the advice given at pre-test. Phone calls were used because they have been shown to support adherence to health interventions.[56] Congruent with evidence-based methods previously outlined, weekly emails were sent consisting of educational blog posts on varying topics related to sleep health, PA, nutrition, and support for a healthy immune system. Content was derived from health authorities via publicly available information from the World Health Organization and the Centers for Disease Control and Prevention. During the COVID-19 lockdown, content was tailored to pandemic conditions, including strategies for PA at home, healthy recipes, and immune system health information.

2.4. Control group

The participants in the control group were blind to the intervention and received no intervention or instruction regarding health behaviors between pre- and post-test. Control group pilots were invited to voluntarily complete an electronic survey, and those who completed it during the previously defined pre-test period prior to COVID-19 lockdown were sent an invitation via email to voluntarily complete the survey again during the post-test period in order to provide insight into the effects of COVID-19 lockdown on their health behaviors.

2.5. Instruments

The PSQI was utilized to evaluate subjective sleep quality, and scores were obtained before the start of the study at the pre-test and were compared to scores obtained at the post-test stage. The PSQI is a self-rated, 19-item questionnaire designed to measure sleep quality and disturbances over a 1-month retrospective period.[57] Sleep quality component scores are derived for subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction, and collectively produce a global sleep score.[57] Lower scores denote a healthier sleep quality and range from 0 (*no difficulty*) to 21 (*severe sleep difficulties*).[57] The PSQI has demonstrated good test−retest reliability and validity and has been implemented in many population groups.[57,58] The outcome measurements were the change in global score between each group at post-test.

PA levels were assessed using the International Physical Activity Questionnaire (IPAQ) Short Form, a validated self-report measurement tool for MVPA that has been widely utilized in large cohort studies, including New Zealand population surveys.[59] The IPAQ Short Form estimates PA achievement by quantifying weekly walking, as well as moderate and vigorous PA duration and frequency. Responses were used to compare participants' PA levels with the health guidelines of 150 min of moderate PA or 75 min of vigorous PA per week, or an equivalent combination of MVPA per week.[31] IPAQ Short Form outcome measures derived were (a) total weekly minutes of moderate + vigorous PA in bouts of 10 min or more, excluding walking (IPAQ−MVPA), and (b) total weekly minutes of walking in bouts of 10 min or more (IPAQ−walk). Responses were capped at 3 h per day and 21 h per week, as recommended by the IPAQ guidelines.[60] Fruit and vegetable intake were measured using 2 questions with acceptable validity and reliability derived from the New Zealand Health Survey.[59] The questions asked participants to report, on average, over the last week, how many servings of fruit and vegetables they ate per day. Responses to these questions were combined to determine total daily fruit and vegetable intake.

Subjective self-report physical and mental health was determined using the Short Form 12v2 (SF-12v2), a short version of the SF-36, which reduces the burden on participants and has demonstrated a high correlation with SF-36 physical and mental component summary scale scores.[61] The 12-item survey produces a physical component summary (PCS-12) scale and a mental component summary (MCS-12) scale, both of which have shown good test−retest reliability and convergent validity in detecting changes in mental and physical health over time in adults.[62] Scoring of the SF-12v2 was carried out in accordance with standard summary scoring methods.[61] The summary scores are on a scale of 0−100, with clinical significance change scores suggested to be 5−10 points.[63]

2.6. Statistical analyses

For all statistical analyses, raw data were extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into the SPSS (Version 26; IBM Corp., Armonk, NY, USA). Listwise deletion was applied for individual datasets with missing values or participants who did not complete post-test. Stem and leaf plots were inspected to ascertain whether there were any outliers in the data for each variable. A Shapiro-Wilk's test ($p > 0.05$) and its histograms, Q−Q plots and box plots were inspected for normality of data distribution for all variables. Levene's test was used to test homogeneity of variance. Time-related effects within and between groups on pre-test and post-test were assessed using t tests and repeated measures mixed-design analysis of variance. Age, sex, and number of flights were included as covariates in the analysis of variance. Effect sizes were calculated using Cohen's d in order to quantify between-group effects from pre-test to post-test. Effect size thresholds were set at greater than 1.2, greater than 0.6, greater than 0.2, and less than 0.2, which were classified as large, moderate, small, and trivial, respecitvely.[64] The α level was set at a p value of less than 0.05.

3. Results

The demographic and baseline health characteristics between the intervention and control groups are given in Table 1. The attrition rates were 16% and 30% for the intervention and control group, respectively. Intervention group attrition was influenced by employment layoffs, whereas control group attrition was due to non-response to the online invitation to voluntarily complete the survey at the post-test period. In order to measure compliance, average sleep hours, exercise sessions per week, and daily fruit and vegetable consumption was collected at the time of the mid-intervention phone call. In the intervention group, 35 participants (92%) were achieving 7.0 h or more of sleep per night and 3 (8%) were achieving 6.9 h or less per night. For fruit and vegetable servings per day, 36 participants (95%) were eating 5 or more servings of fruit and vegetables per day, whereas 2 (5%) were eating 2−4 servings per day. For MVPA, 33 participants (87%) were completing 150 min or more of MVPA per week and 5 (13%) were completing 149 min or less of MVPA per week.

At baseline, the control group achieved significantly ($p < 0.05$) more sleep per night (36 min), a lower global PSQI score (−1.9) (denoting better health), higher consumption of daily fruit and vegetables (1.2 servings), a greater amount of weekly walking (94 min), and higher SF-12v2 physical and mental component scores (8.4 and 6.7, respectively). At baseline, the control group exhibited an MVPA of 171 ± 78 min per week, surpassing the MVPA recommended in the health guidelines of 150 min or more per week,[31] whereas the intervention group exhibited 116 ± 51 min per week of MVPA, which is beneath the health guidelines threshold. However, the between-group difference in MVPA was not statistically significant ($p \geq 0.05$).

Group changes from pre-test to post-test are presented in Table 2. Significant main effects for time × group were found for IPAQ-walk ($p = 0.02$) and for all other outcome measures ($p < 0.01$), which is associated with small to large effect size differences between groups. The within-group analysis revealed that the intervention elicited significant improvements ($p < 0.01$) in all health metrics at post-test and IPAQ-walk ($p = 0.02$). The control group reported a significantly higher PSQI score ($p < 0.01$), decreased hours of sleep and MCS-12 score ($p < 0.01$), yet no significant change was reported in other health metrics.

4. Discussion

To our knowledge, this study is the first controlled experiment that has explored the effects of a lifestyle intervention on health outcomes among pilots during a national pandemic lockdown. This study aimed to improve health-related behaviors and promote positive change in subjective health of pilots through personalized advice on healthy eating, sleep hygiene, and PA. For most outcome measures, the controlled trial demonstrated significant improvements in the intervention group compared to the control group. These results are important in order for researchers and health care professionals to provide insight into potential health and quality-of-life perturbations resulting from COVID-19 that may have potential implications to flight safety. Furthermore, given the dearth of published data pertaining to health behavior interventions during a pandemic and the limited availability of preventive lifestyle-based interventions for pilots, our findings provide novel contributions to this field.

The average PSQI score for the intervention group decreased (−2.3), compared to a significant increase for the control group (0.8). These results support previous studies that used non-pilot populations, which have reported PSQI score decreases of −1.5 to −1.8 following a sleep hygiene education intervention[46,65] and −2.5 after a PA and sleep education intervention based on a mobile health app.[66] An app-based intervention to reduce fatigue in a pilot population reported a smaller effect on PSQI score (−0.59) after a 6-month intervention that focused on advice regarding daylight exposure and sleep duration. None of these studies were conducted under global pandemic conditions. A potential confounding factor to sleep quality and quantity improvements during COVID-19 due to social isolation and lockdown constraints has been proposed,[67] where more time at home and flexible sleep−wake schedules may promote enhancements in sleep. Furthermore, sleep disruption is an inherent risk for pilots, and they are likely to have better sleep quality and quantity when not at work.

Curiously, in our study the control group significantly increased its PSQI score. Similar findings have been reported elsewhere in a general-population-based study in Australia ($n = 1491$), which reported that 40.1% of the participants indicated a negative change in sleep quantity during lockdown.[8] In another study, sleep quantity improved while sleep quality was degraded in Austrian adults ($n = 435$).[68] In that study, an increase in subject burden and decreased physical and mental well-being were also observed. Cognitive states of elevated distress and emotional disturbances have been associated with unhealthy dietary patterns and poor diet quality and may impair health behavior motivation.[5] Researchers have advocated for implementation of strategies to mitigate the effects of lockdown on sleep quality, including obtaining sufficient PA, exposure to natural daylight,[68] and well-balanced meals rich in vitamins and minerals.[5] Our study findings support these messages in that we observed significant improvements in PCS-12 and MCS-12 scores among the intervention group

Table 2
Changes in health behaviors from baseline to post-test at 17 weeks (mean ± SD).

	Intervention group			Control group			ANOVA (time × group interaction)	
	Pre	Post	Change	Pre	Post	Change	p	d
Hours of sleep (h:mm)	7:00 ± 0:54	7:48 ± 0:48**	0:48 ± 0:54	7:36 ± 0:48	7:12 ± 1:00**	−0:24 ± 0:42	<0.01	1.35, Large
PSQI global	6.4 ± 2.7	4.1 ± 1.8**	−2.3 ± 2.4	4.5 ± 2.5	5.3 ± 2.9**	0.8 ± 0.9	<0.01	1.14, Moderate
IPAQ-walk	61 ± 69	93 ± 96	32 ± 105	155 ± 135	136 ± 111	−19 ± 79	0.02	0.45, Small
IPAQ-MVPA	116 ± 51	201 ± 77**	85 ± 100	171 ± 78	146 ± 75	−25 ± 82	<0.01	1.44, Large
Fruit and vegetable intake	3.0 ± 0.6	6.1 ± 1.7**	3.1 ± 1.5	4.2 ± 0.9	4.1 ± 1.5	−0.1 ± 1.3	<0.01	2.09, Large
PCS-12	43.3 ± 5.2	52.6 ± 4.9**	9.3 ± 5.5	51.7 ± 5.7	51.5 ± 6.0	−0.2 ± 2.2	<0.01	1.52, Large
MCS-12	48.0 ± 4.0	54.8 ± 1.0**	6.8 ± 4.1	54.7 ± 4.3	51.9 ± 4.5**	−2.8 ± 4.4	<0.01	2.09, Large

Note: d = Cohen's d effect size, effect threshold.
* $p < 0.05$, ** $p < 0.01$, compared with pre within group.
Abbreviations: ANOVA = analysis of variance; IPAQ = International Physical Activity Questionnaire; MCS-12 = Short Form 12v2 Mental Component Summary Scale; MVPA = moderate-to-vigorous physical activity; PCS-12 = Short Form 12v2 Physical Component Summary Scale; PSQI = Pittsburgh Sleep Quality Index.

compared to the control group, after implementation of a 3-component healthy sleep, eating, and PA intervention during an unprecedented global pandemic.

The average MVPA and fruit and vegetable consumption significantly increased in our intervention group, compared to no significant change in the control group. The intervention group increased MVPA from 116 min to 201 min at post-test, which crossed the MVPA guideline threshold of 150 min or more per week.[31] Conversely, the control group decreased MVPA from 171 min to 146 min per week at post-test, decreasing to below the guideline threshold. Both the control and intervention groups did not achieve the recommendation of 5 or more servings per day for fruit and vegetable intake at baseline.[69] The intervention group elevated its intake per day, achieving the guideline threshold at post-test. Our study findings suggest that the 3-component intervention supported achievement of PA and fruit and vegetable guideline thresholds and significantly improved PCS-12 and MCS-12 scores in the intervention group. Furthermore, the intervention appeared to mitigate decay in both SF-12v2 summary scales, which were observed in the control group.

Research exploring the relationships among COVID-19, PA and dietary behaviors have yielded mixed outcomes. Within an Italian population ($n = 3533$) during COVID-19 lockdown, similar proportions of the participants stated that they ate less or had better diets (35.8% and 37.4%, respectively) in regard to intake of fruit, vegetables, nuts, and legumes.[7] Furthermore, their PA behaviors did not significantly change; however, a greater amount of exercise was completed at home.[7] In a study with Australians participants, 48.9% expressed a negative change in PA during lockdown and also reported that negative changes in PA and sleep were associated with expression of higher anxiety, depression and stress levels.[8] In a Canadian sample ($n = 1098$), those who engaged in more outdoor PA time during lockdown had lower anxiety levels than those who did not.[70] The COVID-19 lockdown in New Zealand at Levels 3, 4 presented barriers for engaging in PA, such as social distancing, travel restrictions and inaccessibility to parks, gyms, and other recreational facilities, which may have promoted sedentary behavior and contributed to the decline in PA observed in the control group.[4,17] Other studies found that life stressors, including job uncertainty,[9] anxiety and psychological stress,[2] financial loss and disconnection with community and nature may have impacted health behaviors during this time.[17] In contrast, the reduced time at work has been suggested as a potential facilitative factor in enhancing health behaviors during lockdown,[67] because this naturally alleviates one of the most commonly expressed barriers to engagement in PA: a lack of time.

A limited number of studies have investigated the efficacy of interventions targeting healthy dietary and PA behaviors among pilots. A study of an app-based, 6-month intervention using a pilot population reported significant improvements in their weekly moderate and strenuous activity (0.21 days and 0.19 days per week, respectively), as well as a reduction in their snacking behavior (−0.88 servings per duty).[71] Consultations with pilots on their diet and physical exercise behaviors yielded a positive change in their blood lipids and body mass index.[12] Our findings pertaining to MVPA, fruit and vegetable intake, PSQI and SF-12v2 among pilots provide promising preliminary outcomes regarding the effects of a 3-component intervention and warrant further investigation with objective measures of outcomes.

The differential recruitment strategies and limited exclusion criteria for the intervention and control groups are limitations that may have contributed to the significant differences observed at baseline for sleep quantity and PSQI score, IPAQ-walk, MVPA, fruit and vegetable consumption, and SF-12v2 subjective health scores, with superior results in favor of the control group. Thus, it is recommended that future research studies have more robust randomization assignment conditions for participant allocation to groups in order to increase the probability of capturing the true population average and enhance the generalizability of findings. Future research should also increase the sample size, given the apparent variances in health behaviors amongst the pilot population, which in itself warrants further investigation in order to characterize these variances.

Future research with pilot populations that compare single- to multiple-behavior interventions would provide valuable insight into the magnitude of the effects when these differing intervention approaches are used. Given the bidirectional relationship between sleep, nutrition, and PA and some evidence to suggest multiple-component interventions may elicit stronger participation and adherence,[72] we suggest future research examine more time-efficient and scalable strategies for implementation of a 3-component sleep, nutrition, and PA program. For feasibility reasons, self-report methods were utilized in this study, and the limitations of this approach have been discussed elsewhere.[73] To enhance outcome measure validity and reliability, it would be preferrable to use objective measurement methods such as actigraphy to monitor sleep and PA and photo logging of dietary behaviors to quantify health behavior metrics. Comparisons of our study to related studies are limited because most other studies were conducted under normal societal conditions while ours was conducted under pandemic conditions.

5. Conclusion

Behavioral countermeasures for individuals are vital determinants of health resilience during exposure to unprecedented environmental events such as the COVID-19 pandemic.[5] The attainment of sleep, fruit and vegetable intake, and PA guidelines is associated with increased physical and mental health, enhanced immune defenses, and a reduction in the risk of obesity. Evidence-based interventions targeting the promotion of these behaviors will enable individuals to protect themselves physically and psychologically during a pandemic, and therefore are of immense public health importance. The 3-component healthy sleep, eating, and PA intervention implemented in this study elicited significant improvements in sleep quality and quantity, fruit and vegetable intake, and MVPA and suggests that achieving these 3 guideline thresholds promotes mental and physical health and improves quality of life among pilots during a global pandemic. Our study of this intervention provides preliminary evidence that a low-intensity, multi-behavior intervention may be efficacious during a pandemic and that similar outcomes may be transferrable to other populations. However, more robust recruitment methods are required to confirm our findings and increase their generalizability.

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Authors' contributions

DW and NG participated in conceptualization of the study, data collection and contributed to the design of the study, data analysis, interpretation of the results, and manuscript writing; MD and BJ contributed to the design of the study, data analysis, interpretation of the results, and manuscript writing. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare they have no competing interests.

Appendix

Sleep hygiene strategies for enhancing sleep	Yes achieving	Not achieving
1. Sleep at least 7 h		
2. Sleep routine or depower hour		
3. Regular sleep and wake time		
4. Dim lights near bedtime and turn off electronics >30 min before bed		
5. Avoid sleep disruptors 4–6 h before bed, e.g., caffeine, large meals, and alcohol		
6. Have a dark, cool, and quiet sleep environment		
7. Exercise every day, not too close to bedtime		
8. Use the bedroom only for sleeping and intimacy		
9. Do a brain dump on paper before bed		
10. Early morning light exposure		

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The Effects of a Brief Lifestyle Intervention on the Health of Overweight Airline Pilots during COVID-19: A 12-Month Follow-Up Study

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Abstract: The aim of this study was to perform a 12-month follow-up of health parameters after a 17-week lifestyle intervention in overweight airline pilots. A parallel-group (intervention and control) study was conducted amongst 72 overweight airline pilots (body mass index > 25) over a 12-month period following the emergence of COVID-19. The intervention group ($n = 35$) received a personalized dietary, sleep, and physical activity program over a 17-week period. The control group ($n = 37$) received no intervention. Measurements for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) via an electronic survey, and objective measures of body mass and blood pressure were taken at baseline and at 12 months. Significant interactions for group × time from baseline to 12-months were found for all outcome measures ($p < 0.001$). Body mass and mean arterial pressure significantly decreased in the intervention group when compared to the control group ($p < 0.001$). Outcome measures for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) significantly increased in the intervention group when compared to the control group ($p < 0.001$). Results provide preliminary evidence that a brief three-component healthy sleep, diet and physical activity intervention can elicit and sustain long-term improvements in body mass and blood pressure management, health behaviors, and perceived subjective health in pilots and may support quality of life during an unprecedented global pandemic.

Keywords: healthy eating; weight loss; moderate-to-vigorous physical activity; sleep; lifestyle medicine

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1. Introduction

The COVID-19 pandemic has impacted operations of numerous industries, including the aviation industry which has been significantly disrupted by global travel restrictions, causing a substantial economic decline within the industry [1]. Following the World Health Organization's characterization of COVID-19 as a pandemic on 11 March 2020, the global commercial airline industry experienced an approximate 60–80% decrease in flight operations during the proceeding months [2]. Accordingly, airline pilots have been affected by decreased work availability [1], job security, financial concerns, increased time spent confined to the indoors due to self-isolation requirements during travel [3], and limited control over food choices during hotel self-isolation after flying internationally. The consequent psychosocial impacts of these conditions may adversely affect the engagement in health promoting behaviors [4].

The COVID-19 pandemic has influenced considerable changes to behavior, and subsequent physical and mental health related outcomes [4]. Authorities in countries worldwide have implemented strict control strategies in attempt to limit the spread of the virus [5]. Consequently, these viral spread mitigation measures in the community pose significant barriers to engagement with health promoting behaviors [6]. For example, financial insecurity, elevated psychosocial stress, and emotional dysregulation may lower motivation and limit accessibility to healthful dietary behaviors [7,8]. Further, stay at home isolation and lockdown measures present an inhibitory effect on engagement in physical activity [4,9].

Negative effects on physical [10] and mental wellbeing, along with elevated levels of psychosocial stress [11] have been reported in research exploring the effects of COVID-19 environmental conditions, such as social distancing and lockdown confinement in adults. Decreases in physical and mental health during COVID-19 have shown associations with unhealthy lifestyle behaviors; sedentary behavior, physical inactivity, poor sleep quality, and unhealthy dietary intake [11]. Prospective cohort studies exploring health behavior status during lockdowns have reported increased sedentary behavior and physical inactivity [12], decreased fruit and vegetable intake [13], increased alcohol intake [8], and increased sleep problems [14], yet little evidence has been reported regarding the prolonged effects after lockdown.

Overweight, obesity and hypertension are independently associated with unhealthy lifestyle behaviors; insufficient sleep, poor diet, and physical inactivity [15–18]. Widespread societal and economic implications of COVID-19 present perturbations to these health behaviors [3,4,8,10]. Unhealthy lifestyle risk factors synonymous with an elevated risk of non-communicable disease are a risk factor for COVID-19 complications and severity of health outcomes following infection [6]. Markedly, obesity is associated with chronic low-grade inflammation, impaired innate immunity and immunologic compromise [19]. Indeed, recent studies report increased morbidity and mortality risk from COVID-19 in those with obesity [20]. Overweight and obesity are also major risk factors for essential hypertension, of which emerging evidence denotes as a risk factor strongly associated with adverse outcomes from COVID-19 [21].

Behavioral countermeasures for individuals are vital determinants to health resilience amongst exposure to unprecedented environmental events such as the COVID-19 pandemic and its widespread implications [7]. Obtaining seven to nine hours of sleep per night [22], consuming $\geq$400 g of fruit and vegetables per day fruits and vegetables [23], and engaging in $\geq$150 min of moderate-to-vigorous physical activity intensity per week are three protective lifestyle behaviors that significantly reduce all-cause mortality [23–25], and have a positive effect on physical and mental health [26,27], support healthy bodyweight and blood pressure management [15], and support immune system function [28]. Given the evidence for physical activity, healthy nutrition and sleep quality in promoting health outcomes, it is of public health importance that effective evidence-based interventions targeting the promotion of these behaviors are established for intervention preventive measures to mitigate the adverse health effects of future lockdowns [7].

Our previous research investigated the use of a personalized three-component healthy eating, physical activity and sleep hygiene intervention for promoting health during a COVID-19 lockdown in New Zealand [29]. The intervention's effectiveness at four-months has been reported [29], which revealed significant improvements in health behavior and subjective health. The aim of the current study is to report on the longer-term outcomes of the intervention; specifically, to evaluate the effects on weight loss and blood pressure. Further, to evaluate what health behavioral changes are sustained or decayed over a period of 12-months and what influence they have on health parameters. It was hypothesized that the intervention group would have significantly greater improvements in health behaviors and health parameters compared to the control group at 12-months. It was also hypothesized that some decay in health behaviors and parameters would be evident in the intervention group from post intervention (4 months) to 12 months.

2. Materials and Methods

2.1. Design

A two-arm, parallel, controlled design was utilized to evaluate the effectiveness of a brief three-component lifestyle intervention for enhancing and maintaining health behaviors, body mass, and blood pressure management during the COVID-19 pandemic in New Zealand. The acute (17-week) effects of this lifestyle intervention on subjective measures for physical activity, sleep duration, and fruit and vegetable intake have been previously reported [29]. Therefore, the purpose of the present study was to complete a 12-month follow-up to that study [29].

This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07. The trial protocol is registered at The Australian New Zealand Clinical Trials Registry (ACTRN12621001105831).

2.2. Intervention Timing

After baseline testing, the first five weeks of the intervention period preceded the New Zealand (NZ) Government's implementation of a four-tier response system to COVID-19 on 21 March 2020 [30]. Thereafter, five weeks were at highest alert level 4, two and a half weeks were at alert level 3, and two weeks were at alert level 2. Thereafter, NZ returned to alert level 1 [31]. Restrictions associated with each alert level is defined elsewhere [29]. Pre-testing occurred between 14 February and 9 March 2020 and follow-up testing was carried out during February and March 2021.

2.3. Participants

The study population for both groups consisted of commercial pilots from a large international airline. Inclusion criteria were (a) pilots with a valid commercial flying license, (b) working on a full-time basis, (c) having a body mass index (BMI) of $\geq$25 (overweight), and (d) a resting blood pressure of >120/80 (systolic/diastolic).

Control group participants consisted of airline pilot volunteers recruited at the time of completing their routine aviation medical examinations located at the airline medical unit during the time of the pre-test period. The intervention group volunteered to participate in the lifestyle intervention by responding to an invitation delivered to all pilots within the company via internal organization communication channels. Participants consisted of pilot rosters including long haul (international flights), short haul (regional flights), and mixed-fleet (variable schedule of regional and short international flights).

All participants provided informed consent prior to participation in the study and were made aware that they could withdraw from the study at any time should they wish to do so. Participants were provided with a unique identification code on their informed consent form, which they were instructed to input into their electronic health survey instead of their name at each data collection timepoint, in order to support anonymity and dataset blinding during data analysis.

The sample size was based on previous research with congruent outcome measures [29]. Clinically significant weight loss is defined as at least a 5% reduction in body mass from the baseline level [32]. Our power calculation suggested that 37 participants were required in each group to achieve an 80% power and 5% significance criterion to detect a 4 kg body mass reduction difference between the intervention and the control. To account for 20% attrition [33], we recruited 89 participants.

2.4. Intervention Group

The intervention group participated in a 17-week health intervention consisting of individualized goal setting for physical activity, healthy eating, and sleep hygiene. The intervention commenced with a one-hour individual face-to-face consultation session with an experienced health coach at the airline medical unit. For the intervention group, all participants conducted consultations with the same health coach. In this initial consultation session, the pilots' barriers and facilitators to health behavior change were assessed with methods outlined elsewhere [34], which were factored into the development of an individualized health program. Further, personalized collaborative goal setting was carried out for the pilot with assistance from the health coach, establishing appropriate outcome, performance, and process goals [35] for (a) sleep hygiene, (b) healthy eating, and (c) physical activity. A mid-intervention phone call was utilized to support adherence, monitor progress and measure compliance to health behaviors. The intervention utilized 20 participant contacts; including 2 face-to-face consultations (baseline and follow-up), 1 telephone call and 17 intra-intervention emails. For full detail of the procedures associated with the intervention readers are referred to the study of Wilson and colleagues [29].

2.5. Control Group

The participants in the control group received no intervention or instruction regarding health behaviors during the study timeframe. Pilots were invited to voluntarily complete an electronic survey and consent to providing records of their cardiovascular disease risk factor data from their aviation medical examinations. Pilots who volunteered to participate during the previously defined baseline testing period were sent an invitation via email to voluntarily complete the electronic survey again during the post intervention period and then finally again at the completion of their proceeding annual aviation medical examination to provide insight into the effects of COVID-19 on their health. The control group were invited to participate in the intervention after follow-up testing.

2.6. Outcome Measures

Measurements for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) via an electronic survey, and objective measures of body mass and blood pressure were taken at baseline and 12-month follow-up (see Figure 1).

Prior to attending data collection sessions, participants were instructed to avoid any strenuous exercise, stimulants (for example, caffeine or energy drinks), or large meals 4 h before testing. Height was recorded with a SECA 206 height measures and body mass was measured with SECA 813 electronic scales (SECA, Hamburg, Germany). For body mass measurement, participants were wearing clothes with emptied pockets and footwear removed. Blood pressure was measured with an OMRON HEM-757 device (Omron Corporation, Kyoto, Japan), which has been successfully validated independently against international criteria [36]. Measurements of blood pressure were conducted according to the standardized aviation medicine protocol [37]. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) readings were used to calculate mean arterial pressure (MAP) with the following formula: $DP + 1/3(SP-DP)$ [38]. Resting pulse was measured using a Rossmax pulse oximeter SB220 (Rossmax Taipei, Taiwan, China) after a 5-min period of sitting in a chair quietly. All measurement instruments were calibrated prior to data collection.

Outcome measures for subjective health (physical activity, sleep quality and quantity, fruit and vegetable intake, and self-rated health) have been previously described in detail [29]. In brief, moderate-to-vigorous physical activity was determined using the International Physical Activity Questionnaire Short Form (IPAQ) [39]. To measure subjective sleep quality and quantity, the Pittsburgh Sleep Quality Index (PSQI) [40] was utilized. Daily fruit and vegetable intake were measured using dietary recall questions derived from the New Zealand Health Survey [39], and self-rated health was determined using the Short Health Form 12v2 (SF-12v2) [41].

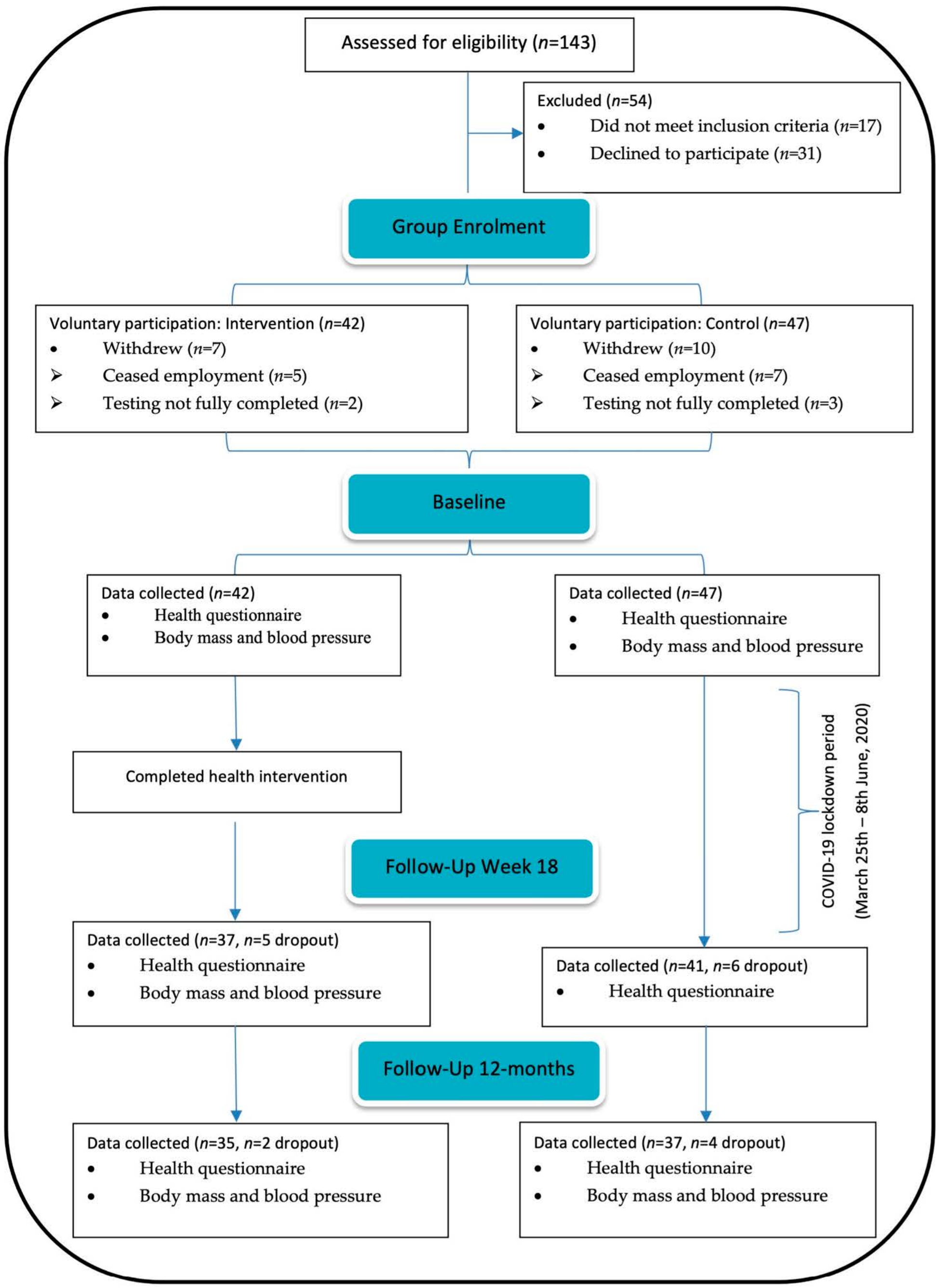

Figure 1. Flow diagram of participant recruitment and data collection.

2.7. Statistical Analysis

Raw data was extracted from the Qualtrics online survey software (Qualtrics, Provo, UT, USA), entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) and then imported into the Statistical Package for the Social Sciences (SPSS, version 27; IBM, New York, NY, USA) for all statistical analyses. All variables were assessed using the Shapiro–Wilk's test ($p > 0.05$) and its histograms, Q-Q plots and box plots for inspection for data normality. Levene's test was used to test homogeneity of variance. Listwise deletion was applied for individual datasets with missing values or participants who did not complete post-testing.

t-Tests were utilized to explore baseline differences between groups. A Chi-squared test was utilized to calculate whether any significant differences exist between fleet types at baseline. A one-way analysis of variance (ANOVA) was utilized to calculate whether any significant differences exist between fleet type for flight frequency and flight hours. Repeated-measures ANOVA using the General Linear Modelling function in SPSS was utilized test for group x time interactions, group effects, and time effects (baseline to 12-months). Age, sex, and flights were included as covariates in the ANOVA. As an additional analysis utilizing paired *t*-test, we examined change in health parameters within the intervention group from post intervention at 4-months to 12-months follow-up. Effect sizes were calculated using Cohen's *d* to quantify between group effects from pre-testing to post-testing. Effect sizes thresholds were set at >1.2, >0.6, >0.2, <0.2 were classified as *large*, *moderate*, *small*, and *trivial* [42]. The alpha level was set at $p < 0.05$.

3. Results

3.1. Baseline Characteristics of the Study Population

A total of 143 airline pilots were initially assessed for eligibility and 89 were recruited to participate (see Figure 1). Moreover, 72/89 (81%) pilots (mean ± SD, age; 46 ± 11 year, 11 females, 61 males) provided outcome measure data at all data collection timepoints, which consisted of a combination of short haul, long haul, and mixed fleet rosters ($n = 28$, 35, and 9, respectively). The dropout rates from baseline to 12-months were 17% (ceased employment $n = 4$; testing not fully completed $n = 3$) and 21% (testing not fully completed $n = 7$; ceased employment $n = 3$) for the intervention and control group, respectively.

As displayed in Table 1, at baseline the control and intervention group were of similar height, body mass, DBP, resting pulse, and flight hours. The control group were of advanced age (t(70) = 2.342, $p = 0.02$, $d = 0.55$), consumed more fruit and vegetables (t(70) = 4.570, $p = <0.001$, $d = 1.08$), performed more walking (t(70) = 5.650, $p = <0.001$, $d = 1.33$), higher PCS-12 and MCS-12 scores (t(70) = 7.751, $p = <0.001$, $d = 1.82$, and t(70) = 4.798, $p = <0.001$, $d = 1.13$, respectively), achieved greater sleep duration (t(70) = 3.012, $p = 0.004$, $d = 0.71$), and had a lower MAP (t(70) = −2.598, $p = 0.011$, $d = 0.61$). No significant differences were observed between groups for flights during lockdown and flight hours after lockdown.

Table 1. Baseline characteristics of participants.

Parameters	All Participants ($n = 72$)	Intervention ($n = 35$)	Control ($n = 37$)
Sex (f/m)	11/61	7/28	4/33
Age (year)	45.8 ± 11.1	42.8 ± 10.4	48.7 ± 11.2 *
Height (cm)	178.6 ± 7.2	178.5 ± 8.1	178.6 ± 6.3
Body mass (kg)	90.4 ± 13.9	91.7 ± 13.5	89.2 ± 14.5
BMI (kg·m^2)	28.3 ± 3.3	28.7 ± 3.3	27.9 ± 2.8
Systolic BP (mmHg)	134.4 ± 11.8	138.4 ± 10.6	130.6 ± 11.7
Diastolic BP (mmHg)	84.8 ± 8.3	86.7 ± 8.1	83.1 ± 8.2
MAP (mmHg)	101.3 ± 8.5	103.9 ± 8.0	98.9 ± 8.5 *
Pulse (bpm)	68.7 ± 9.5	69.2 ± 7.8	68.1 ± 10.9
Hours slept (h/day)	7.3 ± 0.9	7.0 ± 0.8	7.6 ± 0.8 *
IPAQ-walk (min)	102.4 ± 58.5	69.0 ± 37.9	134.0 ± 57.2 *
IPAQ-MVPA (min)	144.5 ± 89.0	125.9 ± 79.7	162.1 ± 94.7
F&V Intake (serve/day)	3.5 ± 1.4	2.8 ± 1.3	4.1 ± 1.1 *

Table 1. *Cont.*

Parameters	All Participants (n = 72)	Intervention (n = 35)	Control (n = 37)
PCS-12 (score)	46.7 ± 6.6	42.1 ± 4.1	51.1 ± 5.5 *
MCS-12 (score)	49.1 ± 7.5	45.3 ± 8.2	52.7 ± 4.5 *
Short Haul (n, %)	28 (39%)	20 (57%)	8 (22%) *
Long Haul (n, %)	35 (49%)	13 (37%)	22 (59%)
Mixed Fleet (n, %)	9 (12%)	2 (6%)	7 (19%)
Flights during lockdown (n)	8.0 ± 7.4	7.9 ± 7.7	8.1 ± 7.2
Flight hours after lockdown (h)	152.1 ± 71.9	153.9 ± 63.8	150.5 ± 79.7

Mean ± SD reported for all participants, intervention and control. Abbreviations: SD = standard deviation. BMI—body mass index. BP = blood pressure. MAP = mean arterial pressure. IPAQ = International Physical Activity Questionnaire. MVPA = moderate-to-vigorous physical activity. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * indicates statistical significance between groups (p < 0.05). Flight hours after lockdown = flight hours during the 6-months prior to 12-months follow-up testing.

3.2. Intervention Adherence

For the intervention group, compliance was measured mid-intervention for health behaviors, including average sleep hours, weekly MVPA and daily fruit and vegetable consumption. Thirty-two (91%) were achieving ≥7 h sleep per night and three (9%) were obtaining ≤6.9 h per night. For fruit and vegetable servings per day, 33 (94%) were achieving ≥5 serves of fruit and vegetables per day, whereas two (6%) were eating two to four serves per day. Thirty were achieving ≥150 min MVPA (86%), and five (14%) were completing ≤149 min MVPA per week.

3.3. Body Mass, BMI, BP, and Pulse

Group changes from baseline to 12-months are presented in Table 2. Significant interactions for group x time were found for all variables (p = <0.001), associated with *small* to *large* effect size differences between groups from baseline to 12-months (see Table 2). The within-group analysis revealed that the intervention elicited significant improvements (p < 0.001) in all physical metrics at 12-months, associated with *large* effect sizes (see Table 2). The control group reported a significantly higher body mass and BMI (p < 0.001) at 12-months, yet no significant changes were observed in other physical metrics.

3.4. Health Behaviors and Self-Rated Health

Significant interactions for group × time were found for all subjective health measures (p = <0.001). The within-group analysis reported significantly greater improved health changes from baseline to 12-months for all subjective health measures in the intervention group (p < 0.001), associated with *moderate* to *large* effect sizes (see Table 2; Figure 2). In contrast, the control group experienced significant decreases in all outcome measures: sleep duration (t(36) = −2.589, p = 0.014, d = −0.42), PSQI global score (t(36) = 3.853, p = <0.001, d = 0.63), and MCS-12 scores (t(36) = −2.300, p = 0.027, d = −0.38). No significant group differences were reported in other health metrics.

Table 2. Changes in objective and subjective health metrics from baseline and follow-up at 12-months.

	Time (Months)	Intervention (n = 35)			Control (n = 37)			ANOVA (Time × Group Interaction)	Between Group ES
		M	SD	Follow-Up Change (95% CI)	M	SD	Follow-Up Change (95% CI)	p	d
Body mass (kg)	0	91.7	13.5		89.2	14.5			0.2, *Trivial*
	12	86.8	11.3	−4.9 (−3.5–−6.3)	90.5	14.5	1.3 (0.6–1.9)	<0.001	−0.3, *Small*
BMI (kg/m^2)	0	28.7	3.3		27.9	2.8			0.2, *Trivial*
	12	27.1	2.7	−1.6 (−1.1–−2.0)	28.3	3.7	0.4 (0.2–0.6)	<0.001	−0.4, *Small*
Systolic BP (mmHg)	0	138.4	10.6		130.6	11.7			0.7 *, *Moderate*
	12	128.1	10.3	−10.3 (−7.2–−13.5)	134.4	9.9	3.8 (0.0–7.6)	<0.001	−0.6 *, *Moderate*
Diastolic BP (mmHg)	0	86.7	8.1		83.1	8.2			0.4, *Small*
	12	78.9	8.0	−7.8 (−5.0–−10.6)	83.2	7.0	0.1 (−2.6–2.8)	<0.001	−0.6 *, *Moderate*
MAP (mmHg)	0	103.9	8.0		98.9	8.5			0.6 *, *Moderate*
	12	95.3	7.6	−8.6 (−6.0–−11.3)	100.2	7.2	1.3 (−1.2–4.0)	<0.001	−0.7 *, *Moderate*
Pulse (bpm)	0	69.2	7.8		68.1	10.9			0.1, *Trivial*
	12	63.4	8.5	−5.8 (−3.8–−8.2)	69.2	12.2	1.1 (−0.7–5.6)	<0.001	−0.7 *, *Moderate*
Hours slept (h/day)	0	7.0	0.8		7.6	0.8			−0.7 *, *Moderate*
	12	7.7	0.7	0.7 (0.4–1.1)	7.5	0.7	−0.1 (0.0–−0.3)	<0.001	0.4, *Small*
PSQI Global (score)	0	6.4	2.8		4.5	2.6			0.7 *, *Moderate*
	12	4.1	1.5	−2.3 (−1.7–−3.2)	5.0	2.7	0.5 (0.2–0.7)	<0.001	−0.5 *, *Small*
IPAQ-walk (min)	0	69.0	37.9		134.0	57.2			−1.3 **, *Large*
	12	102.3	69.2	33.3 (22.1–49.6)	122.6	77.6	−11.4 (−16.2–9.4)	<0.001	−0.6 *, *Moderate*
IPAQ-MVPA (min)	0	125.9	79.7		162.1	94.7			−0.4, *Small*
	12	227.0	83.0	101.1 (62.2–126.0)	159.0	99.8	−3.1 (−16.9–11.1)	<0.001	0.8 *, *Moderate*
F&V Intake (serve/day)	0	2.8	1.3		4.1	1.1			−1.1 **, *Moderate*
	12	5.5	1.7	2.7 (2.0–3.2)	3.9	1.3	−0.2 (−0.5–0.1)	<0.001	1.1 **, *Moderate*
PCS-12 (score)	0	42.1	4.1		51.1	5.5			−1.8 **, *Large*
	12	51.7	4.0	9.6 (7.1–10.8)	50.7	4.9	−0.4 (−1.3–0.2)	<0.001	0.1, *Trivial*
MCS-12 (score)	0	45.3	8.2		52.7	4.5			−1.1 **, *Moderate*
	12	51.1	4.9	5.8 (3.6–8.0)	51.8	4.7	−0.9 (−0.1–−1.7)	<0.001	0.2, *Trivial*

Mean ± SD reported for all participants, intervention, and control. Abbreviations: SD = standard deviation. BMI = body mass index. BP = blood pressure. MAP = mean arterial pressure. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * indicates statistical significance between groups ($p < 0.05$). ** indicates statistical significance between groups ($p < 0.001$).

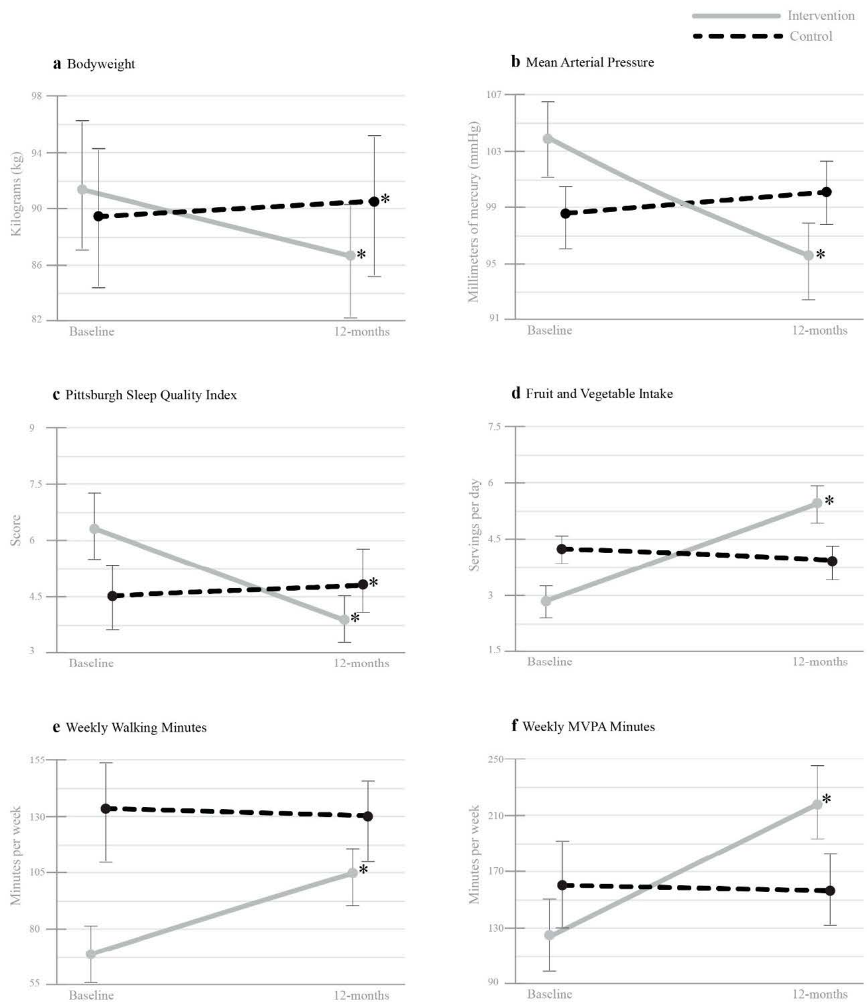

Figure 2. *Cont.*

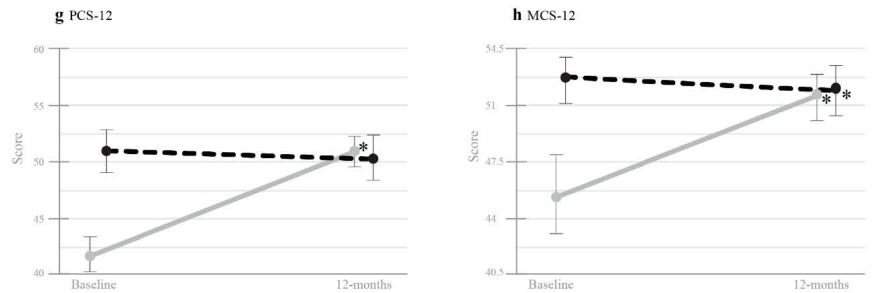

Figure 2. Mean values on objective and subjective health outcomes measured across time (Baseline and 12-months), showing 95% confidence intervals. (**a**), Bodyweight; (**b**), Mean Arterial Presurre; (**c**), Pittsburgh Sleep Quality Indx; (**d**), Fruit and Vegetable Intake, (**e**) Weekly Waliking Minuters; (**f**), Weekly MVPA Minutes; (**g**) PCS-12; (**h**), MCS-12. MVPA = moderate-to-vigorous physical activity. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * indicates a significant difference compared to Baseline.

3.5. Additional Analysis: Four-Month Post-Intervention to 12-Month Follow-Up Change

Table 3 presents changes within the intervention group between four-months (post-intervention) and 12-months follow-up. There were significant within group differences reported for body mass, BMI, MAP, weekly MVPA ($p = < 0.05$), and DBP ($p = < 0.001$), which were associated with *small* to *moderate* effect sizes towards positive health change. Conversely, a decay of *small* magnitude was observed for health parameters average sleep hours ($d = -0.23$), PCS-12 score ($d = -0.22$), and MCS-12 score ($d = -0.20$). No significant differences were observed for other health parameters.

Table 3. Additional analysis: Changes in objective and subjective health metrics from post intervention at 4-months to follow-up at 12-months in the intervention group.

	Time (Months)	Intervention (n = 35)			Effect Size
		M	**SD**	**Post-Follow-Up Change (95% CI)**	d
Body mass (kg)	4	87.7	12.8	-	-
	12	86.8	11.3	−0.97 (−1.81–0.1)	−0.47, *small* *
BMI (kg/m^2)	4	27.5	3.1	-	-
	12	27.1	2.7	−0.32 (−0.58–0.07)	−0.44, *small* *
Systolic BP (mmHg)	4	130.9	11.1	-	-
	12	128.1	10.3	−2.89 (−6.09–0.32)	−0.31, *small*
Diastolic BP (mmHg)	4	83.8	9.7	-	-
	12	78.9	8.0	−4.86 (−7.56–−2.15)	−0.62, *moderate* **
MAP (mmHg)	4	99.5	9.4	-	-
	12	95.3	7.6	−4.11 (−6.77–−1.46)	−0.53, *small* *
Pulse (bpm)	4	62.6	7.2	-	-
	12	63.4	8.5	0.74 (−2.0–3.5)	0.09, *trivial*
Hours slept (h/day)	4	7.8	1.0	-	-
	12	7.7	0.7	−0.11 (−0.27–0.05)	−0.23, *small*
PSQI Global (score)	4	4.1	1.8	-	-
	12	4.1	1.5	−0.09 (−0.31–0.14)	−0.13, *trivial*
IPAQ-walk (min)	4	94.3	96.5	-	-
	12	102.3	69.2	8.0 (−10.4–26.4)	0.15, *trivial*

Table 3. *Cont.*

	Time (Months)	Intervention (n = 35)			Effect Size
		M	SD	Post-Follow-Up Change (95% CI)	*d*
IPAQ-MVPA (min)	4	207.6	79.0	-	-
	12	227.0	82.6	19.7 (5.57–33.74)	0.48, *small* *
F&V Intake (serve/day)	4	5.6	1.9	-	-
	12	5.5	1.7	−0.13 (−0.49–0.23)	0.12, *trivial*
PCS-12 (score)	4	52.3	4.5	-	-
	12	51.7	4.0	−0.54 (−1.38–0.29)	−0.22, *small*
MCS-12 (score)	4	54.5	5.7	-	-
	12	51.1	4.9	−0.52 (−1.41–0.36)	−0.20, *small*

Mean ± SD reported for the intervention group. Abbreviations: SD = standard deviation. BMI = body mass index. BP = blood pressure. MAP = mean arterial pressure. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = physical component summary score. MCS-12 = mental component summary score. * indicates statistical significance ($p < 0.05$). ** indicates statistical significance ($p < 0.001$).

4. Discussion

This is the first 12-month follow-up study after a lifestyle health intervention during the COVID-19 pandemic. The present intervention aimed to improve health-related behaviors and promote healthy changes in bodyweight and blood pressure within overweight pilots through a personalized intervention on healthy eating, sleep hygiene and physical activity. The controlled trial showed that at 12-months follow-up, there appeared to be a significant improvement on health parameters from being provided the 17-week intervention [29], relative to our control group which supports our initial hypothesis. These results are important for researchers and health care professionals to provide insight into prolonged health and quality of life perturbations resulting from COVID-19 that may have potential implications to flight safety. Furthermore, given the dearth of published data pertaining to health behavior interventions during a pandemic and the limited availability of preventive lifestyle-based interventions in pilots, these findings provide novel contributions to this field.

Poor long-term maintenance of weight loss and health behavior change achieved from lifestyle diet and exercise interventions is frequently reported [43]. In our intervention group we observed sustained positive change in health behaviors at 12-months follow-up, relative to baseline characteristics. Further, body mass, blood pressure, and weekly MVPA continued to improve at 12-months compared to post-intervention, whereas other health parameter improvements demonstrated non-significant *trivial* to *small* magnitudes of decay from post intervention. These findings support our secondary hypothesis and are consistent with other health behavior research reporting reduced magnitude of change in health parameters at longitudinal follow-up, compared to post-intervention [44]. A contributing factor that has been proposed is the discontinuation of health care professional support, following intervention completion [45]. Thus, highlighting the importance of ongoing care to facilitate additional health outcome improvements after a brief intervention.

Prospective cohort studies have reported significant increases in body mass within four-months after the onset of the initial COVID-19 lockdown [46,47], yet limited studies have evaluated whether body mass gain is sustained longitudinally after lockdown conditions are lifted. In the present study, participants in the intervention group lost 4.9 kg (↓5.4%), while the control group gained 1.2 kg (↑1.3%) at 12-months, resulting in a 6.1 kg difference in body mass change between groups. Existing literature of lifestyle interventions targeting combined diet, physical activity, and sleep with longitudinal follow-up measures are scarce, limiting comparison accuracy of the present findings to existing research. Airline pilot populations are often male dominant [48]; indeed, our participant sample reflected this demographic. Contrarily, a recent meta-analysis reported the majority of participants in diet and exercise weight management interventions were women [49]. Thus, our study provides important evidence regarding the effectiveness of lifestyle interventions within males.

The intervention utilized 20 participant contacts; including two face-to-face consultations, one telephone call, and 17 intra-intervention emails. Comparatively, a recent review indicated a mean body mass reduction of 2.5 kg at one year follow-up within dietary interventions consisting of 13–24 intra-intervention participant contacts [50]. Another review reported a higher mean body mass reduction of 6.7 kg at one year follow-up pertaining to intensive combined diet and exercise interventions [33]. However, the average length of treatment of these interventions were 37 weeks [33], which is considerably higher than our 17-week intervention [29].

Another gap in the literature base is whether body mass gain observed during lockdown conditions is associated with increased blood pressure, which remains largely unexplored. The body mass gain evident in our control group was associated with a 3.8 mmHg increase in SBP at 12-months, compared to a reduction of 10.3 mmHg observed in the intervention group. The SBP reduction observed in the intervention group is comparable with previous research, which reported a 9.5 mmHg reduction in SBP at 12-months following an intensive diet and exercise lifestyle intervention [51]. Correspondingly, in our intervention group we observed a DBP reduction of 2.9 mmHg, and a further 4.9 mmHg at four-months and 12-months, respectively. Compared with our present findings, a similar longitudinal relationship between body mass and blood pressure following intentional weight loss has been reported [52]. Stevens and colleagues reported participants who succeeded at weight loss maintenance at 36 months post-intervention also maintained blood pressure reduction obtained after the intervention, whereas participants who gained weight also experienced increased blood pressure [52].

We discovered a significantly reduced MCS-12 score and increased PSQI global score (denoting worse sleep) at 12-months follow-up in our control group, with no significant change in other subjective measures. Indeed, previous studies have demonstrated associations between sleep and mental health [53]. Further, negative changes in sleep quality during the pandemic have been associated with negative affect, worry and elevated psychosocial stress [54,55]. These findings may be contributed to by additional factors acting on the pilot population during the time of this study, including decreased work availability [1], job security, financial concerns, increased time spent confined to the indoors due to self-isolation requirements during travel [3], and limited control over food choices during hotel self-isolation after flying internationally.

The magnitude of change observed in the present intervention may be at least partly attributable to; (a) the three-component diet, exercise, and sleep approach, (b) behavioral approaches including collaborative goal setting, face-to-face coaching, telephone call and regular emails, and (c) the potential active interest of the pilot population in enhancing their health to support their aviation medical license. Weight loss factors such as restrictive diets and restrictive caloric patterns have been suggested as effective in the short term, but often have a poor long term success rate, leading to weight regain [56]. Whereas the methods utilized in the present study supported a physically active lifestyle, managing life stress with health behaviors, accountability, and facilitation of autonomy via self-determined goal setting, all of which are associated with successful weight loss maintenance [57]. Airline pilots have been reported to exhibit higher personality scores for maturity, emotional stability, and intelligence when compared to general population norms [58]. These characteristics may positively influence intervention engagement and adherence, thus presenting an important consideration when generalizing our findings to the general population.

Potential limitations of the current study need to be considered in the interpretation of our findings. Firstly, although the sample size provided adequate power to distinguish statistically significant effects in the key outcome variables, the differential recruitment strategies and participant self-selection may have contributed to the differences which were observed at baseline for age, fruit and vegetable intake, weekly walking minutes, PCS-12 and MCS-12 scores, sleep duration, and MAP, with healthier characteristics in favor of the control group. Further, those who voluntarily participated in the intervention may have had strong motivation to engage in healthy change, which may have supported the magnitude of intervention effects observed. Thus, it is advisable that future research implements a randomization design, assigning conditions to participants. Secondly, for feasibility purposes the present study utilized self-report measures for health behaviors, which inherently produce lower accuracy to more invasive objective measures. To enhance outcome measure validity and reliability, utilization of objective methods would be preferential such as actigraphy to monitor sleep and physical activity, and photo logging of dietary behaviors to quantify health behavior metrics; however, this would be somewhat difficult to achieve over a period of 12-months.

5. Conclusions

In conclusion, the individualized 17-week healthy eating, physical activity, and sleep hygiene intervention implemented in this study elicited sustained positive change in all outcome measures at 12-months follow-up, relative to baseline characteristics. Further, body mass, blood pressure, and weekly MVPA continued to improve at 12-months compared to post-intervention, whereas other health parameter improvements demonstrated non-significant *trivial* to *small* magnitudes of decay from post intervention. These findings suggest that achievement of these three guidelines promote physical and mental health and improves quality of life among pilots during a global pandemic, yet more regular monitoring post intervention may further strengthen behavior change maintenance. Our study provides preliminary evidence that a multi-behavior intervention may be efficacious during a pandemic and that similar outcomes may be transferrable to other populations.

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Conflicts of Interest: The authors declare no conflict of interest.

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Chapter Seven Publication Print

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Article

The Effectiveness of a Combined Healthy Eating, Physical Activity, and Sleep Hygiene Lifestyle Intervention on Health and Fitness of Overweight Airline Pilots: A Controlled Trial

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Abstract: (1) Background: The aim of this study was to evaluate the effectiveness of a three-component nutrition, sleep, and physical activity (PA) program on cardiorespiratory fitness, body composition, and health behaviors in overweight airline pilots. (2) Methods: A parallel group study was conducted amongst 125 airline pilots. The intervention group participated in a 16-week personalized healthy eating, sleep hygiene, and PA program. Outcome measures of objective health (maximal oxygen consumption (VO_{2max}), body mass, skinfolds, girths, blood pressure, resting heart rate, push-ups, plank hold) and self-reported health (weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) were collected at baseline and post-intervention. The wait-list control completed the same assessments. (3) Results: Significant group main effects in favor of the intervention group were found for all outcome measures ($p < 0.001$) except for weekly walking ($p = 0.163$). All objective health measures significantly improved in the intervention group when compared to the control group ($p < 0.001$, $d = 0.41$–1.04). Self-report measures (moderate-to-vigorous PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) significantly increased in the intervention group when compared to the control group ($p < 0.001$, $d = 1.00$–2.69). (4) Conclusion: Our findings demonstrate that a personalized 16-week healthy eating, PA, and sleep hygiene intervention can elicit significant short-term improvements in physical and mental health outcomes among overweight airline pilots. Further research is required to examine whether the observed effects are maintained longitudinally.

Keywords: weight loss; nutrition; fruit and vegetable intake; aerobic capacity; moderate-to-vigorous physical activity; lifestyle medicine

1. Introduction

Adverse health outcomes promoted by occupational demands of airline pilots including shift and irregular work schedules, circadian disruption, sedentary activity, and high fatigue [1] may be mitigated through attainment of health guidelines for lifestyle behaviors: healthy diet, physical activity (PA), and sleep [2,3]. Non-communicable diseases (NCDs) including cardiovascular disease (CVD), stroke, type 2 diabetes, and their major risk factors are among leading causes of mortality and morbidity worldwide [4]. The presence of modifiable behavioral NCD risk factors including obesity, hypertension, physical inactivity, low cardiorespiratory fitness, unhealthy dietary patterns, short sleep, depression, high perceived stress levels, and high fatigue are each associated with adverse outcomes to acute and chronic health [4–6]. Obesity is a complex, widespread, yet modifiable NCD risk factor that poses a significant public health threat [7]. The obesity prevalence worldwide was estimated as 13% in 2015, which is nearly double the prevalence from 1980 [7]. In 2020, 67% of male airline pilots in New Zealand were classified as overweight or obese with hypertension affecting 27% of the population [8]. Moreover, this study reported the prevalence of insufficient fruit and vegetable intake, physical inactivity, and <7 h sleep per night among airline pilots as 68%, 48%, 33.5%, respectively [8].

The global economic burden associated with NCDs is estimated as $47 trillion between 2010 and 2030 [4]. Previous research has demonstrated evidence of significantly reduced longitudinal health care cost utilization following diet and exercise lifestyle interventions [9]. Relevantly, airline pilots undergo annual or biannual medical examinations, results of which influence flight certification status [10]. Ongoing health care costs associated with the presence of NCDs and their risk factors present economic implications for aviation medical care [4,10].

Better health status is generally associated with enhanced productivity and work performance [11]. In the context of commercial aviation, pilot work performance is imperative to flight operation safety. As established in the International Civil Aviation Organization's Annex 1, aviation medicine providers are required to implement appropriate health promotion for license holders (pilots) to reduce future medical risks to flight safety [10]. Thus, interventions that promote positive health of pilots, mitigate health risk factors for NCDs, and reduce longitudinal health care costs of employees are of importance to aviation medicine, health practices, and policies.

Limited studies have investigated the efficacy of health promotion interventions among airline pilots, and no studies to date have reported on cardiorespiratory fitness or body fat percentage among this occupational group [1]. Based on the findings of our recent preliminary research [2,12], we found a personalized three-component healthy eating, sleep hygiene, and PA intervention produced favorable outcomes in subjective health and reductions in body mass and blood pressure among airline pilots. Utilizing a different sample of pilots, the aim of the present study was to evaluate the effects of a three-component healthy eating, sleep hygiene, and PA program on cardiorespiratory fitness, body composition, and health behaviors in overweight airline pilots. It was hypothesized that the intervention group would have significantly greater improvements in physical fitness, body composition and health behaviors compared to the wait-list control group at four months.

2. Materials and Methods

2.1. Design

A parallel controlled study (intervention and control) with pre- and post-testing was conducted to evaluate the effectiveness of a personalized three-component, 16-week lifestyle intervention for enhancing subjective and objective health indices in airline pilots. This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07. The trial protocol is registered at The Australian New Zealand Clinical Trials Registry (ACTRN12622000233729).

2.2. Participants

The participants comprised of self-selected airline pilots who were recruited from a large international airline in New Zealand. Invitations to participate in the study were distributed to all airline pilots within the company through internal communication networks. Group allocation was determined by a first in, first serve basis due to intervention implementation capacity. Accordingly, pilots who expressed interest to participate in the study early and satisfied the eligibility criteria were allocated to the intervention group

(n = 86) and subsequent enrolments that exceeded initial capacity were allocated to the wait-list control (n = 80). Participants involved pilots from short-haul (regional flights) and long-haul (international flights) rosters. The participants allocated to the wait-list control group received no intervention and were invited to participate in the intervention after the study period.

Potentially eligible pilots who volunteered to participate were screened according to the following eligibility criteria: (a) aged >18 years, (b) pilots with a valid commercial flying license, (c) working on a full-time basis, (d) having a body mass index (BMI) of $\geq$25 (overweight), and (e) a resting blood pressure of >120/80 (systolic/diastolic). Pilots were excluded if medical clearance was deemed necessary prior to engagement in a PA program after completion of the 2020 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) [13].

Informed consent was obtained from participants prior to commencement of participation in the study and participants were notified that they were permitted to withdraw at any time during the study if they wish to do so. To encourage data blinding and anonymity during data analysis, participants were allocated a unique identifier code on their informed consent form and were instructed to input this into their online health survey in lieu of their name.

2.3. Intervention

At baseline the intervention group completed an individual face-to-face 60-min consultation session with an experienced health coach practitioner located at the airline occupational health facility, followed by provision of a personalized health program. Participants also received weekly educational content emails throughout the intervention and a mid-intervention follow-up phone call with a health coach to discuss progress and support adherence. Health coaching advice delivered to pilots was evidence-based and derived from experts in the fields of dietetics, physical activity, and sleep science.

For extended details of the procedures associated with the three-component intervention, readers are referred to the study of Wilson and colleagues [12]. In brief, the intervention incorporated seven behavior change techniques (BCT) including collaborative goal setting, action planning, problem solving, information about health consequences, self-monitoring, feedback on behaviors, and reviewing of outcomes. The intervention utilized 35 participant interactions: including two face-to-face consultations (baseline and post-intervention), one mid-intervention telephone call, 16 weekly emails, and 16 weekly self-monitoring surveys.

Between the participant and health coach, personalized collaborative outcome, process, and performance goals [12] were established at baseline for (a) sleep hygiene, (b) healthy eating, and (c) PA. Healthy eating goals were defined based on a healthy eating resource (see Appendix A, adapted from Beeken and colleagues [14] with amendments derived from Cena and Calder [15]). Sleep goals were set based on a Sleep Hygiene Checklist (see Appendix B) which was derived from previous sleep hygiene and stimulus control studies [12]. Physical activity prescription goals were established based on assessment of individual barriers and facilitators to physical activity, implementation of the frequency, intensity, time, and type principles [16], and progression to fulfillment of sufficient moderate-to-vigorous-intensity physical activity (MVPA) to meet World Health Organization health guidelines [17] according to individual capabilities. Sufficient physical activity was defined as $\geq$150 min moderate-intensity, or $\geq$75 min vigorous-intensity, or an equivalent combination MVPA per week [17].

2.4. Outcome Measures

Objective measures of health (maximal oxygen consumption (VO_{2max}), body mass, skinfolds, girths, blood pressure, resting heart rate, pushups, plank hold) and self-report measures (weekly PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) were collected at baseline and 4 months (post-intervention). Self-report measures (weekly MVPA, sleep duration, fruit, and vegetable intake) were also collected weekly to monitor intervention adherence via an online survey delivered through Qualtrics software (Qualtrics, Provo, UT, USA).

Participants were instructed to avoid large quantities of food, stimulants such as caffeine, and strenuous exercise 4 h prior to measurement of physiological outcome measures. Outcome measurement protocols for body mass, blood pressure, and subjective health have been previously described in detail [2,12]. In brief, at the start of the consultation session, participants completed an electronic questionnaire via an iPad (Apple, California, CA, USA) to provide data for self-report measures. Using standardized methods previously described [2], resting heart rate was measured utilizing a Rossmax pulse oximeter SB220 (Rossmax Taipei, Taiwan, China), height was recorded with SECA 206 height measures, body mass was measured with SECA 813 electronic scales (SECA, Hamburg, Germany), and blood pressure was measured with an OMRON HEM-757 device (Omron Corporation, Kyoto, Japan).

Skinfold measurements were collected following standardized procedures of the International Society for the Advancement of Kinanthropometry (ISAK) [18]. The skinfold sum was determined by measurements obtained for eight locations: biceps, triceps, subscapular, abdominal, supraspinale, iliac crest, mid-thigh, and medial calf. All skinfold measurements were taken from the right side of the body twice, with a third measurement taken if the difference between recordings were greater than 4%. The anthropometrical technical errors were under the recommended limits [18] for all final recorded measurements. Skinfold measurements were conducted by an accredited ISAK anthropometrist, using Harpenden calipers (British Indicators, Hertfordshire, UK) which were sufficiently calibrated as per the manufacturers' guidelines. Body fat percentage was derived from skinfold assessments and was calculated using updated sex and ethnicity specific equations reported elsewhere [19]. Girth measurements for the waist and hip locations were measured with a thin-line metric tape measure (Lufkin; Apex Tool Group, Sparks, MD, USA) congruent with standardized technique [20].

Push-ups and the plank isometric hold were utilized as assessments of musculoskeletal fitness, using previously reported standardized methods [21,22]. For push-ups, the hand release technique was utilized, where participants were instructed to keep their torso tight so that the shoulders, hips, knees, and ankles were aligned throughout the range of motion. At the bottom position, the hands were lifted from the floor between each push-up. Push-up cadence was coordinated by a metronome and participants completed maximum full range of motion repetitions until the onset of failure to maintain correct form [21]. The basic plank isometric hold technique was utilized, consisting of the participant holding a prone bridge position supported by their feet and forearms. Elbows were below the shoulders with the forearms and fingers extending forward. The neck was maintained in a neutral position so that the body remained straight from the head to the heels. Time was recorded from initiation of the position until the loss of the plank position [22].

For quantification of aerobic fitness, estimated VO_{2max} was obtained by participants performing a previously validated [23,24] 3-min aerobic test (3mAT) on a Wattbike (Woodway USA, Waukesha, WI, USA) electro-magnetically and air-braked cycle ergometer. Participants were given a full explanation of the protocol, safety procedures, the Wattbike seat and handle were fitted appropriately for the participant, who was also fitted with a Polar H10 heart rate strap (Polar Electro, Kempele, Finland). Full details on the procedure have been detailed elsewhere [23]. Participants completed a 10-min warmup consisting of self-paced cycling at 70–90 rpm with two 6-s sprints within that timeframe, as suggested by the manufacturer. The goal of the 3mAT was to maintain the highest power output possible for 3 full minutes. Verbal encouragement was provided, and participants were allowed to adjust the resistance and pedal cadence as needed throughout the test. Each participant's customized setup was noted, and the same procedures were carried out for the retest at 4 months.

Prior to baseline testing, the Wattbike was calibrated by the manufacturer, and a between session reliability assessment was conducted with the Wattbike utilizing a convenience sample of seven untrained airline pilots (aged = 42 ± 12 years, body mass = 80 ± 11 kg, height = 173 ± 4 cm, mean ± standard deviation (SD), 5 males, 2 females). Following standardized procedures [23,24], participants of the reliability trial performed the 3mAT twice separated by >48 h between assessments. For measurement of estimated VO_{2max}, the reliability trial produced a coefficient of variation (CV) of 4.3% and an intraclass correlation coefficient (ICC) of 0.98 (0.90–0.99), denoting acceptable CV [25] and excellent ICC reliability [26].

Self-report measures (PA, sleep quality and duration, fruit and vegetable intake, and self-rated health) have been previously described in detail [12]. In brief, self-rated health (physical and mental) were measured utilizing the Short Health Form 12v2 (SF-12v2) [27]. The International Physical Activity Questionnaire Short Form (IPAQ) was utilized to quantify self-report MVPA [28]. Self-report subjective sleep quality and duration were measured with the Pittsburgh Sleep Quality Index (PSQI) [29]. Daily fruit and vegetable intake were measured using dietary recall questions derived from the New Zealand Health Survey [28].

2.5. Statistical Analyses

G-Power software was utilized to calculate sample size required to detect a clinically significant change in primary outcome measures of ≥5% weight loss and a change of 3.5 mL/kg/min for VO_{2max} [30]. Our sample size power calculation suggested 65 pilots were required in each group to achieve 90% power and a 5% significance criterion to detect relevant differences between the intervention and wait-list control groups. To account for 20% dropout observed in a similar study [2], our target sample size was 156.

Statistical Package for the Social Sciences (SPSS, version 28; IBM Corp., Armonk, NY, USA) was utilized for all analyses. Listwise deletion (i.e., entire case record removal) was applied if individual datasets had missing values or for participants who did not complete post-tests. Stem and leaf plots were inspected to ascertain whether there were any outliers in the data for each variable. A Shapiro–Wilk test ($p > 0.05$) and its histograms, Q–Q plots, and box plots were analyzed for the normality of data distribution for all variables. Levene's test was used to test homogeneity of variance.

Independent *t*-tests were utilized to calculate whether any significant differences existed between groups at baseline. For categorical variables (long haul and short haul) the Chi square test was used. Between group analysis of pre-test and post-test were assessed using paired *t*-tests and analysis of covariance (ANCOVA) (respectively). To control for baseline differences between groups, baseline data were included as a covariate in the ANCOVA [31], in addition to inclusion of age and sex. Effect sizes were calculated using Cohen's d to quantify between-group effects from pre-test to post-test. Effect size thresholds were set at >1.2, >0.6, >0.2, and <0.2, which were classified as large, moderate, small, and trivial, respectively [32]. The α level was set at a p value of less than 0.05.

3. Results

3.1. Characteristics of the Study Population

Two-hundred twelve airline pilots were considered for eligibility and 148 were recruited to participate (Figure 1). Of them, 84% ($n = 125$) of recruits provided data for both timepoints, which comprised a combination of short-haul and long-haul rosters ($n = 60$ and 65, respectively). The dropout rates from baseline to post-intervention were 12% (time commitment $n = 5$; ceased employment $n = 3$; testing not fully completed $n = 1$) and 19% (time commitment $n = 8$; ceased employment $n = 4$) for the intervention and wait-list control groups, respectively. As displayed in Table 1, at baseline both groups demonstrated similar characteristics for most health parameters, yet the wait-list control group had lower SBP ($t(123) = 1.191$, $p = 0.03$, $d = 0.39$) and lower MAP ($t(123) = 2.113$, $p = 0.03$, $d = 0.38$). No significant differences were observed between groups for sex and fleet type.

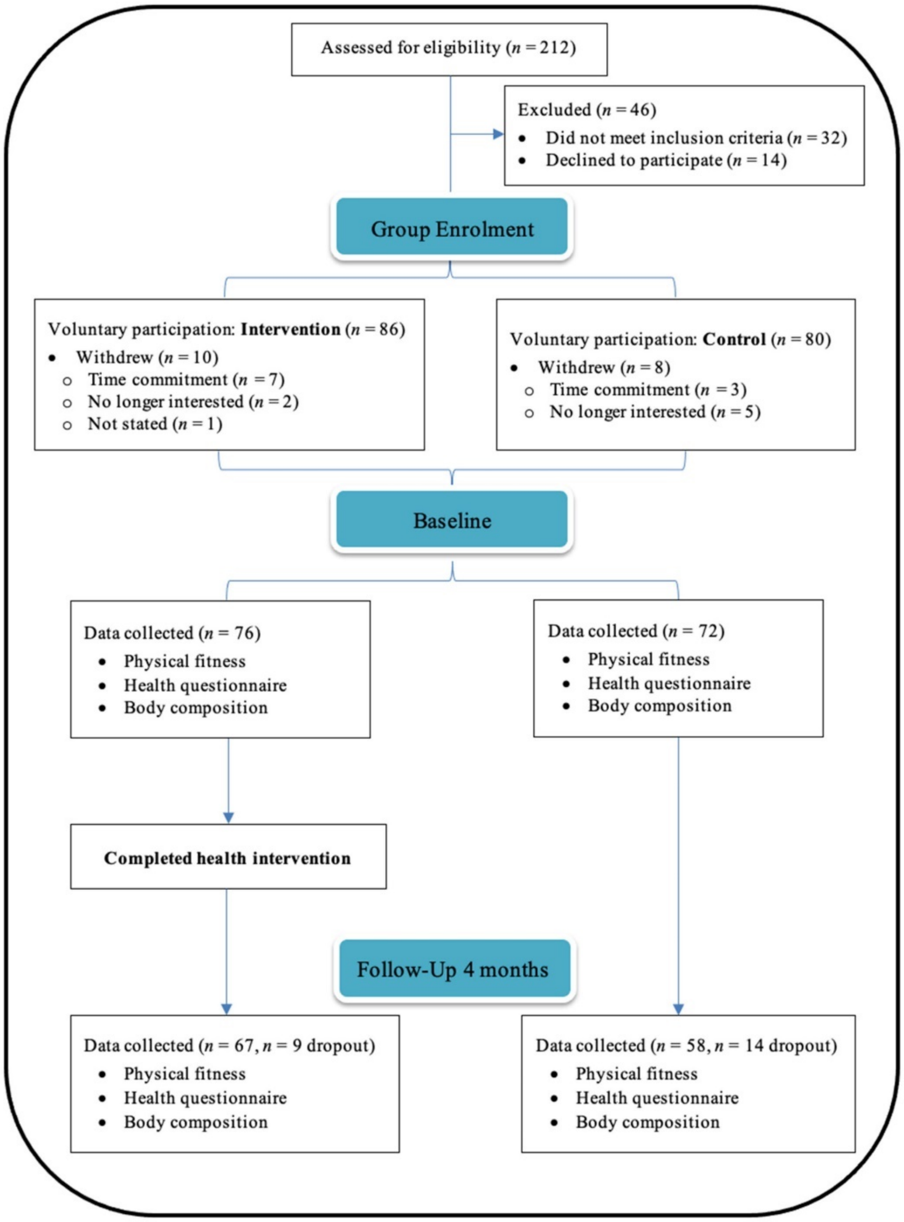

Figure 1. Flow diagram of participant recruitment and data collection.

Table 1. Baseline characteristics of participants.

Parameters	All subjects (*n* = 125)	Intervention (*n* = 67)	Control (*n* = 58)
Sex (female/male)	12/113	6/61	6/52
Age (years)	44.5 ± 10.7	43.7 ± 10.0	45.6 ± 11.4
Short haul (*n*)	60	34	26
Long haul (*n*)	65	33	32
Height (cm)	178.4 ± 7.4	179.2 ± 6.9	177.4 ± 7.8
Systolic BP (mmHg)	132.3 ± 5.6	133.3 ± 6.0	131.1 ± 4.9 *
Diastolic BP (mmHg)	85.6 ± 3.8	86.0 ± 3.9	85.0 ± 3.6
MAP (mmHg)	101.1 ± 3.8	101.8 ± 3.8	100.4 ± 3.6 *
Pulse (bpm)	66.9 ± 6.6	67.4 ± 6.1	66.4 ± 7.2
Body mass (kg)	90.5 ± 9.2	91.1 ± 8.0	89.8 ± 10.5
BMI (kg/m^2)	28.4 ± 2.0	28.3 ± 1.7	28.5 ± 3.4
Skinfold sum × 8 sites (mm)	136.5 ± 24.1	138.3 ± 17.7	134.4 ± 29.9
Bodyfat (%)	24.3 ± 3.6	24.7 ± 3.2	23.9 ± 4.0
Waist girth (cm)	96.6 ± 7.6	97.8 ± 8.1	95.2 ± 6.8
Waist to hip ratio	0.93 ± 0.07	0.94 ± 0.07	0.93 ± 0.08
VO_{2max} (mL/kg/min)	36.3 ± 5.4	35.6 ± 5.8	37.0 ± 4.8
Push-ups (repetitions)	17.2 ± 7.3	16.4 ± 6.8	18.1 ± 7.7
Plank hold (s)	79.7 ± 24.7	77.2 ± 25.5	82.5 ± 23.7
Walking per week (min)	73.8 ± 42.5	70.5 ± 32.2	77.7 ± 52.0
MVPA per week (min)	141.8 ± 41.1	138.0 ± 41.6	146.2 ± 40.3
Fruit intake (serve/day)	1.3 ± 0.7	1.5 ± 0.8	1.0 ± 0.6
Vegetable intake (serve/day)	2.0 ± 0.7	1.8 ± 0.7	2.4 ± 0.5
F&V intake (serve/day)	3.3 ± 0.7	3.3 ± 0.7	3.4 ± 0.7
Sleep per day (h)	7.0 ± 0.5	7.0 ± 0.4	7.0 ± 0.6
Global PSQI (score)	6.3 ± 2.1	6.4 ± 2.2	6.1 ± 1.9
MCS-12 (score)	48.9 ± 4.6	48.6 ± 5.8	49.3 ± 2.8
PCS-12 (score)	46.7 ± 3.4	46.3 ± 3.8	47.2 ± 2.8

Note: Mean ± SD reported for all subjects, intervention and control. Abbreviations: SD = Standard deviation; BMI = body mass index; VO_{2max} = maximal oxygen consumption; BP = blood pressure; MAP = mean arterial pressure; MVPA = moderate-to-vigorous physical activity; F&V = fruit and vegetable intake; MCS-12 = Short Health Form 12v2 mental component summary scale; PCS-12 = Short Health Form 12v2 physical health component summary scale; PSQI = Pittsburgh Sleep Quality Index. * Indicates statistical significance ($p < 0.05$).

3.2. Intervention Adherence

For the intervention group, compliance was measured mid-intervention for health behaviors, including self-report weekly MVPA, daily fruit and vegetable intake and average sleep duration per night. Sixty-four (97%) were achieving ≥5 serves of fruit and vegetables per day, 94% reported sleeping ≥7 h sleep per night, and 97% were obtaining ≥150 MVPA (min) per week. Comparatively, 36% of the wait-list control group were achieving ≥5 serves of fruit and vegetables per day, 71% were sleeping ≥7 h per night, and 53% were obtaining ≥150 MVPA (min) per week.

3.3. Body Mass, Skinfolds, Waist Girth, Bodyfat Percentage, Blood Pressure and Pulse

Significant group main effects ($p < 0.001$) in favor of the intervention group were found for all variables. Small to large effect size differences were observed from baseline to post-intervention (Table 2). The within-group analysis revealed that the intervention elicited significant improvements ($p < 0.001$) in all measures at post-intervention associated with moderate to large effect sizes (Table 2; Figure 2). The wait-list control group reported a significantly lower body mass (t(57) = 2.538, $p = 0.014$, d = 0.33) and reduced waist girth (t(57) = 2.358, $p = 0.022$, $d = 0.31$), yet no significant changes were observed in other measures.

Table 2. Changes in objective and self-report health measures from baseline to post-intervention at 4-months.

		Intervention (n = 67)			Control (n = 58)			ANCOVA (Group Main Effects)	Between Group ES
	Time (Months)	M	SD	Follow Up Change (95% CI)	M	SD	Follow Up Change (95% CI)	p	d
Body mass (kg)	0	91.1	8.0		89.8	10.5			0.14, Trivial
	4	85.6	7.7	5.5 (4.8–6.1)	89.4	85.6	0.4 (0.1–0.7)	<0.001	−0.41, Small
BMI (kg/m^2)	0	28.3	1.7		28.5	3.4			0.08, Trivial
	4	26.7	1.6	1.7 (1.5–1.9)	28.4	2.4	0.1 (0.0–0.2)	<0.001	−0.86, Moderate
Systolic BP (mmHg)	0	133.3	6.0		131.1	4.9			0.39, Small
	4	125.2	5.8	8.1 (7.3–8.9)	132.5	5.9	1.3 (0.1–2.8)	<0.001	−1.25, Large
Diastolic BP (mmHg)	0	86.0	3.9		85.0	3.6			0.27, Small
	4	80.8	5.4	5.2 (4.2–6.2)	84.8	4.7	0.2 (0.9–1.4)	<0.001	−0.77, Moderate
MAP (mmHg)	0	101.8	3.8		100.4	3.6			0.38, Small
	4	95.6	5.0	6.2 (5.4–6.9)	100.7	4.7	0.3 (0.8–1.4)	<0.001	−1.04, Moderate
Pulse (bpm)	0	67.4	6.1		66.4	7.2			0.15, Trivial
	4	61.0	6.5	6.3 (4.8–7.8)	67.0	8.8	0.6 (1.0–2.2)	<0.001	−0.78, Moderate
Skinfold sum (mm)	0	138.3	17.7		134.4	29.9			0.16, Trivial
	4	110.1	14.5	28.2 (26–30.5)	133.0	29.8	1.5 (0.5–3.4)	<0.001	−1.00, Moderate
Bodyfat (%)	0	24.7	3.2		23.9	4.0			0.21, Small
	4	21.0	2.8	3.6 (3.3–4.0)	23.7	4.1	0.2 (0.1–0.4)	<0.001	−0.79, Moderate
Waist (cm)	0	97.8	8.1		95.2	6.8			0.35, Small
	4	91.8	7.9	6.0 (5.3–6.8)	94.3	6.9	1.0 (0.1–1.8)	<0.001	−0.34, Small
Waist to hip ratio	0	0.94	0.07		0.93	0.08			0.09, Trivial
	4	0.90	0.07	0.03 (0.02–0.04)	0.92	0.07	0.1 (0.0–0.2)	<0.001	−0.22, Small
VO_{2max} (mL/kg/min)	0	35.6	5.8		37.0	4.8			−0.26, Small
	4	40.2	5.9	4.5 (4.0–5.0)	37.3	5.1	0.2 (0.1–0.6)	<0.001	0.52, Small
Push-ups (repetitions)	0	16.4	6.8		18.1	7.7			−0.22, Small
	4	24.3	7.1	7.8 (6.5–9.1)	19.9	8.1	1.9 (1.2–2.6)	<0.001	0.57, Small
Plank hold (s)	0	77.2	25.5		82.5	23.7			−0.21, Small
	4	120.0	39.6	42.8 (34.4–51.3)	92.1	32.1	9.5 (3.8–15.1)	<0.001	0.77, Moderate
Hours slept (h/day)	0	7.0	0.4		7.0	0.6			−0.17, Trivial
	4	7.6	0.5	0.7 (0.6–0.8)	7.1	0.5	0.1 (0.0–0.2)	<0.001	1.00, Moderate
PSQI Global (score)	0	6.4	2.2		6.1	1.9			0.14, Trivial
	4	4.0	1.3	2.4 (2.0–2.8)	5.8	1.8	0.3 (0.1–0.5)	<0.001	−1.16, Moderate
IPAQ-walk (min)	0	70.5	32.2		77.7	52.0			−0.17, Trivial
	4	97.0	30.0	26.5 (18.1–34.9)	95.4	49.0	17.8 (8.0–27.6)	0.163	0.04, Trivial
IPAQ-MVPA (min)	0	138.0	41.6		146.2	40.3			−0.20, Small
	4	210.3	44.3	72.4 (60.0–84.8)	156.9	46.4	10.8 (5.0–16.5)	<0.001	1.18, Moderate
F&V Intake (serve/day)	0	3.3	0.7		3.4	0.7			−0.17, Trivial
	4	6.9	1.3	3.6 (3.3–4.0)	3.8	0.9	0.4 (0.1–0.7)	<0.001	2.69, Large
PCS-12 (score)	0	46.3	3.8		47.2	2.8			−0.28, Small
	4	51.5	3.4	5.2 (4.4–5.9)	47.9	2.8	0.7 (0.3–1.1)	<0.001	1.14, Moderate
MCS-12 (score)	0	48.6	5.8		49.3	2.8			−0.15, Trivial
	4	53.3	3.6	4.7 (3.7–5.8)	49.5	2.9	0.2 (0.2–0.7)	<0.001	1.15, Moderate

Note: Mean ± SD reported for all participants, intervention and control. Abbreviations: M = mean; SD = standard deviation; CI = Confidence interval; ES = effect size; BMI = body mass index. BP = blood pressure. MAP = mean arterial pressure. MVPA = moderate-to-vigorous physical activity. PSQI = Pittsburgh Sleep Quality Index. IPAQ = International Physical Activity Questionnaire. F&V = fruit and vegetable intake. PCS-12 = Short Health Form 12v2 physical component summary score. MCS-12 = Short Health Form 12v2 mental component summary score.

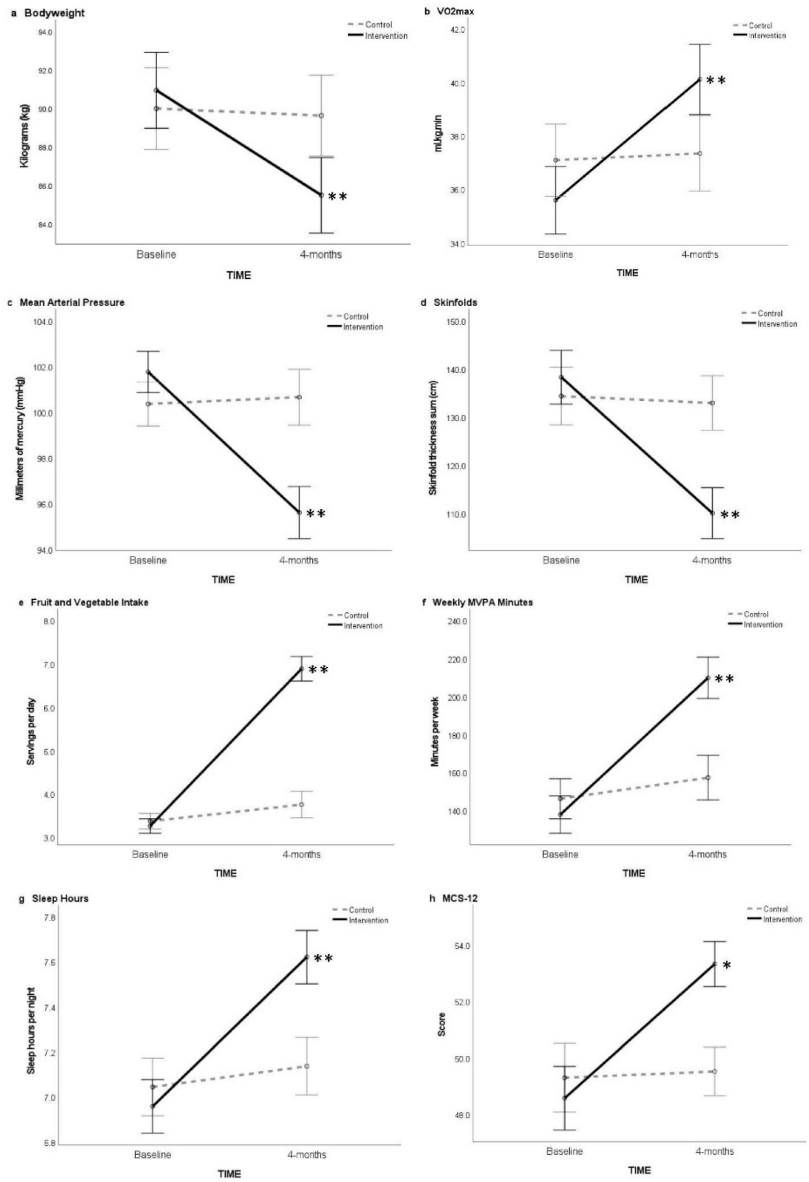

Figure 2. Mean values for health outcomes across time (baseline and 4-months), showing 95% confidence intervals ((**a**), bodyweight; (**b**), VO_{2max}; (**c**), Mean Arterial Pressure; (**d**), Skinfolds; (**e**), Fruit and Vegetable Intake; (**f**), Weekly MVPA Minutes; (**g**), Sleep Hours; (**h**), MCS-12). Abbreviations: VO_{2max} = maximal oxygen consumption; MVPA = moderate-to-vigorous physical activity; MCS-12 = Short Health Form 12v2 mental component summary score. Notes: * indicates moderate within group effect size from baseline to 4-months. ** indicates large within group effect size from baseline to 4-months.

3.4. VO_{2max}, Pushups and Plank Hold

Significant group main effects were found for all measures ($p < 0.001$) in favor of the intervention group. The within-group analysis reported significantly greater improved changes from baseline to post-intervention for all physical performance measures in the intervention group ($p < 0.001$), associated with large effect sizes (Table 2; Figure 2). In contrast, the wait-list control group significantly increased push-ups ($t(57) = 5.323$, $p < 0.001$, $d = 0.69$) and plank hold ($t(57) = 3.365$, $p = 0.001$, $d = 0.44$), yet no significant change was observed for VO_{2max}.

3.5. Health Behaviors and Self-Rated Health

Significant group main effects in favor of the intervention group were found for all self-report health measures ($p < 0.001$) except for weekly walking minutes ($p = 0.163$). The within-group analysis reported significantly greater improved health changes from baseline to post-intervention for all self-report health measures in the intervention group ($p < 0.001$), associated with moderate to large effect sizes (see Table 2; Figure 2). Further, the wait-list control group significantly improved weekly walking, weekly MVPA, global PSQI score, and Short Health Form 12v2 physical component summary scale score (PCS-12, $p < 0.001$), enhanced fruit and vegetable intake ($p = 0.008$), and increased sleep hours ($p = 0.020$). The significant changes observed within the wait-list control group from baseline to post-intervention were associated with trivial to small effect sizes (see Table 2).

4. Discussion

To our knowledge, this study is the first clinical trial that has explored the effects of a lifestyle intervention on physical fitness and body composition measures among airline pilots. This study aimed to promote enhancement in cardiorespiratory and musculoskeletal fitness, body composition, and health behaviors through a personalized intervention on healthy eating, sleep hygiene, and PA.

For most outcome measures, in support of our initial hypothesis the controlled trial revealed significantly higher improvements in the intervention group compared to the wait-list control group. Our findings suggest that a face-to-face health assessment alone with no provision of an intervention may promote small short-term effects for improvements in health behaviors and weight management among airline pilots. Furthermore, the provision of a personalized multicomponent lifestyle intervention may facilitate moderate to large short-term effects for promoting healthy changes in physical fitness, body composition, and health behaviors among airline pilots.

These findings are important for health care professionals and researchers to provide insight regarding the efficacy of lifestyle interventions for promoting health, and to inform practices relating to disease prevention, health promotion, and public health policymaking. Furthermore, in relation to the limited literature base pertaining to three-component sleep, nutrition, and PA interventions and the insufficient depth of health behavior intervention research among airline pilots, our findings provide novel contributions to this field.

Excessive adiposity is evidently associated with higher all-cause mortality and elevated risk of cardiometabolic NCDs [33]. Counteractively, clinically significant improvements in NCD risk factors have been reported with as little as 2–3% of weight loss among those with high BMI [34]. A meta-analysis of 59 lifestyle weight loss interventions reported a pooled mean weight loss range of 5–8.5 kg (5–9% body mass) within the initial six months, and among studies exceeding 48 months a mean weight loss range of 3–6 kg (3–6% body mass) [35]. Comparatively, in our intervention group we observed 6% weight loss and 1.6 reduction in BMI at four months. Weight loss and BMI alone as assessments of body composition change are inherently limited due to their inability to precisely measure central adiposity, fat distribution, bone density, and lean mass [36].

In the present study we assessed additional body composition metrics with girth and skinfold measures. Waist circumference has been reported as being strongly associated with all-cause and cardiovascular mortality, with or without adjustment for BMI [36]. Further, skinfold thickness has been reported as a better predictor of body fatness compared to BMI [37]. We found the intervention elicited a decrease of 6 cm waist circumference and 28 mm skinfold thickness sum reduction, which were associated with an overall 3.7% reduction in predicted body fat percentage and a decrease of 8.1 mmHg for systolic blood pressure (SBP). These findings are consistent, yet of higher magnitude than a previous meta-analysis which reported exercise training programs were associated with pooled mean reductions of 5.1 mmHg SBP and 2.2 cm waist girth [38]. This study also reported that reductions in blood pressure (BP) and waist circumference were associated with reduced high-density lipoprotein (HDL) cholesterol and metabolic syndrome risk reduction [38]. Thus, interventions which induce these adaptations are of importance for risk reduction of these well-established NCD risk factors [4].

To our knowledge, our study is the first to report on objective measures of cardiorespiratory capacity among airline pilots. Prospective cohort research suggests exercise capacity is an authoritative predictor of mortality among adults, and an increase of 1 MET (3.5 mL/kg/min) is associated with a 12% CVD risk reduction [30]. A meta-analysis of aerobic exercise training interventions among adults (aged 41 ± 5 y) reported a pooled mean increase in VO_{2max} of 3.5 mL/kg/min (1.9–5.2, 95% confidence interval (CI)), associated with a moderate effect size of 0.6 [39]. In comparison, we observed an increase of 4.5 mL/kg/min within our intervention group, associated with a large effect size which exceeds previously suggested thresholds for clinical relevance [26]. However, future research is required to determine whether these acute adaptations are longitudinally maintained after the brief 16-week intervention.

The intervention promoted significant positive health outcomes for health behaviors and self-rated health, associated with moderate to large effect sizes. Sleep duration increased by 0.6 h in the intervention group, which is a lower magnitude compared with a recent meta-analysis of behavioral interventions to extend sleep length, which reported a pooled increase of 0.8 h per night (0.28–1.31, 95% CI) [40]. In part, this variance may be related to the different nature of interventions, where the present intervention targeted multiple-behavior modification for nutrition, sleep, and PA simultaneously, compared with the individual component focus in other studies (i.e., targeting sleep modification alone) [40].

For weekly MVPA we found the intervention elicited an increase of 72 min/week, which is notably higher than a previous meta-analysis which reported a mean increase of 24 min/week from PA interventions implemented in primary care settings [41]. Similarly, a meta-analysis of behavior interventions to increase fruit and vegetable intake reported a pooled mean increase of 1.1 servings per day [42], which was a lower magnitude of change compared to the increase of 3.6 servings following the present intervention. Notably, a meta-analysis of effective BCTs for promoting PA and healthy eating in overweight and obese adults highlighted the use of goal setting and self-monitoring of behavior as strong predictors of positive short and long-term health behavior change [43]. Congruently, our intervention implemented these components in addition to five other BCTs, which may have contributed to the observed effect sizes of change.

Strengths and Limitations

A strength of this study is our findings add valuable contribution to a small global literature base pertaining to interventions that include components for each healthy eating, PA, and sleep hygiene. The magnitude of effect sizes for positive health change observed in the intervention may be at least partly attributable to; (a) the implementation of seven BCTs including collaborative goal setting, (b) the personalized multiple-component nutrition, PA and sleep approach, (c) the multimodal intra-intervention communication administered via face-to-face consultations, a telephone call, and regular educational emails, and (d) the potential underlying motivation of airline pilots to improve their health to maintain their aviation medical license.

Potential limitations of this study need to be considered in the interpretation of our findings. Firstly, pilots voluntarily participated in the study via self-selection. Thus, those who enrolled may have exhibited higher readiness and motivation for health behavior change than the general population, which may limit the generalizability of our findings. Secondly, for feasibility of implementation and to minimize participant burden, self-report measures for health behaviors were utilized which inherently possess inferior validity to more invasive objective methods. Accordingly, future research, including measures such as a food frequency questionnaire or photo meal logging for dietary behaviors and actigraphy coupled with heart rate monitoring (e.g., smart watches) for PA and sleep monitoring, would be valuable contributions to increase the validity of findings. Third, although the sex characteristics of our sample are congruent with the general airline pilot population [8], the lack of female participants limits the generalizability of our findings to female populations. Thus, future research should evaluate the effects of the intervention among an ample sample size of females. Finally, the intervention was delivered by an experienced health coach, which presents a barrier to intervention adoption at scale. Future research should evaluate the delivery of interventions using similar procedures via cost-effective and scalable methods, such as online modes of delivery (i.e., smartphone application).

5. Conclusions

The personalized 16-week healthy eating, sleep hygiene, and PA intervention implemented in this study elicited significant positive changes associated with moderate to large effects sizes in all main outcome measures at four months follow-up, relative to the wait-list control group. Our findings suggest that the achievement of these three guidelines promotes physical and mental health among overweight airline pilots and these outcomes may be transferrable to other populations. However, there is a need for future research to examine whether the observed effects are longitudinally maintained following the intervention.

Author Contributions: D.W. and N.G. participated in conceptualization of the study and data collection; D.W., M.D., B.J., P.W., T.C. and N.G. contributed to the design of the study, data analysis, interpretation of the results, and manuscript writing. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was approved by the Human Research Ethics Committee of the University of Waikato in New Zealand; reference number 2020#07. The trial protocol is registered at The Australian New Zealand Clinical Trials Registry (ACTRN12622000233729).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

TOP TEN TIPS FOR HEALTHY EATING

A system of habits to support a healthier you.

1. Emphasize whole foods

Choose unprocessed natural foods.

As food processing increases, nutrient density decreases. The more ingredients that are listed on a food, the more processed the food will likely be.

2. Reduce sugar where possible

Limit foods with added sugar (cookies, cakes, sugar sweetened beverages etc.) where you can. Read labels to avoid hidden sugars (sauces, cereals, dairy products etc.). Aim for less than 10% of daily energy from sugar or under 5% for better health.

3. Eat a rainbow of foods

Eat a variety of fruit and vegetables each day. Try those with rich colors of red, blue, green and orange. The more color in your day the more antioxidant, vitamins and minerals you will be getting.

4. Reduce white

Try to avoid the energy dense white foods like pasta, rice, bread, and potato. Use MyFitnessPal to understand other options. For example, 2 cups of broccoli with a curry is a healthier meal and some would say tastier than 2 cups of rice, and far fewer calories! Also consider having more vegetables that grow above the ground than those that grow below the ground.

5. Eat lean protein with each meal

Protein foods such as lean meat, chicken, fish, eggs, low fat dairy foods, bean, nuts, seeds, legumes and lentils aid in muscle repair and support lean body mass.

6. Caution with your portions

Do not heap food on your plate (except vegetables). Use the hand portion sizing guide to make good meal size decisions. Think twice before having second helpings.

7. Eat slowly and mindfully

Set aside adequate time for your meal so you're not rushed and chew your food well. While eating try to avoid watching TV or eating on the go. Pay attention to your food. Eat until you feel 80% full.

8. Think about your drinks

Drink 2 L of fluids a day. Choose mainly water. Unsweetened fruit juice contains natural sugar so limit to one glass a day (200 mL/one third pint). Alcohol is high in calories; limit to one unit a day for women and two for men.

9. Choose good fats

Choose fats that enhance your recovery and immune system not those that break it down. Some good sources of are nuts and seeds, nut butters, avocado, fatty fish, olive oil, and flaxseed oils.

10. Setup your healthy environment

If a food is in your house or possession, either you or someone you love, will eat it. If you remove the temptation of unhealthy foods from your surroundings and add more healthy options, you will set yourself up for success.

Appendix B

Sleep Hygiene Strategies for Enhancing Sleep	YES Achieving	NOT Achieving
1. Sleep at least 7 h		
2. Sleep routine or depower hour		
3. Regular sleep and wake time		
4. Dim lights near bedtime and turn off electronics >30 min before bed		
5. Avoid sleep disruptors 4–6 h before bed e.g., caffeine, large meals, alcohol		
6. Have a dark, cool, quiet sleep environment		
7. Exercise every day, not too close to bedtime		
8. Use the bedroom only for sleeping and intimacy		
9. Do a brain dump on paper before bed		
10. Early morning light exposure		

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