The menstrual cycle's effect on sleep in adolescent female athletes.

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Abstract

Sleep is a crucial aspect of recovery and overall well-being, yet many adolescent female athletes experience disruptions influenced by hormonal changes throughout the menstrual cycle. While research on elite adult athletes has explored sleep disturbances related to training and competition, there is limited understanding of how menstrual cycle fluctuations impact sleep in younger athletes. Variations in estrogen and progesterone levels across the follicular and luteal phases are known to affect sleep patterns, including sleep quality, duration and onset latency. Increased progesterone in the luteal phase, for example, has been linked to poorer sleep efficiency and greater difficulty falling asleep. Additionally, menstrual-related symptoms such as cramps, fatigue, and mood changes may further interfere with rest and recovery. Given the importance of sleep for athletic performance and well-being, the first chapter of this thesis seeks to examine the current knowledge on how different phases of the menstrual cycle influence sleep in adolescent female athletes.

The second chapter of this thesis presents an original study that examined how different phases of the menstrual cycle affect sleep in adolescent female athletes. Over the course of three menstrual cycles, ten participants (14.5 ± 1.9) who were in their early-to-mid and mid-to-late pubertal stages, tracked their sleep using both subjective and objective methods. They recorded sleep duration and perceived sleep quality in a sleep diary. Simultaneously, wrist-worn actigraphy devices (Fitbit) measured objective sleep metrics, including sleep duration, sleep quality, sleep onset latency, wake episodes, and wake time. The reliability of both subjective and objective sleep measures in adolescent female athletes during the follicular phase (FP) and luteal phases (LP) of the menstrual cycle was examined.

Subjective measures demonstrated poor reliability in the luteal phase (sleep duration: ICC = -0.22; sleep quality: ICC = -0.49) but fair to good reliability during the follicular phase for sleep duration (ICC= 0.69; CV = 4.9%) and sleep quality (ICC = 0.57; CV = 8.9%). Objective measures showed poor reliability during the luteal phase for sleep duration (ICC = -0.17; CV 11%) and sleep quality (ICC= 0.00; CV = 9.2%) but fair reliability during the follicular phase for sleep duration (ICC = 0.38; CV = 7.2%) and sleep quality (ICC = 0.51; CV = 5.8%).

When comparing objective data to subjective data, participants overestimated subjective sleep duration compared to the objective sleep duration data with the average difference being (1.38 h; p = 3.00 x 10^{-47}; effect size = 1.20). When comparing the two menstrual phases, sleep onset latency was non-significantly worse during the luteal phase compared to the follicular phase (LP = 20.8 mins; FP = 16.0 mins; p= 0.68; effect size = -1.54). Objective sleep quality was non-significantly worse in the luteal phase in comparison to the follicular phase (LP = 75.4; FP = 77.1%; p = 0.34; effect size = 1.56) and sleep duration was non-significantly shorter in the luteal phase compared to the follicular phase (LP = 9.04 hrs; FP = 9.09 hrs; p = 0.72; effect size = 0.24). Lastly, the mid-late pubertal group had

significantly longer sleep duration during the follicular phase compared to the early-mid pubertal group (7.98 vs 7.44 h; p =0.03; effect size = -4.36 ± 0.12).

The final chapter discusses the study's findings, indicating that although both subjective and objective measures have their advantages, the subjective measures tended to be more reliable during specific menstrual cycle phases. The participants underestimated their sleep duration, reinforcing the importance of combining objective and subjective measures to get more accurate assessments of sleep duration. The adolescent female athlete's sleep quality and sleep onset latency can slightly be impacted by the menstrual cycle phases and sleep patterns were subtly worse during the luteal phase in comparison to the follicular phase; however, there were no statistically significant differences observed in the sleep measures studied. Sleep patterns do seem to improve in the mid-late pubertal maturation stage when compared to the early-mid pubertal stage. The data show that it is important to understand and take into consideration the menstrual cycle phases and the maturation stages of our athletes when creating training and recovery plans for these adolescent female athletes; however, more investigation is required to understand the potential effects of the menstrual cycle on sleep disturbances and its effect on female participation and performance in sport.

Abbreviations

ANOVA – Analysis of Variance

BMI – Body Mass Index

CWI - Cold Water Immersion

E1 – Oestrone

E2 – Oestradiol or 17β- Oestradiol

E3 – Oestriol

EEG – Electroencephalography

ECG – Electrocardiography

EMG – Electromyography

EOG - Electrooculography

FOL – Follicular Phase

FSH – Follicle-Stimulating Hormone.

HWI – Hot Water Immersion

LH – Luteinising Hormone

LUT – Luteal Phase

mPOA – Medical preoptic area

MVPA - Moderate to Vigorous Physical Activity

OVU – Ovulation Phase

PMDD - Premenstrual Dysphoric Disorder

PMOS - Pubertal Maturation Observational Scale

PMS - Premenstrual Syndrome

POA – Preoptic area

PSG - Polysomnography

SD – Sleep Duration

SDEV – Standard Deviation

SL – Sleep Latency

SQ – Sleep Quality

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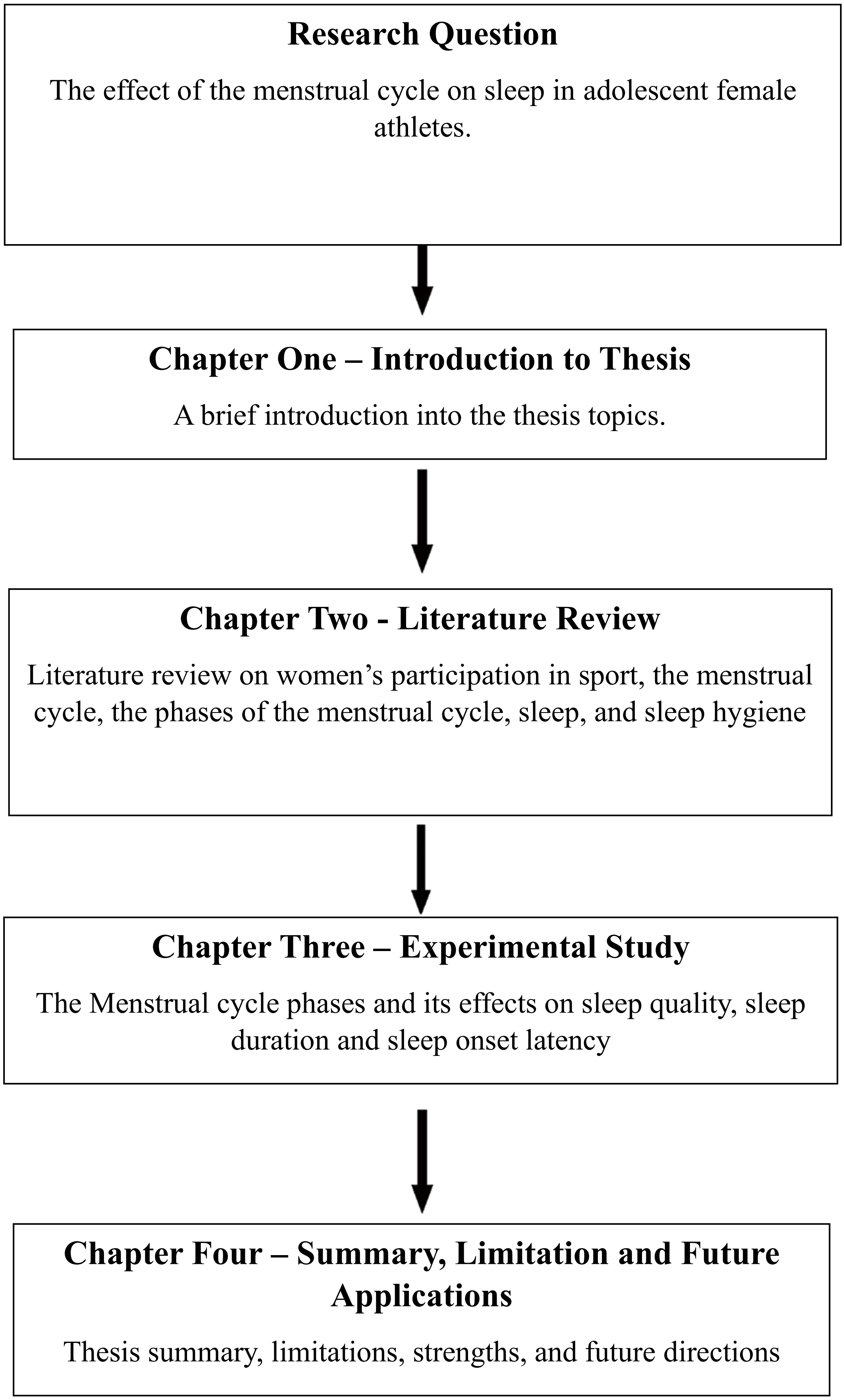
Thesis overview

The thesis's primary objective was to study the various effects of the menstrual cycle phases on sleep quality, quantity, and sleep latency in adolescent female athletes who all participate in water-dominant sports, such as surf lifesaving, swimming, water polo, and synchronized swimming. Four chapters make up the entirety of this thesis (See Figure 1). Chapter One contains a brief introduction to the thesis and the topics associated with the study. A literature review on the menstrual cycle, female sex hormones, menstrual cycle phases, sleep, and sleep hygiene is presented in Chapter Two. An experimental study outlaying the methodology, reliability of the instrumentation used, and results regarding the effects of menstrual cycle phases on sleep patterns in early-mid and mid-late pubertal stages are presented in Chapter Three and is in a format that would be suitable for peer-reviewed publications. To conclude the experimental study and the literature review Chapter Four discusses the study's limitations, implications, and recommendations for future directions in this area of research.

Research Aims and Objectives

The aims of the study were to investigate and determine how female adolescent athletes' sleep duration, sleep quality, and sleep onset latency may be affected by the two main phases of the menstrual cycle: the follicular and luteal phases. This study investigates the reliability of the subjective and objective sleep measure data, objective vs subjective measures, investigating and understanding how the menstrual cycle may have effects on sleep metrics, and whether there were any differences in sleep measures across the early-mid pubertal stage and the mid-late pubertal stage, which could help provide coaches, athletes, medical professionals, and parents with a deeper knowledge of how the menstrual cycle can affect sleep. Additionally, the study concentrates on understanding the various effects of the luteal and follicular phases on sleep, as well as the physical and psychological aspects of the menstrual cycle that may impact sleep patterns.

Figure 1: Flow diagram of the structure of the thesis



Chapter One – Introduction to thesis

Introduction

Sleep has been consistently identified as a critical recovery modality by both elite and sub-elite athletes and represents a novel frontier in performance optimisation for athletes (Halson, 2008). The restorative effects of sleep extend to the immune and endocrine systems, facilitate the recovery of the nervous system and metabolic processes associated with wakefulness, and are integral to cognitive function (Halson, 2008). The intersection of sleep, nutrition, and recovery is emerging as a significant area of growing interest (Halson, 2008). In New Zealand, the Ministry of Health (MOH) data from the 2020/21 period indicated notable differences in adherence to the recommended sleep duration between age groups. Specifically, approximately 69.1% of adults aged 15 years and older consistently met the recommended amount of sleep within a 24-hour period (MOH, 2024). In contrast, 78.3% of those aged 0 to 14 years achieved the recommended sleep guidelines (MOH, 2024). This disparity may reflect inherent differences in sleep requirements between adults and children, as well as varying external factors such as work commitments, educational responsibilities, sporting commitments, and screen time usage (MOH, 2024)

By the time a child reaches the age of 18, sleep accounts for about 40% of their life (Meltzer et al., 2013). Getting enough sleep is important for a child's health and wellbeing in many ways. A range of problems have been related to inadequate or disrupted sleep, such as obesity, poor emotional regulation, including symptoms of sadness and anxiety, problems with learning difficulties, poor attention, and academic performance, and problems with family dynamics (Meltzer et al., 2013). Other studies have shown that the negative effects of sleep deprivation are underappreciated despite studies confirming their links to disorders like hypertension, obesity, type-2 diabetes, cardiovascular disease, and impaired immune function (Chattu et al., 2018; Irish et al., 2015; Varma et al., 2021; Worley, 2018). Societal norms and underreporting in healthcare further obscure the negative impact of poor sleep, underscoring the need for greater public health emphasis on sleep as vital to overall well-being (Chattu et al., 2018). As a result, it is critical to evaluate many aspects of children's sleep using thorough metrics such as sleep diaries and polysomnography.

An additional factor to be considered in terms of its influence on sleep for this youth demographic is the menstrual cycle in female adolescents. The hormonal variations across the menstrual cycle add another level of complexity and have previously been shown to impact sleep patterns (Baker & Lee, 2022). Research indicates that these hormonal fluctuations throughout the menstrual cycle can affect sleep quality and duration, with greater disruptions reported during the luteal phase (Kuehner, 2017; Yonkers et al., 2008). Despite these findings, there is a significant research gap concerning how menstrual cycle phases specifically affect sleep and performance in adolescent female athletes, a group with unique developmental and training needs (Constantini et al., 2005). Therefore, this thesis aimed to investigate how the menstrual cycle phases affect sleep patterns in adolescent female athletes. Additionally, the thesis investigates the reliability of objective and subjective measures of sleep, the magnitude of the differences between objective vs subjective measures, and how the different pubertal stages affect sleep measures across the menstrual cycle phases.

Chapter Two - Literature Review: The effects of the menstrual cycle on sleep in adolescent female athletes

The purpose of this literature review is to conduct a scoping and critical synthesis of existing research surrounding the relationship between the menstrual cycle phases and sleep patterns in adolescent female athletes. This review aims to identify current knowledge, key findings, discrepancies, and gaps in the literature. By evaluating studies on this topic, the literature review attempts to understand the impact of the menstrual cycle on sleep, identifying areas where future research is needed, and may offer insights that could inform both clinical practice and future investigations.

2.0 Literature search methods

An online search method was implemented across four academic databases: PubMed, Medline, SPORT Discus, and Google Scholar. Keywords including "Female," "youth," "menstrual cycle," sleep disturbances," "Athletes," "Sleep," and "hormonal effects" were entered to retrieve peer-reviewed articles and clinical research were used. Abstracts and titles were first selected for relevance, followed by an evaluation of full-text papers to extract relevant information on sleep disruptions across the menstrual cycle. To ensure an unbiased synthesis of the literature, citation tracking and reference list reviews from relevant papers were performed. This methodological approach allowed for the collation of current findings, demonstrating how the menstrual cycle and the different phases within it may affect sleep in youth female athletes.

2.1 Women's participation in sport

Although women from all around the world have been participating in recreational and competitive sports for over one hundred years, sports have traditionally been associated with masculinity (Pfister, 2010). According to Pfister (2010), women in sports had always been the 'other sex' and they were outsiders, newcomers, or "latecomers" who could only participate in 'suitable' types of exercise and sport. Interestingly, the organisers of the first modern Olympics held in 1896, barred women from participating (de Borja et al., 2022). It was considered that women's engagement in competitive sports contradicted popular ideas at the time that soft, timid, and fragile women were more beautiful and desirable (de Borja et al., 2022). Misconceptions regarding physical effort as a threat to women's reproductive capacities misled the public into believing that women should only participate in sports that were perceived to be feminine and leisurely (de Borja et al., 2022). Lopiano (2000) described how medical authorities dating back to Aristotle declared that women were dominated by their reproductive systems, with a finite amount of energy running through their bodies, which was already depleted to dangerous levels by monthly hormonal expenditure (Lopiano, 2000). There is a historical record of females in sporting events; however, considerable progress was not seen until the 1948 Summer Olympic Games, when 385 female athletes competed (O'Brien & Robertson, 2010).

Female athletes have refuted stereotypes and broken down barriers, as seen by the exponential growth in women's participation in competitive sports (Lopiano, 2000). Over the last six decades, the number of female athletes has increased significantly, peaking in 2024 with the Paris Olympic Games being the first games to achieve strict parity between women and men (Suggs, 2024). Nowadays, girls' and women's sports involvement in all age groups is still expanding, especially in team sports, which in the past were looked down upon (Lopiano, 2000). More than fifty-five million women today engage in leisure sports and fitness activities regularly (Lopiano, 2000); however, there is still an obvious need for a better understanding of the physical exercise involvement of our female athletes (Coleman et al., 2008). Furthermore, to increase physical activity levels, we must understand the elements that determine 'whether', 'why,' and 'when' young women discontinue their participation in sport (Coleman et al., 2008). Similarly, we should be aware of the circumstances that support, discourage, or hinder their engagement in physical activity going forward (Coleman et al., 2008).

The prominent levels of disengagement from sport and physical activity among young women can be attributed to a range of complex factors. The serious and competitive nature of many traditional sports may deter participation due to perceived judgement and a lack of enjoyment. Concurrently, adolescence is marked by significant physiological, hormonal, and social changes that can affect engagement. Heather et al. (2021) state that physiological transitions, such as body changes and increased injury susceptibility, alongside shifting social dynamics and evolving pressures, can influence young women's motivation and opportunities for physical activity (Heather et al., 2021). According to the World Health Organisation, adolescents are recommended to engage in 60 minutes of moderate to vigorous physical activity daily; however, a concerning 81% of females aged 11 to 17 years do not meet these guidelines (Hopkins et al., 2022). Additionally, Hopkins et al. (2022) reported that adolescent girls are at an elevated risk of disengaging from sports earlier than their male counterparts. Globally, 85% of female adolescents of all ages fail to reach the recommended levels of physical activity, highlighting the urgent need for targeted interventions to address the distinct barriers faced by adolescent girls and to boost the overall engagement of female youth in physical activities (Hopkins et al., 2022). Increasing participation among specific groups, including adolescent females, is crucial for achieving these objectives and improving public health outcomes.

Given that the teenage years are crucial for establishing lifelong habits and positive relationships with physical activity, it is vital to address these barriers by promoting inclusive and supportive environments (Heather et al., 2021). This promotion includes designing accessible and engaging programmes, providing education on body changes and injury prevention, fostering supportive communities, and offering a variety of activities that emphasise enjoyment and personal satisfaction. Such measures can help young women build enduring habits and a lasting connection to physical activity (Heather et al., 2021).

In Aotearoa New Zealand, participation rates in sports and activities have declined among both adults and children. The average weekly participation among young people (5 to 18 years) fell from 5.0 activities in 2021 to 4.7 in 2022, down from a peak of 5.4 activities per week in 2018 (Sports New Zealand, 2023). In this context, “activities” are defined as structured human activities that involve physical exertion and skill with elements of competition or social interaction. These activities are regulated by formal rules and behavioural norms established by organisations and are broadly recognised as ‘sport’. Additionally, gender disparities are evident in the 2022 participation statistics, with female involvement decreasing from 5.1 to 4.5 activities per week, particularly among females aged 12 to 14 years of age (Sports New Zealand, 2023). The proportion of Aotearoa New Zealand females meeting the physical activity guideline of 7 hours per week has dropped to 49%, the lowest level recorded, down from 54% in 2018 and 2019, and a peak of 57% in 2021 (Sports New Zealand, 2023).

In Aotearoa New Zealand, significant disparities persist in the participation, involvement, and visibility of women and girls within sports and active recreation. These inequalities stem from a lack of meaningful engagement, which has led to unequal access to opportunities. It is crucial to recognise that women and girls are not a homogeneous group; their diverse needs must be met to ensure comprehensive support and engagement (Sport New Zealand - Ihi Aotearoa, Women and Girls’ Strategy, 2018). The New Zealand Government’s Women and Girls in Sport and Active Recreation Strategy aims to empower women and girls to achieve their potential in sport and recreation. It focuses on four principal areas: Leadership, Participation, Value and Visibility (Sport New Zealand - Ihi Aotearoa, Women and Girls’

Strategy, 2018). The goal of this strategy is to create a supportive environment where women and girls are not only visible but also valued and empowered in all roles within sport and active recreation. Achieving this vision requires systemic change, which can be accomplished through the combined efforts of key organisations like Sport NZ, High Performance Sport NZ, and other government bodies (Sport New Zealand - Ihi Aotearoa, Women and Girls' Strategy, 2018). This collaborative approach aims to challenge existing biases and implement evidence-based solutions to create real and measurable progress.

2.2 Puberty and its correlation with dropout

The biological and psychological factors that can affect adolescent females' participation in physical activity must be taken into consideration to effectively support them during the stage of puberty, a time when dropout rates for females are increased. For women one important biological marker of puberty is menarche. The age of menarche, marking the onset of a girl's first menstrual cycle usually occurs between 12 and 13 years of age, but can vary from 9 to 15 years and ends at menopause at an average age of 51 (Teixeira et al., 2012). The timing of menarche is influenced by several factors, including genetics, nutritional status, body composition, and physical activity levels. A study conducted by De Sousa et al. (2014), indicates that engaging in high-intensity physical activities, especially in sports that focus on maintaining a lean physique, can delay the onset of menarche. The amount of blood loss a female will experience during her menstrual cycle can range from slight spotting to 80 mL, with the average being 30 mL (Thiyagarajan et al., 2002).

The female reproductive cycle is an important biological process, and the menstrual cycle is known to be a prime example of a bio-psycho-social process (Brown et al., 2021). Chrisler (2008) reported this as a bidirectional phenomenon, representing a normal physiological process that both influences and is influenced by women's behaviours. These behaviours are shaped by underlying beliefs and attitudes, which are themselves informed by physiological experiences (Chrisler, 2008). From a physiological perspective, the menstrual cycle is a result of the activities of the hypothalamus, hypophysis, and ovarian hormones, which cause a range of changes in the female reproductive system. Hormones are released in a negative and positive feedback mechanism to govern the menstrual cycle (Teixeira et al., 2012). Eumenorrheic menstrual cycles are those that occur regularly and last between 21 and 35 days (Carmicheal et al., 2021).

Between 67% and 91% of elite female athletes are eumenorrheic, with half of these athletes not using contraception (Carmichael et al., 2021). These data show that a large proportion of female athletes may experience periodic hormonal variations (Carmichael et al., 2021); therefore, understanding how the menstrual cycle can impact exercise for females is critical for coaches and sports professionals to appropriately prescribe training and ensure optimal health and well-being (Brown et al., 2021). Developing an educational framework to advise coaches about the impact of the menstrual cycle and hormonal contraceptives in athletes participating in team sports, however, is difficult because most research on these topics is conducted on endurance or weight-restricted athletes (Clarke et al., 2021). It is also important to note that these reproductive hormones not only control reproductive function during the menstrual cycle, but they can also affect body temperature and circadian rhythms, with the potential to impact sleep hygiene for women (Nowakowski et al., 2013).

Research indicates that hormonal fluctuations throughout the menstrual cycle can affect sleep quality and duration, with disruptions occurring during the luteal phase (Kuehner, 2017; Yonkers et al., 2008). Extensive evidence suggests a strong connection between the regulation of sleep and body temperature, with the preoptic area (POA), particularly the medial preoptic area (mPOA), playing a critical role. Research indicates that the POA is integral to both sleep patterns and thermoregulation, with temperature-sensitive neurons in this region linked to sleep control mechanisms (Kumar., 2004). As noted by Kumar (2004), these overlapping regulatory systems may operate through a shared pathway, highlighting the relationship between sleep and thermoregulation.

In athletes, menstrual cycle phases can impact performance, with improved outcomes observed during the follicular phase and potential declines during the luteal phase (Kuehner, 2017; Constantini et al., 2005). According to Kissow et al (2022), maximal muscle strength is notably higher during the follicular phase and the ovulation than in the luteal phase, both in untrained and trained females. Furthermore, the recovery and repair of muscle fibres following eccentric exercise are more rapid in the mid-follicular phase compared to the luteal phase (Kissow et al., 2022; Haines et al., 2018). Additionally, mood changes related to premenstrual syndrome (PMS), or premenstrual dysphoric disorder (PMDD) can further influence sleep and performance (Yonkers et al., 2008). Despite these findings, there is a significant research gap concerning how menstrual cycles specifically affect sleep and performance in adolescent female athletes, a group with unique developmental and training needs (Constantini et al., 2005).

2.2.1 Follicular phase

The follicular phase marks the initial stage of the menstrual cycle, commencing on the first day of menstruation and typically lasting until the ninth day (Teixeira et al., 2012). This phase is primarily driven by the oestrogen hormones, specifically 17β-oestradiol (Thiyagarajan et al., 2002). Oestradiol (also known as estrogen) plays a critical role in preparing the endometrium for potential implantation. Through its action, 17β-oestradiol promotes the proliferation of the endometrial layer by increasing stromal and glandular components while deepening the spiral arteries that supply the endometrium (Thiyagarajan et al., 2002).

Oestrogens are a group of biologically active steroid hormones, and fluctuate significantly throughout the menstrual cycle, particularly during a woman's reproductive years (Hackney, 2017). These hormonal variations are primarily driven by oestradiol and progesterone (Hackney, 2017). In premenopausal women, oestrogens are synthesised in the ovaries, corpus luteum, and placenta, with additional contributions from nongonadal tissues such as the liver, heart, skin, and brain (Barbieri, 2014; Cui et al, 2013; Reed & Carr, 2015). The three principal forms of physiological oestrogens - oestrogen (E1), oestradiol (E2 or 17β-oestradiol), and oestriol (E3) - are produced through a series of enzymatic conversions of cholesterol (Barbieri, 2014; Cui et al, 2013; Reed & Carr, 2015). Notably, 17β-oestradiol is the most biologically potent and predominant oestrogen in premenopausal women (Cui et al., 2013).

Beyond its pivotal role in thickening the uterine lining during the menstrual cycle (Van Iten, 2016), 17β-oestradiol exerts widespread physiological effects across multiple systems. It influences reproductive and urinary tracts, cardiovascular function, bone metabolism, breasts, skin, hair, mucous membranes, pelvic muscles, and cognitive processes (Van Iten, 2016). Oestrogens act as signalling molecules by binding to specific cellular receptors, triggering distinct physiological responses, including tissue proliferation, menstrual regulation, and modulation of gonadotropin secretion to facilitate ovulation (Van iten, 2016; Nelson & Bulun, 2001). Additionally, oestrogens play critical roles in developing secondary sexual characteristics, maintaining bone density, regulating lipoprotein levels, controlling insulin sensitivity, and preventing urogenital atrophy (Nelson & Bulun, 2001). To summarise, during the follicular phase, 17β-oestradiol emerges as the dominant oestrogen, supporting endometrial proliferation and broader systemic functions essential to reproductive health and overall homeostasis in premenopausal women.

2.2.2 Luteal phase

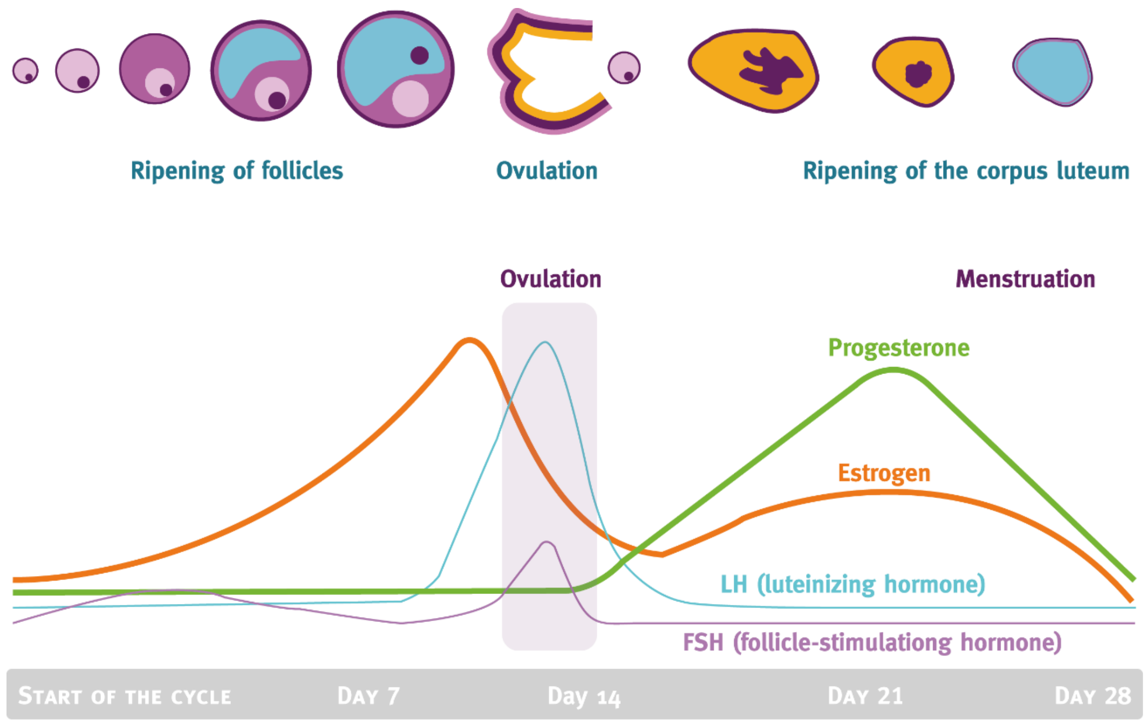
The luteal phase begins at the conclusion of ovulation and lasts until the onset of menstrual flow (Teixeira et al., 2012). This phase is characterised by elevated progesterone levels, which dominate the hormonal milieu to prepare the corpus luteum and endometrium for potential implantation of a fertilised ovum (Thiyagarajan et al., 2002). Progesterone plays a central role in maintaining the structural integrity of the endometrium and creating a conducive environment for pregnancy. During the luteal phase, the combined elevation of 17β-oestradiol and progesterone can lead to increased core body temperature, potentially impacting sleep (Charest & Grandner, 2022).

Progesterone is a steroid hormone primarily synthesised in the corpus luteum, a highly vascularised structure formed from the remnants of the dominant ovarian follicle following ovulation under the influence of luteinising hormone (LH) (Reynolds et al., 2018; Sundström-Poromaa et al., 2020). The corpus luteum typically remains active for approximately 14 days per menstrual cycle. Progesterone biosynthesis involves two key enzymatic steps: cholesterol is initially converted into pregnenolone within the mitochondria via cholesterol side-chain cleavage. Pregnenolone is then converted into progesterone through the action of 3β-hydroxysteroid dehydrogenase (Sundström-Poromaa et al., 2020). While the corpus luteum is the primary site of progesterone production, smaller contributions come from the adrenal glands, the placenta, and the brain (Sundström-Poromaa et al., 2020).

Progesterone secretion during the luteal phase exhibits distinct temporal dynamics. In the early luteal phase, its release is stable and not linked to pulsatile LH secretion. However, in the mid-to-late luteal phases, secretion becomes episodic, aligning with the pulsatile release of LH (Nagy et al., 2021). This hormonal orchestration ensures optimal endometrial receptivity during the critical implantation window.

Across the menstrual cycle, these hormonal fluctuations dictate distinct physiological transitions. During the follicular phase (Days 0-14), rising 17β-oestradiol levels from maturing ovarian follicles stimulate the proliferation of the endometrial lining (Figure 2). Follicle-stimulating hormone (FSH) initially remains elevated to support follicular development, while luteinising hormone (LH) stays low. At mid-cycle, a surge in 17β-oestradiol triggers an LH and FSH peak, precipitating ovulation around day 14. The subsequent luteal phase (Days 15-28) is marked by increased progesterone and 17β-oestradiol production from the corpus luteum, alongside suppressed LH and FSH levels. If fertilisation and implantation do not occur, declining progesterone levels lead to endometrial shedding, which initiates the next menstrual cycle with LH and FSH remaining low.

Figure 2: Diagram of the phases in a menstrual cycle



2.2.3 Monitoring the menstrual cycle.

Menstrual cycle tracking applications were first introduced in 2013 and have since become increasingly popular, with estimates suggesting that 50 million women globally use these applications (Worsfold et al, 2021). These applications enable users to monitor their menstrual cycles, providing forecasts for the onset of future cycles, as well as predictions for ovulation and fertile windows in the days preceding ovulation. These applications work by employing self-learning algorithms that refine their predictions based on accumulated user data, primarily using average cycle information. A review by Dole et al (2023), outlined other methods for monitoring the menstrual cycle, including self-reported tracking, where athletes log their cycle phases and symptoms, and objective measures such as hormone assays to quantify 17β-oestradiol and progesterone levels. Additionally, wearable devices that monitor physiological metrics such as body temperature and heart rate variability are employed to infer hormonal fluctuations (Dole et al, 2023).

Menstrual tracking applications present a significant opportunity to integrate educational content related to pain and symptom management, which can enhance the ability to manage menstrual-related symptoms more effectively. The high prevalence of these applications underscores their importance, with menstrual tracking applications being among the most frequently downloaded health-related applications, particularly among adolescents. This widespread use highlights the potential for these tools to support better menstrual health management and education (Worsfold et al, 2021).

2.2.4 Symptoms of the reproductive cycle in female youth

Menstrual cycle symptoms can significantly affect athletic training and performance, with distinct impacts across phases. Research highlights that during menstruation, symptoms like fatigue and cramps can hinder training (Manore, 2002). The follicular phase, characterised by rising oestrogen levels, typically enhances muscle repair and energy (Galliven et al., 1997). In the luteal phase, elevated progesterone often leads to symptoms such as bloating and decreased energy, thus negatively impacting training (Manore, 2002). While these effects are well-documented for adult athletes, there is limited research on youth athletes, underscoring the need for further investigation to tailor training programs to their unique physiological needs (Manore, 2002).

Research notes that these menstrual cycle symptoms are quite common and can be pronounced, even among otherwise healthy young women. Many women find that their mood, sense of well-being, information–processing capacity, and physical well-being can fluctuate during the menstrual cycle (Morse et al., 1988). Research has revealed that more than 70% of women report experiencing premenstrual symptoms such as irritability, decreased morale, depression, tension, fatigue, abdominal bloating, or backache (Moos et al., 1969). Additionally, Moos et al. (1996), reported that only 17% of a sample of 150 women were free from pain during the menstrual phase.

The menstrual cycle is shown to affect women in many ways. Changes in the menstrual cycle, such as irregular or absent periods, or excessive or painful bleeding may signal that the body is under stress due to an imbalance between physical and psychological demands (Sport New Zealand, 2023). Mental health is also affected through a multitude of processes. For example, many experience physical discomfort during menstruation and this physical discomfort can be related to increases in psychological anguish, impatience, and worsened self-esteem (Handy et al., 2022). For many female athletes, evidence suggests that they can experience psychological and behavioural symptoms associated with the menstrual cycle, including fatigue, insomnia, lethargy, poor coordination, and focus, all of which can negatively impact sports performance (Brown et al., 2021).

2.2.5 Impact of phases on sleep

Sleep is regulated by circadian rhythms, homeostatic processes, and thermoregulation, with core body temperature playing a key role in sleep readiness. Typically, core temperature drops before and during sleep, promoting sleep onset and reinforcing sleep duration. However, menstrual cycle-related hormonal fluctuations influence this process (Troynikov et al., 2018). Women can experience biphasic changes in body temperature and sleep quality throughout the menstrual cycle, which can have impacts on sleep patterns (Driver et al., 2008). When compared to the mid-follicular phase, higher body temperature is more typical in the mid-luteal phase which is associated with increased heart rates during sleep, decreased REM sleep, increased stage two sleep, and increased spindle frequency (Driver et al., 2008).

According to Nowakowski et al. (2013), women are more likely to experience insomnia, restless leg syndrome, and sleep dissatisfaction. It is believed that the influence of sex hormones on the circadian rhythm contributes to the differences in sleep patterns between men and women (Silvia et al., 2019). Baker & Driver (2004) found that 71% of women reported sleep disturbances due to symptoms like bloating, breast sensitivity, headaches, and cramps. The cyclical changes in oestradiol, progesterone, and body temperature can lead to a longer sleep onset and poorer sleep quality, particularly in the late luteal phase compared to that of the mid-follicular phase. When females have measured subjective sleep quality both right before and during menstruation, sleep quality tends to decline during these times, many women have also reported that menstrual symptoms like bloating, headaches, cramps, and breast tenderness tend to interfere with their ability to sleep (Baker & Driver, 2004).

Specifically, the survey conducted by Baker & Driver. (2004) found that 514 women reported menstruation symptoms cause sleep disturbances for approximately 70% of these females. Additionally, women reported more sleep disturbances during the late-luteal phase; however, no significant change in sleep duration compared to the mid-follicular phase, indicating that sleep disturbances are common in the luteal phase, even in the absence of premenstrual syndrome (PMS) symptoms (Manber & Bootzin, 1997). Much of the female population is vulnerable to sleep disturbances during reproductive hormonal changes, such as the menstrual cycle, although disturbances such as insomnia affect the general population to varied degrees (Meers et al., 2019). Poorer sleep quality during the premenstrual stage and the first few days of menstruation can be the result of hormonal fluctuations, which can alter circadian rhythms and sleep patterns (Meers et al., 2019). However, not all studies conducted on the menstrual cycle and its effect on sleep show a significant impact. There is individual variability in the relationship between the menstrual cycle and sleep quality; however, it is still evident that menstrual cycle-related sleep disturbance is widespread despite variability, more so during the premenstrual and menstrual phases of the cycle (Driver et al., 2008)

2.3 Sleep

For humans, sleep is a vital and intricate physiological and behavioural process that is essential for human survival and well-being. Sejnowski & Destexhe (2000), defined sleep as a reversible state of perceptual disengagement and unresponsiveness to the surroundings, which is accompanied by closed eyes, behavioural quiescence, and recumbence. Sleep is a physical state in which the brain never stops activity but becomes oblivious to the surroundings (Vennenman, 2023). In general, sleep is characterised by reduced interaction with surroundings, decreased muscle activity and mobility, and a partial or total temporary suspension of voluntary consciousness and behaviours (Venneman, 2023). It has also been shown that approximately four to five times during an average night, the physiological process of sleep can alternate between non-rapid eye movement (NREM) and rapid eye movement (REM) phases (Kumar, 2008).

Non-REM sleep is the start of the sleep cycle and after this REM sleep follows (Kumar, 2008). The average adult typically needs 7 to 8.5 hours of sleep per night to fully recover, though this can vary from person to person (Kumar, 2008). Overall, the average person spends between 20% to 40% each day sleeping, and approximately one-third of their life, asleep (Grander, 2022). Sleep helps maintain physical and mental health while also increasing energy levels; however, sleep deprivation is dramatically increasing among adolescents and young adults, with as little as a third regularly meeting sleeping guidelines (Giuntella et al., 2024).

Table 1: Studies examining sleep measures and the menstrual cycle

Study	Subjects (n)	Population	Sleep Measures	Results
Baker & Driver (2004)	26	University student population (18-31 years)	Sleep quality	↓ Sleep quality in LP
Kawasaki et al. (2024)	45	Female athletes (22.2 ± 1.1 years)	Sleep quality	↓ Sleep quality in MFP
Hrozanova et al. (2021)	15	Winter endurance athletes between (17.5 ± 5 years)	Sleep duration	↓ in SE, REM and REML in LP
Koikawa et al. (2020)	45	Female collegiate athletes (20.1± 1.1 years)	Sleep duration and sleep latency	↓TST and ↑SOL in LP
Topranin et al. (2023)	41	Female endurance athletes (27 ± 8 years)	Sleep quality	↓sleep quality in MLP
Carmichael et al. (2021)	5	Australian Football Athletes (18 - 35 years)	Sleep quality and sleep duration	↓ Sleep duration and sleep quality in LP
Matos et al. (2025)	214	Endurance and Ultra-Endurance runners (43 ± 13 years)	Sleep quality	↓ Sleep quality during the luteal phase
Lerfald (2020)	16	Female high-school cross-country athletes (17.5 ± 0.5 years)	Sleep quality	↓ sleep quality in LP
Taylor et al. (2024)	15	Endurance trained women (32 ± 5 years)	Sleep Onset Latency and Sleep Efficiency	↑SOL in MLP and ↓SE in MLP

Notes: Statistically significant (p<0.05)
Abbreviations, Sleep efficiency; REM, Rapid Eye Movement; REML, Rapid Eye Movement Latency; SL, Sleep Latency; TST, total sleep time; SOL, Sleep Onset Latency; SD, Sleep duration; SE, Sleep efficiency; M1/2, first or second night after menses onset; MF, Mid follicular; LP, Luteal Phase; MLP, Mid Luteal Phase; FP, Follicular phase

2.4 Discussion

Table 1 describes nine studies that fit the inclusion criteria for the review. Specifically, these studies investigated sleep patterns and their interaction with the female menstrual cycle. These nine studies show a general trend that indicates poorer sleep quality and sleep duration during the luteal phase in female populations, particularly among those females who are athletes. Baker and Driver's (2004) study determined that university students have poorer sleep quality during the luteal phase of their menstrual cycle and this finding is consistent with recent studies that focus on other female athletes. For instance, Koikawa et al. (2020) found that female college athletes had higher sleep onset latency (SOL) and a decrease in their total sleep time (TST) during the luteal phase, while a study by Kawaski et al. (2024) found that female athletes had a decrease in sleep quality during the mid-follicular phase (MFP).

Additionally, Hrozanova et al. (2021) reported that winter female athletes experienced a decline in rapid eye movement latency (REML), rapid eye movement (REM), and sleep efficiency (SE) during the luteal phase (LP). Similarly, Topranin et al. (2023) reported that female endurance athletes had poorer sleep quality during the mid-luteal phase (MLP). These results align with Carmichael et al. (2021) whose study on female Australian football players reported shorter sleep durations and decreased sleep quality during the luteal phase. These results are further supported by Matos et al. (2025) who reported that endurance and ultra-endurance runners had worsened sleep quality in the luteal phase of their menstrual cycle.

Overall, the evidence suggests a consistent trend towards worsened sleep quality during the luteal phase, especially within the population of female athletes. These studies suggest that when creating sleep and recovery plans it may be vital to consider taking the menstrual cycle into account. It is also clear that most of the research in this area has solely focused on participants who are roughly least 17 or older; the only study found that included adolescent female athletes (17.5 ± 0.5 years) is Lerfald (2020) whose study discovered poorer sleep quality in the luteal phase of the menstrual cycle. A significant gap is identified in the literature as there is limited inclusion of the younger female population. More research should be done on this understudied age demographic due to their unique pubertal maturation and during their early years of menarche which could impact the menstrual cycle phase interactions with sleep patterns and their participation in sport.

2.5 Measures of Sleep

Polysomnography

Sleep can be evaluated using both scientific and individual perspectives. Objective methods like polysomnography (PSG) and actigraphy are known for their reliability in gathering precise data on sleep parameters (Fabbri et al., 2021). Polysomnography measures numerous physiological attributes during both sleep and wakefulness, serving as a diagnostic tool to assess normal and disrupted sleep patterns (Bloch, 1997) The term "polysomnography" is derived from Greek and Roman roots, refers to the recording of various sleep-related signals. In practice, a variety of measurement techniques are used to record neurophysiological, cardiorespiratory, and other physiological and physical data across several hours, usually an entire night (overnight or whole-night PSG). Polysomnography provides information on the function of several organ systems and how they interact in connection to sleep and wakefulness (Bloch, 1997). The major physiological signal measured during PSG is brain electrical activity, often known as electroencephalography (EEG) (Kline, 2020). The simultaneous assessment of eye movement (electrooculography, or EOG), sub-mentalis muscle activity (electromyography, or EMG), and cardiac activity (electrocardiography, or ECG) is necessary for the distinction of specific stages of sleep (Kline, 2020). As such, PSG is considered the gold standard for sleep assessment.

Actigraphy

Actigraphy refers to the use of small, computerised wristwatch-like devices to monitor and collect movement-generated data. Actigraphy is a less intrusive and cost-effective alternative to polysomnography (PSG). Actigraphy devices can be worn continuously for lengthy periods of time (days, weeks, or even months) (Fekedulegn et al., 2020). Activity monitoring has a long history in both medicine and sleep research and collecting actigraphy data across numerous nights in the participant's natural surroundings can yield more valid estimates of sleep than PSG, which is typically performed for only one or two nights in a sleep laboratory (Fekedulegn et al., 2020). Most actigraphy devices use an analogue mechanism to detect movement (Sadeh & Acebo, 2002). The initial activity scores (such as those recorded in 1-minuite intervals) are converted into sleep-wake scores using a computerised scoring algorithm (Sadeh, 2011).

Actigraphy has been validated for general sleep measurement and is widely used in clinical and research settings due to its affordability, non-invasiveness, and ease of use without requiring a sleep technician (Mantua et al., 2016). However, a key limitation of research-grade actigraphy is its dependence on manually scored data, often guided by participant-reported sleep diaries that document bedtime, wake time, and time in bed (Mantua et al., 2016).While manual scoring has traditionally been the standard, new research indicates that technological advancements have made it achievable for automatic scoring algorithms to help generate sleep measurements that align with manual scoring techniques, suggesting increased practical utility and reliability (Edgar et al., 2023) Additionally, there has been limited research on the reliability of sleep staging provided by commercially available devices (Mantua et al., 2016). Various commercial devices are available, each with unique measurement features, necessitating specific sleep-wake scoring algorithms and validation studies (Sadeh, 2011). Notably, wearable devices such as the WHOOP and the Fitbit Charge 4 have demonstrated enhanced multistate sleep sensitivity and relative agreement, indicating their potential use in estimating important sleep parameters in research settings (Schyvens et al., 2024)

Sleep diaries

Due to their affordability, accessibility, and ease to use, sleep diaries and sleep questionnaires are commonly used for subjective sleep assessments and are one of the most popular tools in sleep research and clinical practices (Short et al., 2017; Mallinson et al., 2019; Gass et al., 2025). Sleep diaries are useful for capturing sleep-wake behaviours in naturalistic settings because they are frequently used to gather comprehensive, real-time date on sleep timing and duration over periods of time (Short et al., 2017; Mallinson., 2019). People who participate in filling out sleep diaries are required to record important sleep-related information, including bedtime, sleep onset time, wake-up time, get-up time, number and duration of nighttime awakenings, and napping. Subsequently, key sleep parameters such as total sleep time, sleep onset latency, sleep efficiency, and wake after sleep onset can be derived (Gass et al., 2025, Mallinson et al., 2019). Sleep diaries can be frequently used for both diagnostic purposes, such as identifying insomnia or circadian rhythm sleep-wake disorders, and for monitoring the effectiveness of treatment interventions (Gass et al., 2025). However, despite their positive effects, diaries depend on participant compliance and consistency and lack a universally accepted standard format, which limits the comparability across studies (Mallinson et al.,2019; Short et al, 2017). As a self-report tool, sleep diaries are also subject to participant recall and potential bias.

Table 2: Definitions of Sleep measurements measured through wrist-actigraphy

Sleep Measurements	**Units**	**Definition**
Total Sleep Time (TST)	Minutes	Minutes between lights off and lights on
Sleep Efficiency (SE)	%	% of time spent asleep in bed
Sleep Onset Latency (SOL)	Minutes	Time it takes to fall asleep after turning lights out
Wake After Sleep Onset (WASO)	Minutes	Total awakenings per night
Total Time in Bed (TTB)	Minutes	Total time spent in bed
Sleep Latency (SL)	Minutes	Total time taken for sleep onset
Sleep Onset Time (SOT)	Time Of Day	Total time of transition from wakefulness into sleep

2.5.2 Sleep as recovery for athletes

Sleep has been identified as an important strategy that can impact on athletic recovery. During sleep, the body conducts essential maintenance tasks, such as repairing tissues and clearing waste from the brain (Vennemann, 2023). Specifically, during non-REM sleep, blood flow to the muscle's increases, energy is replenished, tissues are repaired and grown, and growth hormone is released in children (El–Sheikh & Sadeh, 2014; Schlieber & Han, 2021). Consequently, a lack of sleep can affect growth and muscle repair (Vennemann, 2023). Athletes are commonly at a greater risk of sleep deprivation than non-athletes due to their training schedules, the pressures of competition, and the stress of competitive environments. Sleep also can indirectly affect athletic performance, due to impacting cognition, reaction time, and immune function (Cho & Im, 2024). For athletes, getting sufficient quality sleep is essential for recovery and to prevent non-functional overreaching or overtraining (Cho & Im, 2024). Overreaching results in short-term performance declines from accumulated stress, while overtraining leads to longer-term performance reductions with both physical and psychological maladaptation.

For any athlete, sporting achievements are based on optimal preparation and enough recovery time between training and competition. Sleep is becoming more recognised as playing a crucial role in the performance and recovery of athletes (O'Donnell & Driller, 2017). Sleep plays a complex role in human physiology, with well-documented effects on cognitive, cardiovascular, and metabolic systems (Carter et al., 2020). Sleep quality and quantity are said to be the single best psychological and physiological recovery approach accessible to athletes (O'Donnell & Driller, 2017). To have a restorative effect on the body, sleep must be adequate in duration, quality, and timing (Doherty et al., 2021). The National Sleep Foundation has developed sleep duration guidelines for adolescents (8-10 hours), adults (7-9 hours), and the elderly (7-8 hours) (Doherty et al., 2021).

Further, Doherty et al., (2021) stated that athletes may need higher-quality sleep than non-athletes, and therefore these sleep recommendations may be inadequate for athletic performance and health. A study by Charest & Grandner (2022), reported that if athletes do not get enough sleep this can impair muscular strength, speed, and other aspects of physical performance. The study also reported that poor sleep quality can increase the risk of concussions and impair recovery following injury (Charest & Grandner, 2022). Athletes frequently self-report poor sleep quality, especially before competitions, due to the anxiety, stress and even training load prior to competition, which can have an impact on performance (Silvia et al., 2019). Another study that investigated athletes and sleep prior to competition revealed that 64% of athletes experience poor sleep more than once in the nights prior to a major competition (Juliff et al., 2015). The most frequent sleep issue is trouble falling asleep, with 82.1% reporting the issue (Juliff et al., 2015). Andrade et al. (2021), argued that young athletes were 2.30 times more likely to experience poor sleep than adult athletes.

A night of insufficient sleep can impact an athlete's metabolism, endocrine function, and both athletic and cognitive outcomes, while also increasing their perceived effort during exercise (Charest & Grandner, 2022). Athletes tend to get less sleep than nonathletes, with O'Donnell & Driller (2017) reporting that athletes average 6.8 hours of sleep per night. Their study further revealed that female athletes sleep an average of 6 hours and 56 minutes. It is important to note that oestrogen and progesterone receptors, which are key female reproductive hormones, are in the brain's sleep-regulating areas (Hrozanova et al., 2021). This positioning allows for a significant hormonal influence on sleep in women (Hrozanova et al., 2021) and it is noteworthy that women report more sleep issues than men (Silvia et al., 2019). Research completed by Carter et al., (2020) showed that women were reported to have higher mean WASO, and lower total sleep time and sleep onset latency than men, however objective TST was non-significant between male and female ($p = 0.993$), according to a 2004 meta-analysis of 65 studies with healthy participants.

According to Hausswirth & Mujika (2013), recovery remains one of the least understood and least researched aspects of the exercise-adaptation cycle. The significance of the recovery phase cannot be emphasised enough and ignoring an athlete's recovery needs can lead to excessive fatigue accumulation, which not only diminishes workload tolerance and performance but also, raises the risk of injuries, as well as cognitive and mood disturbances. The complexity of fine-tuning recovery and stress can only be fully understood by considering all the factors that affect performance (Kellmann et al., 2018). These include all aspects of training, lifestyle, well-being, and the environment. Ignoring the importance of balancing recovery and stress can lead to problematic behaviours, such as poor time management, excessive training, and misaligned priorities (Kellmann et al., 2018). Continuous exposure to such dysfunctional demands can overwhelm an athlete's resources, potentially leading to serious health issues like under-recovery, overtraining syndrome, or even burnout (Kellmann et al., 2018). When the relationship between training and recovery becomes imbalanced, symptoms of fatigue develop, followed by a decrease in performance (Hausswirth & Mujika, 2013). Without proper recovery, athletes risk overtraining, fatigue, and reduced performance (Mardiana et al., 2013; Skorski et al., 2019).

This recovery process is crucial for resting, refuelling, and repairing the body after intense physical activity (Bonilla et al., 2021; Lee et al., 2017). It involves calculating emerging requirements based on activity levels and ensuring adequate nutritional intake (Siqueira et al., 2018). Understanding fatigue and muscle tissue damage is essential for effective recovery and improved work capacity. A review by Yoda et al., (2024) highlighted those aquatic therapies such as hot and cold-water immersion (HWI) and cold-water immersion (CWI), along with alternative methods like curcumin supplements, and electrostimulation offer promising potential for enhancing recovery and performance after training or competition for athletes. However, Yoda et al., (2024) state that future research is necessary to provide deeper insights and more effective solutions for supporting athletes' recovery and boosting overall performance. Overall, key aspects of recovery include adequate sleep, good hydration, nutritious food intake, and scheduling rest days in training (Boguszewski, 2015).

2.5.3 Sleep and recovery for youth athletes

For young athletes, monitoring training responses and balancing training load with appropriate sleep and recovery should contribute to their long-term development. The International Olympic Committee's consensus statement on youth athletic development emphasises the objectives of focusing on developing healthy, capable, and resilient young athletes, while encouraging widespread, inclusive, sustainable, and enjoyable participation and success at all levels of individual athletic achievement (Bergeron et al., 2015). Nevertheless, current evidence shows that with the rise in both training and competitive events, these athletes are engaging in significant and demanding training loads due to their involvement in multiple sports (Temm et al., 2022). Many youth athletes compete for a school team, a club, or a representative team in one or more sports, in addition to participating in regular physical education at school. This level of involvement contributes not only to a rise in injury rates among youth but also an increase in burnout rates (Temm et al., 2022). Burnout occurs when an athlete withdraws from a previously enjoyable sport due to chronic stress.

Fatigue plays a crucial role in influencing injury, burnout, and performance, and it is considered multifactorial, with various contributing mechanisms and effects. Factors such as stress, training load, nutrition, hydration, and sleep quality can all impact fatigue (Temm et al., 2022). Therefore, monitoring these factors and the resulting fatigue should include performance, biomechanical, physiological, and subjective measures, as each of these can be negatively affected by the training load. Moreover, this relationship is bidirectional, as fatigue can also impact the intended training load, potentially hindering an athlete's ability to meet established training targets (Halson et al., 2022). Thus, monitoring the training load, sleep, and recovery should be approached from both retrospective and prospective perspectives. Athletes striving for optimal performance must carefully balance the push toward their physical limits with the need for sufficient sleep and recovery time.

2.5.4 Sleep hygiene.

Given the importance of sleep for youth athletes, interventions to enhance sleep are called for. Sleep hygiene is defined as adjustable habits and environmental changes that can enhance sleep quality and extend sleep duration (De Pasquale et al., 2024). Thus, behavioural and environmental guidelines aimed at promoting sound sleep contribute to good sleep hygiene and were initially created to treat mild to moderate insomnia (Irish et al., 2015). Sleep hygiene education involves providing guidance on a range of lifestyle, behavioural, and environmental factors that impact sleep, including light exposure, noise levels, and temperature. Such education is aimed at equipping athletes with effective strategies to enhance both the quantity and the quality of their sleep. By addressing these various aspects, sleep hygiene practices help athletes optimise their sleep, which is crucial for improving performance, recovery, and overall health (O'Donnell & Driller, 2017). Sleep hygiene also relates to the development of healthy personal sleeping patterns and is a non-intrusive behavioural therapy that can treat insomnia, enhance sleep quality, and reduce daytime sleepiness (Chen et al., 2010).

2.6 Gaps in the literature

Although researchers have demonstrated that the menstrual cycle can influence sleep patterns, no study has sought to understand the levels of sleep disruption across the different phases of the menstrual cycle in adolescent athletes. Currently, little evidence exists on the interaction between the menstrual phases and sleep in early-mid pubertal females. Therefore, research is required to gain a better understanding of the effects of the menstrual cycle and how it can influence sleep in young athletic women. A better understanding of how the phases of the menstrual cycle can affect sleep in early adolescent populations, could be useful to athletes, parents, strength and conditioning coaches, and the general population.

Although research has explored the broader impacts of hormonal changes on sleep, few studies have specifically investigated how menstrual cycles affect sleep patterns in adolescent female athletes, with limited research examining the link between sleep duration, sleep quality, and early pubertal female athletes. This thesis will focus exclusively on this demographic, examining how menstrual cycle phases impact sleep quality, quantity, and latency in a population that is both physically active and under significant social, athletic, and academic pressures. By doing so, it aims to provide targeted insights and may help to inform interventions tailored to improve sleep and overall performance among adolescent female athletes with the goal of maximising participation in sport.

In conclusion, addressing the existing gaps in the literature regarding the effects of the menstrual cycle phases on sleep in adolescent female athletes will help to advance our understanding and may provide insight to enhance their overall well-being through targeted interventions. Focusing on this specific demographic and incorporating objective measures of sleep will enable researchers to assess how menstrual phases interact with both objective and perceived sleep measures. By bridging these gaps, we can move towards generating valuable insights for both sleep science and sports medicine, leading to the development of targeted interventions that improve sleep quality, optimise athletic performance, and support sport participation and the overall health of young female athletes.

2.7 Research Questions

1. Are objective and subjective measures reliable tools to use when assessing sleep parameters in studies involving adolescent female athletes?

2. How comparable are objective and subjective measures of sleep quality and duration in adolescent female athletes?

3. Is there a difference in sleep quality, sleep duration, and sleep onset latency during the luteal and follicular phases of the menstrual cycle in adolescent female athletes?

4. Does pubertal maturation have an influence on sleep patterns across the menstrual cycle in adolescent female athletes?

Chapter Three - Original Study

The effects of the menstrual cycle on sleep in adolescent female athletes

3.0 Abstract

Introduction: Hormonal fluctuations associated with the menstrual cycle influence sleep efficiency, latency, and disturbances, potentially affecting performance and training adaptation. While research suggests poorer sleep in the luteal phase, findings remain inconsistent, with a lack of research including younger athletes. This study aimed to investigate the reliability of objective and subjective sleep measures in adolescent female athletes across multiple menstrual cycles and assess the impact of menstrual phase on sleep measures.

Methods: The study employed a mixed-method longitudinal observational. Sleep data was collected over three to four menstrual cycles using Fitbit Charge 5™ actigraphy, sleep diaries, and menstrual tracking applications in a cohort of ten female athletes (14.5 ± 1.9 years). Participants were categorised by pubertal stages (early-mid pubertal and mid-late pubertal). The reliability of subjective and objective measures used to report the sleep parameters were reported as typical errors, intra-class correlations, and coefficients of variation. Pairwise comparisons assessed differences in sleep duration, latency, and quality between follicular and luteal phases.

Results: Subjective measures demonstrated poor reliability in the luteal phase, sleep duration (ICC = -0.22) and sleep quality (ICC = -0.49) but fair to good reliability during the follicular phase, sleep duration (ICC= 0.69; CV = 4.9%) and sleep quality (ICC = 0.57; CV = 8.9%). Objective Fitbit measures observed poor reliability during the luteal phase, sleep duration (ICC = -0.17; CV 11%) and sleep quality (ICC= 0.00; CV = 9.2%) but fair reliability during the follicular phase, sleep duration (ICC = 0.38; CV = 7.2%) and sleep quality (ICC = 0.51; CV = 5.8%). Typical errors seemed to be low during both objective and subjective measures when collecting data in the follicular phase. The typical error was at its lowest during follicular subjective sleep duration (TE = 0.43) indicating better reliability. Objective sleep latency had the highest typical error during the luteal phase (TE = 11.14) indicating a moderate amount of variability between repeated measures. When comparing objective data to subjective data, participants overestimated subjective sleep duration by 1.38 h ($p = 3.00 \times 10^{-47}$; effect size = 1.20) indicating that subjective data cannot be used interchangeably with objective actigraph-based data. When comparing the two menstrual phases, sleep latency was non-significantly longer during the luteal phase compared to follicular phase (LP = 20.8 min; FP = 16.0 min; p = 0.68; effect size = -1.54). Sleep quality was lower in the luteal phase in comparison to the follicular phase when measured with the Fitbit (LP = 75.4%; FP = 77.1%; p = 0.34; effect size = 1.56), and sleep duration was shorter in the luteal phase compared to the follicular phase (LP = 9.04 h; FP = 9.09 h; p = 0.72; effect size = 0.24). Of note, we observed longer

sleep durations in the mid-late pubertal group (7.98 h) compared to the early-mid pubertal group (7.44 h) these results showed statistical significance ($p = 0.03$).

Conclusion: This study investigated the reliability of objective and subjective sleep measures, the accuracy of subjective and objective sleep measures, the impact of the follicular phase and the luteal phase of the menstrual cycle on sleep patterns, and the influence of pubertal maturation on sleep patterns in adolescent female athletes. Although both subjective and objective measures have their advantages, the results indicated that subjective measures are usually more reliable during specific menstrual cycle phases. The participants underestimated their sleep duration, reinforcing the idea of combining objective and subjective measures to get more accurate assessments of sleep patterns. Sleep quality and sleep onset latency appear to decline slightly during the luteal phase in comparison to the follicular phase; however, these data were not statistically significant in the current study. Lastly, the results indicated that participants who were in the mid-late pubertal stage had longer sleep durations when compared to the early-mid pubertal stage, which may be due to biological rhythms becoming steadier. Together these results highlight the importance of considering the menstrual cycle and developmental factors when monitoring sleep patterns in adolescent female athletes.

3.1 Introduction

Sleep is known to be important for recovery, athletic performance, and overall well-being. For females, sleep can be affected by a vast array of physiological factors, such as hormonal changes relating to the menstrual cycle. According to previous research, sleep quality, sleep latency, and sleep quality may differ between the luteal and follicular phases of menstruation (Baker & Driver, 2004; Baker et al., 2012; Hrozanova et al., 2012). Understanding these variations is essential for optimising rest and recovery strategies for female athletes.

The menstrual cycle consists of distinct phases: follicular, ovulation, and luteal, each characterised by hormonal fluctuations that may affect sleep. Oestrogen and progesterone, have been linked to changes in sleep architecture, including sleep efficiency, latency, and disturbances (Baker & Lee, 2022; Kuehner, 2017). Prior research has reported inconsistencies in sleep quality throughout the phases of the menstrual cycle, while some of these findings may be minimal, others suggest that females experience poorer sleep during the luteal phase of the cycle which may be due to the elevated progesterone levels (Yonkers et al., 2008; Ishikura et al., 2024). A female athlete's capacity to perform well and train effectively could be impacted by these hormonal changes during the cycle which has been shown to affect mood, thermoregulation, and recovery (Kumar, 2004).

Many studies have been done on adult female athletes, however research looking into adolescent female athletes is limited. Despite a growing awareness of how the menstrual cycle can impact athletic performance, sleep, and recovery, little is known about how menstrual phases can affect sleep and recovery in adolescent populations. Therefore, this study aimed to assess how reliable sleep measures are across menstrual phases, how objective and subjective sleep measures compare, and the impact of the menstrual phases on sleep measures in this population where decreasing participation in sports is a concern.

3.2 Methods

3.2.1 Design

The study conducted was a mixed-method longitudinal observational approach and examined the effect of the luteal and follicular phase on sleep patterns over three to four full menstrual cycles. The study used quantitative methodologies to be able to test our hypothesis on how the menstrual cycle phases could affect sleep duration, sleep latency, and sleep quality (Rehman & Alharti, 2016). Sleep data was collected during this study using both subjective (sleep diaries) and objective measures (e.g., Fitbit Charge 5). During the study, no experimental manipulation was involved. This approach allowed the assessment of sleep variations in both early-mid and mid-late pubertal female athletes during their follicular and luteal phases.

3.2.2 Classification of Menstrual Cycle Days

Each day was categorised based on the phase of the menstrual cycle. Menstrual cycle days were classified into two phases: Follicular Phase (FOL), which included: the days from the start of menstruation, and the Luteal phase (LUT), which spans from ovulation until the onset of the next menstrual cycle. Participants measured the first three days of each of these phases. This classification allowed for an analysis of the reliability of sleep measures, the comparison of objective and subjective sleep measures, and the impact of menstrual cycle phases on sleep measures in both early-mid and mid-late pubertal female athletes.

3.2.3 Participants

A cohort of ten female adolescent athletes, ranging from eleven to eighteen years old (mean age: 14.5 $\pm$ 1.9 y), who had engaged in sports at a club level or higher, were selected for this study. Participants were recruited from sports teams, clubs, and schools within the Western Bay of Plenty region. Prior to recruitment, we collaborated with these institutions to obtain consent, distribute recruitment flyers, display posters, and advertise the study, ensuring that candidates met the inclusion and exclusion criteria.

3.2.4 Inclusion Criteria

Eligible participants had to be adolescent, between twelve and eighteen years of age, and had started a regular menstrual cycle. Participants were also given one-on-one instructions on how to complete the sleep diary and to use the Fitbit Charge 5 TM. To enhance the generalisability of the study, a diverse sample was recruited, encompassing a range of socioeconomic backgrounds and racial/ ethnic origins. Participation then commenced only after obtaining consent from the parents or legal guardian of any minors involved.

3.2.5 Exclusion Criteria

Exclusion criteria were implemented to mitigate potential limitations and control for factors that could confound the study results. Participants with a history of clinically recognised sleep disorders, such as insomnia or sleep apnea, were deemed ineligible, as these conditions may adversely affect sleep patterns. Additionally, females who were on any medications or substances that could interfere with their sleep were excluded from this study. Due to potential hormonal changes or changes to the menstrual cycle, women who were pregnant or had recently given birth were excluded. Any females who were on any forms of contraception, hormonal replacement treatments, or who had irregular menstrual cycles were not asked to participate. No males were considered for this study. Furthermore, participants who were unable get a parent/guardian consent were not considered for participation in the study. All participants were informed that failure to meet inclusion criteria or failure to gather proper consent would not be allowed to participate in this study.

The participants who met all inclusion requirements were then categorised into two groups: early-mid pubertal and mid-late pubertal; this was based on their pubertal development. To appropriately categorise these groups, the Tanner stages (Tanner, 1998) or the Puberal Maturation Observational scale (PMOS) were used. Both participants and parents/guardians were involved during this process and all participants were appropriately placed in these groups.

Table 3: Participants categorised into different pubertal stages (Mean ± SD)

Category	Age (y)
Early- mid pubertal (n=5)	13. 2 ± 1.0
Mid-late pubertal (n=5)	15.6 ± 6.6

3.2.6 Demographic Information

Participant information, such as height, weight, age, and the age of first menstruation was collected via meetings set up between the participant and the researcher before the study to help determine subgroups for our research.

Table 4: Baseline characteristics of participants (Mean ± SD)

	All Participants (n = 10)
Demographics	
Age (y)	14.5 ± 1.9
Height (cm)	168.2 ± 5.7
Body Mass (kg)	60.6 ± 6.8
BMI (kg-m^{-2})	21.4± 1.8
Age of menarche (y)	11.9 ± 0.9
Sports Played	3.1 ± 0.9

3.2.7 Pilot study

A pilot study was conducted to track menstrual cycles in the two months preceding data collection to ensure regular cycles, increase the familiarity of the athletes with the collection tools, and to increase the study's validity. It also eliminated some potential participants whose cycles were irregular and provided an opportunity to refine the instrumentation used for the study. Twenty-five participants were used during this pilot study and out of these ten were selected to participate in the study with an averaging a menstrual cycle length of 29 ± 2.3 days.

3.3 Measures

3.3.1 Sleep monitoring.

Throughout the study, each participant was provided with and required to wear an actigraphy device, the Fitbit Charge 5™ (Fitbit Inc., San Francisco, CA, USA) to monitor sleep patterns during three consecutive luteal and follicular phases of the menstrual cycle. The data collected was then averaged over the three cycles for statistical analysis. Sleep metrics such as sleep duration, sleep latency, and sleep quality were tracked by the Fitbit Charge 5™ which utilised its built-in sensors and proprietary algorithms. According to reliability studies performed on these watch's the Fitbit sleep trackers have an 81% detection accuracy for light sleep, a 49% detection accuracy for deep sleep, and a 74% detection accuracy for REM sleep (Park et al., 2024; Moreno-Pino et al., 2019). The watch's validity, ranges from 86.5% to 88%. The device employs an accelerometer to detect movement and a heart rate monitor to track nocturnal heat rate fluctuations. Sleep duration was measured from sleep onset to wake time, while sleep latency was determined by detecting the transition from wakefulness to sleep based on movement and heart rate variations. All collected data was processed and displayed with the Fitbit™ mobile application, all data from participants were then downloaded and transferred to Excel (Microsoft, Richmond, USA etc).

3.3.2 Sleep Diaries

The participants used sleep diaries and journals to incorporate qualitative data. This traditional method reports the participants' sleep habits. Studies have shown that sleep quality should be tracked for at least six days to obtain reliable measures using a sleep diary (Aili et al., 2017). Participants tracked the sleep quality and other external factors that could influence sleep. Questions consisted of when they went to bed, when they woke up, their training sessions, whether they were on any electronic devices before going to sleep, and how they rated their sleep quality on a scale from 1 to 10 (1 = poor, 10 = excellent). Studies that have used subjective sleep questionnaires have demonstrated good internal reliability and validity and show strong psychometric properties including high internal consistency and test-retest reliability (Fabbri et al., 2021; de Alcantara Borba D et al., 2020)

3.3.3 Menstruation tracking application.

To track their menstrual cycle, the participants downloaded the menstrual tracking application, FLO (Flo Health, UK). On any electronic device, this application allows the user to track the menstrual cycle, ovulation, fertility, and pregnancy while also tracking physical and emotional well-being during the menstrual cycle. This application allowed the participants to track and record the timing of the phases and duration of the two phases. At the end of every menstruation participant received reports to identify patterns and predict when their next cycle was going to start. This allowed the participants to track and record the timing and duration of the two phases.

3.4 Sample Size

Due to limited access to the Fitbit Charge 5 ™, ten participants were chosen to complete this study. As a result of these equipment limitations, a power analysis was not conducted. The primary focus was on assessing sleep duration, with additional measures including sleep latency and sleep quality in relation to the menstrual cycle.

3.4.1 Statistical analysis

Appropriate scientific software, such as the Statistical Package for the Social Sciences (SPSS, version 26) and Microsoft Excel (Microsoft Excel for Windows; version 2404), were used to store and analyse the collected data. Data were collected on sleep measures, including sleep duration, latency, and sleep quality, during the follicular and luteal phases of the menstrual cycle. Descriptive statistics were calculated, including standard deviations (SD), means, and frequency distributions, to aid in analysing sleep characteristics during each menstrual phase. Dependent samples t-tests were conducted to determine whether significant differences existed between sleep variables between the LUT and FOL phases, between the early-mid pubertal stage and the mid-late pubertal stage, and between the subjective and objective measures collected.

The intraclass correlation coefficient (ICC) was used to assess test-retest reliability, with values interpreted as follows: less than 0.40 was considered poor, 0.40-0.75 was acceptable, 0.75-0.90 was good, and greater than 0.90 was exceptional (Murray et al., 2018). A typical error (TE) and coefficient of variation (CV) were also reported with a CV of less than 10% regarded as acceptable, while a CV greater than 10% was considered suboptimal (Murray et al., 2018). Statistical significance was set at $p < 0.05$.

3.4.2 Procedures

Recruitment

The University of Waikato Human Research Ethics Committee reviewed the study's procedures and potential risks and approved its commencement. Refer to Appendix B for the ethics approval form.

Results

Table 5:Reliability of objective sleep metric during the luteal phase measured using the actigraphy over three months

Comparison					Reliability statistics			
	M1	**M2**	**M3**	**Δ in mean**	**TE (Raw units)**	**CV%**	**ICC**	**p-value**
Sleep Quality (Objective)	74.7 ± 7.7	74.9 ± 5.4	76.6 ± 5.5					
M2 vs M1				0.20	7.48	11.4[7.7, 21.8]	-0.30[-0.77, 0.37]	0.952
M3 vs M2				1.70	4.80	6.4[4.4,12.1]	0.25[-0.41,0.74]	0.449
Overall					6.28	9.2	0.00	
Sleep Duration (hr) (Objective)	8.1 ± 0.7	7.7± 0.9	7.5± 0.6					
M2 vs M1				-0.43	0.85	11.6 [7.8, 22.1]	-0.14[-0.68,0.50]	0.261
M3 vs M2				-0.14	0.75	10.3 [7.0,19.7]	0.07[-0.56,0.64]	0.684
Overall					0.80	11.0	-0.17	
Sleep Onset Latency (min) (Objective)	21.7 ± 13.6	15.8± 12.3	24.8± 15.8					
M2 vs M1				-5.42	9.26	57.4[36.6,128.8]	0.54[-0.09,0.86]	0.187
M3 vs M2				8.99	12.74	83.9[52.1,204.2]	0.22[-0.44,0.72]	0.149
Overall					11.14	71.1	0.41	

M2 VS M1, Month 2 vs Month 1; M3 VS M2, Month 3 vs Month 2; TE, Typical error, CV, Coefficient of variation; ICC, Intra class correlation coefficient; p-value, Statistical significance ($p<0.05$); Δ, change in mean

Table 5 reports the reliability of the objective sleep metrics during the luteal phase. The relative reliability for objective sleep metrics in the luteal phase was deemed poor, with an ICC of 0.00 in sleep quality, poor (ICC=-0.17) in sleep duration, and fair (ICC = 0.41) in sleep onset latency. In terms of absolute reliability for sleep quality demonstrated an acceptable CV of 9.2%; however, sleep duration and sleep onset latency were suboptimal with CV measures of 11% and 71%. There were no statistically significant differences between the sleep metrics when comparing across the three months.

Table 6:Reliability of objective sleep metrics during the follicular phase measured using the actigraphy over three months.

Comparison					Reliability statistics			
	M1	**M2**	**M3**	**Δ in mean**	**TE (Raw units)**	**CV%**	**ICC**	**p-value**
Sleep Quality (Objective)	78.7 ± 4.0	76.4 ± 4.4	75.8 ± 7.9					
M2 vs M1				-1.63	3.43	4.5[3.1,8.3]	0.38[-0.28,0.80]	0.219
M3 vs M2				-0.90	4.83	6.9[4.7,13.0]	0.47[-0.18,0.84]	0.687
Overall					4.19	5.8	0.51	
Sleep Duration (hr) (Objective)	7.9 ± 0.6	7.7 ± 0.8	7.6 ± 0.6					
M2 vs M1				-0.22	0.50	6.7[4.6,12.6]	0.55[-0.07,0.87]	0.480
M3 vs M2				-0.09	0.58	7.7[5.2,14.4]	0.30[-0.37,0.76]	0.740
Overall					0.54	7.2	0.38	
Sleep Onset Latency (min) (Objective)	18.9 ± 14.0	15.6 ± 9.4	13.6 ± 10.4					
M2 vs M1				-3.63	10.01	107.6[65.3, 279.6]	0.33[-0.34,0.78]	0.479
M3 vs M2				-1.93	11.76	187[106.5,585.3]	-0.47[-0.83,0.19]	0.722
Overall					10.92	147.7	0.10	

M2 VS M1, Month 2 vs Month 1; M3 VS M2, Month 3 vs Month 2; TE, Typical error, CV, Coefficient of variation; ICC, Intra class correlation coefficient; p-value, Statistical significance (p<0.05); Δ, change in mean

Table 6 reports the reliability of the objective sleep metrics during the follicular phase. The relative reliability for objective sleep metrics in the follicular phase was deemed fair (ICC = 0.51) in sleep quality, but poor in sleep duration (ICC = 0.38) and sleep onset latency (ICC = 0.10). Absolute reliability for sleep quality was good with a CV of (5.8%). Sleep duration was also considered to have good absolute reliability (CV = 7.2%); however, sleep onset latency was not reliable with a measure of (CV = 147.7). There were no statistically significant differences between the sleep metrics when comparing across the three months.

Table 7:Reliability of subjective sleep metrics during the luteal phase measured using sleep diaries over three months.

Comparison					Reliability statistics			
	M1	**M2**	**M3**	**Δ in mean**	**TE (Raw units)**	**CV%**	**ICC**	**p-value**
Sleep Quality (Objective)	7.2 ± 0.9	6.9 ± 0.6	7.6 ± 0.6					
M2 vs M1				-0.23	0.90	13.2[8.9,25.5]	-0.40[-0.81,0.27]	0.522
M3 vs M2				0.67	0.66	9.4[6.4,17.8]	-0.25[-0.74,0.41]	0.050
Overall					0.79	11.5	-0.22	
Sleep Duration (hr) (Objective)	9.5± 0.8	8.9 ± 0.8	8.7 ± 0.6					
M2 vs M1				-0.49	1.03	11.9[8.0,22.8]	-0.64[-0.90, -0.06]	0.280
M3 vs M2				-0.23	0.72	8.3[5.7,15.7]	-0.11[-0.67,0.52]	0.497
Overall					0.89	10.2	-0.49	

M2 VS M1, Month 2 vs Month 1; M3 VS M2, Month 3 vs Month 2; TE, Typical error, CV, Coefficient of variation; ICC, Intra class correlation coefficient; p-value, Statistical significance (p<0.05); Δ, change in mean

Table 7 above reports the reliability of the subjective sleep measures during the luteal phase. The relative reliability for objective sleep metrics in the luteal phase was deemed poor (ICC = -0.22) in sleep quality and sleep duration (ICC = -0.49). Absolute reliability for sleep quality (CV = 11.5%) and sleep duration (CV = 10.2%) was deemed suboptimal. There was a statistical significance in sleep quality between month three and month two (p = 0.050).

Table 8:Reliability of subjective sleep metrics during the Follicular phase measured using sleep diaries over three months.

Comparison					Reliability statistics			
	M1	**M2**	**M3**	**Δ in mean**	**TE (Raw units)**	**CV%**	**ICC**	**p-value**
Sleep Quality (Objective)	6.9 ± 1.1	7.2 ± 0.5	7.3 ± 0.7					
M2 vs M1				0.30	0.51	8.6[5.9,16.3]	0.69[0.14,0.91]	0.225
M3 vs M2				0.13	0.61	9.2[6.3,17.5]	0.07[-0.55,0.65]	0.637
Overall					0.56	8.9	0.57	
Sleep Duration (hr) (Objective)	9.3 ± 0.9	9.0 ± 0.6	9.0 ± 0.6					
M2 vs M1				-0.25	0.53	6.1[4.1,11.3]	0.56[-0.06,0.87]	0.412
M3 vs M2				-0.08	0.30	3.5[2.4,6.4]	0.80[0.37,0.95]	0.589
Overall					0.43	4.9	0.69	

M2 VS M1, Month 2 vs Month 1; M3 VS M2, Month 3 vs Month 2; TE, Typical error, CV, Coefficient of variation; ICC, Intra class correlation coefficient; p-value, Statistical significance (p<0.05); Δ, change in mean

Table 8 presents the reliability of the subjective sleep measures during the follicular phase. The relative reliability for objective sleep metrics in the luteal phase was deemed fair (ICC = 0.57) in sleep quality and sleep duration (ICC = 0.69). Absolute reliability for sleep quality (CV = 8.9%) and sleep duration was deemed good (4.9%). The results showed no statistical differences in any of the sleep metrics over the three months.

Figure 3: Sleep duration analysis with and without Fitbit during the menstrual cycle

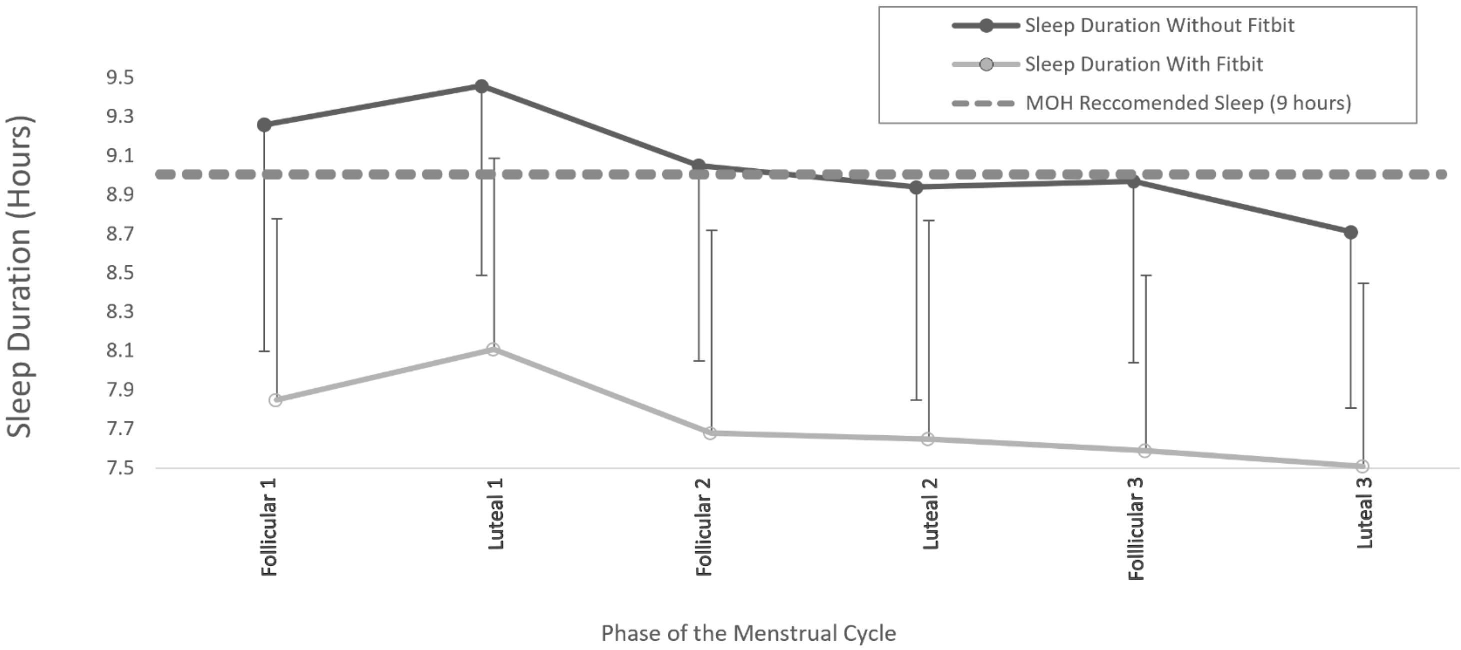


Figure 3 compares the objective (Fitbit) and subjective sleep duration. The subjective sleep duration is shown to exceed the MOH recommendation 9-hours across all phases. The objectively measured sleep duration was significantly lower than MOH recommendation of 9 hours. This shows an average difference of 1.38 h when comparing subjective to objective measures. The overestimation of self-reported sleep duration is shown by the large effect size (Cohen's d = 1.20) and a small p – value ($p = 3.00 \times 10^{-47}$), which show a statistically significant difference.

Table 9:Comparison of sleep indices during the menstrual cycle phase

	Follicular Phase (Mean ± SD)	**Luteal Phase (Mean ± SD)**	**P- value (p)**	**Cohen's *d* (effect size)**
Sleep Indices				
Sleep Quality	7.4 ± 0.2	7.24 ± 0.34	0.64	*-0.43 (moderate)*
Sleep Quality (Fitbit)	77.08 ± 1.5	75.43 ± 1.04	0.34	*1.56 (Large)*
Sleep Duration	9:09 ± 0:15	9.04 ± 0.39	0.72	*0.24 (Small)*
Sleep Duration Fitbit	7.71 ± 0.13	7.76 ± 0.31	0.68	*- 0.25 (Small)*
Sleep Latency (min)	16.03 ± 2.6	20.75 ± 2.6	0.68	*-1.54 (Large)*

*$p < 0.05$, results are statistically significant

The comparison of sleep indices during the menstrual cycle indicates significant discrepancies between self-reported and Fitbit–derived sleep data (Table 9). Self-reported sleep quality was moderately higher in the follicular compared to the luteal phase (FP: 7.4 ± 0.2 vs. LP: 7.24 ± 0.34). The objective sleep efficiency measured with the Fitbit data indicated a large difference with lower sleep efficiency in the luteal phase (FP: 77.08 ±1.5 vs LP :75.43 ± 1.04). The perceived sleep duration is similar between the two phases, with only a small non-significant difference in self - reported sleep duration between the menstrual phases (FP: 9.09 ± 0.15 h vs LP: 9.04 ± 0.39 h) and the Fitbit data suggest a minimal difference between the follicular phase to the luteal phase (FP: 7.71 ± 0.13 h vs LP: 7.76 ± 0.31 h). The objective data shows that sleep latency was longer during the luteal phase (16.03 ± 2.6 min vs 20.75 ± 2.6 min), with a substantial but non-significant effect size ($d = 1.54$).

Table 10:Sleep indices across the pubertal stages in the follicular phase and luteal phase

	Follicular Phase			Luteal Phase		
	Early – Mid Pubertal (Mean ± SD)	Mid – Late Pubertal (Mean ± SD)	p-value & Cohen's *d*	Early – Mid Pubertal (Mean ± SD)	Mid – Late Pubertal (Mean ± SD)	p-value & Cohen's *d*
Sleep Indices						
Sleep Quality	6.87 ± 0.34	7.42 ± 0.03	0.13 *-2.30 ± 0.24 (Large)*	7.29 ± 0.36	7.20 ± 0.24	0.69 *0.29 ± 0.30 (Small)*
Sleep Quality Fitbit	78.0 ± 0.65	76.16 ± 2.07	0.29 *1.20 ± 1.53 (Large)*	76.76 ± 2.02	74.11 ± 1.80	0.39 *1.38 ± 1.91 (Large)*
Sleep Duration	9.05 ± 0.25	9.13 ± 0.05	0.72 *-0.44 ± 0.18 (small)*	9.00 ± 0.46	9.07 ± 0.31	0.85 *-0.17 ± 0.39 (Small)*
Sleep Duration Fitbit	7.44 ± 0.13	7.98 ± 0.12	*0.03* -4.36 ± 0.12 (Large)*	7.63 ± 0.37	7.87 ± 0.33	0.29 *-1.04 ± 0.34 (Large)*
Sleep Latency	17.80 ± 3.81	14.27 ± 0.68	0.27 *1.29 ± 2.7 (Large)*	22.12 ± 5.27	19.40 ± 2.81	0.43 *-1.50 ± 4.22 (Large)*

*$p < 0.05$, results are statistically significant

Sleep indices across pubertal stages in the follicular and luteal phases showed several meaningful differences in sleep quality, duration, and latency (Table 10). Of note, a significant and large difference was seen between objective sleep duration in the follicular phase (Early-mid: 7.44 ± 0.13; Mid-late: 7.98 ± 0.12; p=0.03; Cohen's *d*: 1.29).

Discussion

The main purpose of this study was to examine four main research questions. The first aim was to determine the reliability of subjective and objective sleep measures in adolescent female athletes during the two main phases of the menstrual cycle. The results show that the subjective measures were the most reliable, especially during the follicular phase. Subjective sleep quality showed fair reliability (ICC = 0.57; CV = 8.9%), sleep duration showed fair relative reliability (ICC = 0.69) and good absolute reliability (CV = 4.9%) with a low typical error (TE = 0.43). However, when looking at the subjective results during the luteal phase, the data presented significant variability, with sleep duration and sleep quality both displaying poor reliability. These results could suggest that physiological and psychological fluctuations during the phases may compromise the stability of self-reported sleep data. A significant change in subjective sleep quality between month 2 and month 3 of the luteal phase ($p = 0.050$) supports the claim of this phase-specific instability.

Objective sleep measures that were obtained via Fitbit demonstrated poor to fair reliability during the follicular phase. The results demonstrated that, while the absolute reliability of sleep duration was acceptable (CV = 7.2%), the relative reliability was low (ICC =0.38). However, the results presented in sleep quality that show the relative reliability was deemed fair (ICC = 0.51) with an absolute reliability of (CV = 5.8%), which is acceptable. When looking into the objective measures during the luteal phase, sleep quality data presented an acceptable absolute reliability; however, the relative reliability showed poor reliability. Sleep duration during this phase also presented poor reliability which indicates a high degree of month-to-month variability.

Overall, these results indicate that the subjective measures were more reliable than the objective measures, especially during the follicular phase in comparison to the luteal phase. These data are consistent with the clinical study by Backhaus et al. (2002), that reported the reliability of subjective measures such as the Pittsburgh Sleep Quality Index (PSQI) in evaluating sleep patterns. However, subjective measurements can overestimate sleep duration and underestimate sleep quality. Short et al. (2012) argue that to increase reliability and obtain more thorough understanding of sleep behaviours, it is imperative to combine objective and subjective measures.

The second research question of this study aimed to assess any discrepancy between how participants perceived their sleep and what was captured using objective actigraph measurements. The results of the study showed that during the menstrual cycle, the participants reported a regular sleep duration that typically met or exceeded the Ministry of Health recommendation of 9 hours; however, the Fitbit actigraphy revealed that during the entirety of the menstrual cycle, the average sleep duration of the participants ranged from 7.5 to 7.9, overall, the average difference between subjective and objective measured was 1.38 hrs. This overestimation can be compared to findings by Dietch et al. (2019) and Mallinson et al. (2019), whose research discovered that adolescents tend to overestimate sleep duration and underestimate sleep onset latency when using subjective methods of reporting. Similarly, in a study performed with athletes, Caia et al. (2010) revealed that athletes frequently overestimate their sleep duration by up to 30 to 60 minutes when compared to wearable actigraphy, highlighting the importance of combining subjective measures with objective measures. While the population between this study and our study differ, the consistency of these studies implies that sleep duration overestimation is a common problem in both adolescents and athletes, which may be due to the lack of sleep awareness and cognitive biases. Although subjective measures like sleep diaries are cost-efficient and easier to administer, objective measures like wearable actigraphy may offer more accurate sleep assessments. Therefore, combining both self-reporting with wearable actigraphy can provide a more comprehensive understanding of sleep patterns in athletes.

While subjective measures of sleep can be useful to capture perceived sleep patterns and the behavioural habits of participants, this measure of sleep can lack precision required to accurately detect physiological changes, such as those driven by hormonal fluctuations during the menstrual cycle. Objective measures such as actigraphy provide valid and unbiased outcomes when measuring sleep metrics such as sleep duration and sleep quality. Of note, differences in the objectively measured sleep quality and sleep duration were detected between the luteal and follicular phases in the current study, with no differences noted in the subjective measures. As a result, to gather a comprehensive picture of sleep patterns, it is suggested that both subjective and objective data should be gathered where possible. Coaches, athletes, parents and health professionals dealing with adolescent athletes should avoid solely relying on perceived sleep measures, as this can lead to inaccurate recovery planning. Therefore, incorporating objective sleep measures, like using actigraphy, will enable more accurate and comprehensive strategies around individual athlete sleep pattens, especially when looking into populations undergoing pubertal development and hormonal transitions.

Our research also examined how the follicular phase and the luteal phase of the menstrual cycle affected sleep duration, sleep quality, and sleep latency in adolescent female athletes. Our study discovered that sleep latency was longer, and sleep quality poorer during the luteal phase, but overall sleep duration did not significantly differ between the follicular and luteal phases. These results imply subtle but important sleep disruptions in association with the menstrual cycle in adolescent athletes, which may impact their overall recovery and performance. These findings are consistent with earlier studies conducted in adult female populations; for example, Baker and Driver (2004), Lerfald (2020), and Matos et al. (2025) all reported lower sleep quality during the luteal or mid-luteal phases in university students and endurance athletes. However, Koikawa et al. (2020) and Hrozanova et al. (2021) found declines in sleep quality and increased sleep latency during the luteal phases in female endurance and collegiate athletes. Our population did not exhibit significant changes in sleep duration between the two phases, in contrast to the multiple adult female studies that discovered notable declines in sleep duration during the luteal phase (Koikawa et al., 2020; Hrozanova et al., 2021). These discrepancies could be due to hormonal or developmental differences between adolescents and adults, which may indicate that adolescent athletes may be less affected by the menstrual cycle in terms of sleep duration. Alternatively, the sample size and sensitivity of the assessment tools may have prevented significant differences from being observed. Overall, our research and the previous research have consistently demonstrated that the luteal phase can negatively impact sleep quality and latency, while variation in sleep durations may differ depending on age and athletic population.

Previous research has indicated that hormonal fluctuations throughout the menstrual cycle can impact sleep metrics, especially during the luteal phase, with the female adult population reporting lower sleep quality, longer sleep latency, and more sleep disturbances. However, there is very little known information about sleep patterns within the adolescent female athlete population. As a result of this, the third research question of this study aimed to investigate the menstrual cycle phases and their impacts on sleep quality, sleep onset latency, and sleep duration in adolescent female athletes, measured using both subjective and objective methods. Based on previous literature, it was hypothesised that sleep quality and sleep onset latency would be lower during the luteal phase in comparison to the follicular phase. After three to four months of data collection, the findings of this study provide insight into this under researched population. Specifically, the results suggested that while there was no major effect on overall sleep duration when comparing the luteal and follicular phases, there was evidence of poorer sleep quality and longer sleep latency during the luteal phase.

These data indicate that between the two menstrual phases, in this athletic adolescent population, sleep may be subtly impacted which may have implications for recovery and overall performance.

The results of this study highlight that during the luteal phase, sleep quality and onset latency appear to be negatively impacted among adolescent female athletes. Sleep tracking with Fitbit devices revealed a poorer sleep quality in the luteal phase, as well as longer sleep latency from 16.03 to 20.75 minutes. Although these differences were not statistically significant, the large effect sizes suggest meaningful differences that may disrupt sleep outcomes. These data are consistent with previous research by Baker & Driver (2004) and Hrozanova et al. (2021), who also found reductions in sleep efficiency and REM sleep during the luteal phase. The degree of change observed in the current study was smaller than in adult populations, implying that adolescent athletes may have more subtle menstrual-related sleep interruptions, possibly mitigated by regimented training routines and developmental differences in hormonal sensitivity. Furthermore, the observed increase in sleep latency is consistent with previous research demonstrating that higher progesterone and an increased core body temperature during the luteal phase can delay sleep onset (Kumar, 2004; Charest & Grander, 2002).

Given how important sleep is for athletic recovery, it is important to understand the impact the menstrual cycle can have on the performance, injury risk, and overall well-being of an athlete. Halson, (2008) and Charest & Grandner, (2022), describe sleep as a critical component of physical recovery, cognitive processing, and emotional regulation all are which are required for athletes to manage high volumes of training and competition. The results reported longer sleep onset latency and a decrease in objective sleep quality during the luteal phase, although this difference is subtle, over time it can accumulate, impairing recovery between training sessions. This accumulation is concerning for young adolescents juggling school, social life, and the high demands of sports, making these athletes more vulnerable to fatigue and burnout. Research done by Cho & Im, (2024) and O'Donnell & Driller, (2017), shows that even the smallest variations in sleep quantity or quality can impair response time, decision-making, immune function, and muscle recovery, increasing the risk of injury and impacting performance. The findings from the study emphasise the importance of increasing awareness around the menstrual cycle phases and the importance of developing training and recovery plans, to help improve sleep hygiene, improve female participation in sport, and improve athlete performance and well-being.

Beyond the comparison of the two phases, our study also found that pubertal development emerged as a significant factor in influencing sleep metrics in this study. Regardless of the menstrual cycle phase, participants who were categorised into the mid-late pubertal stage had significantly longer Fitbit-derived sleep duration, along with reduced subjective sleep latency. The data collected suggest that as the participants move through different pubertal maturation stages their sleep patterns may become more efficient. This efficiency can be presumed to be due to an increased stable circadian rhythm and improved homeostatic sleep regulation. These findings are consistent with previous research that sleep patterns can alter throughout adolescence, with pubertal maturation influencing both sleep duration and sleep quality (Carskadon & Dement, 2005). Since mid-to-late pubertal participants experienced shorter sleep latency than the participants who were categorised into the early-to-mid pubertal stage, it could be said that pubertal development, can influence sleep hygiene requirements across the menstrual cycle. Since it is shown that chronological age alone cannot accurately reflect the biological development of our female population, the results of this study help support the idea that pubertal maturation levels should be considered in studies relating to the menstrual cycle and sleep (Bergernon et al., 2015). Studying how pubertal maturation affects sleep may help health professionals, coaches, parents, and athletes develop more individualised sleep hygiene strategies and exercise recovery plans during times of hormonal and physical changes.

Despite the insight this research has provided, this study has a few limitations that may have had an impact on the results. The limited participant size (n = 10) restricts the research generalisability and decreases the statistical power to detect more subtle effects. Although the use of Fitbits is useful, they might not be as accurate as the gold standard techniques such as polysomnography in sleep onset latency detections and in-sleep staging. Self-reported data and application-based tracking was used to identify menstrual cycle phases, which could have created inaccuracies in phase identification, especially in adolescents beginning their cycle or having irregular cycles. Another limitation was that outside variables could have also impacted the study’s results, apart from the menstrual cycle, including academic pressures, fluctuating training loads, social commitments, and screen time as these variables were not able to be controlled.

Overall, to further the reliability of these findings, future research should incorporate larger sample sizes, validate hormonal tracking, and utilise gold-standard sleep measuring devices, such as polysomnography to get more accuracy when recording sleep metrics. Nonetheless, the results provide compelling evidence that the menstrual cycle phases can impact adolescent sleep latency and quality which has implications for their well-being, recovery, and sport participation. The use of objective and subjective sleep monitoring across the several menstrual phases strengthens the credibility of the results and the practical insights gained and improves our knowledge of how biological factors can affect sleep in a female adolescent athletic population

Conclusion

To conclude, this research suggests that, especially during the follicular phase, subjective measures were more reliable than objective sleep measures in adolescent female athletes. When used alone to evaluate sleep measures in this population, objective data exhibited greater variability and lower reliability during the luteal phase. Consistent differences were found when comparing subjective and objective sleep measures. Specifically, participant self-reports typically overestimated sleep duration and underestimated sleep latency. Subjective measures, however, might not fully capture actual sleep behaviours and should be combined with objective measures to provide a more comprehensive picture. The research also found that luteal phase may have a negative effect on sleep quality and sleep onset latency in adolescent female athletes. It was also shown that pubertal development also significantly influenced the results, with the mid-late pubertal participants experiencing longer sleep durations and shorter sleep latencies than early-mid pubertal participants. Compared to previous research with older female cohorts, this research provides novel data specific to youth athletic adolescents and highlights the need for age and developmentally appropriate education and approaches with respect to sleep. Research needs to be conducted to better understand the mechanisms that underlie menstrual cycle-related sleep disruptions, as well as how education and recovery techniques can be customised to help young female athletes at various stages of their menstrual cycle and pubertal development.

Chapter Four - Summary, Practical Applications, Limitations, Future Research and Final Summary

Summary

There has been an increase in interest in understanding how hormonal fluctuations within the phases of menstrual cycle affect sleep measures; however, our current understanding of its impact on adolescent female athletes is lacking. Previous research has indicated that the luteal phase, which is marked by increased progesterone and body temperature, may contribute to poorer sleep measures, such as longer sleep onset latency and worsened sleep quality (Baker & Driver, 2004; Hrozanova et al.,2021). These sleep disturbances have been proposed to impair the recovery process necessary for an increase in athletic performance, including, physical restoration, cognitive functioning, and emotional regulation (Halson, 2008; Charest & Grandner, 2022). However, research conducted by Carkadon and Dement, 2005, suggests that pubertal maturation might alter sleep patterns regardless of the effects of the menstrual cycle, as sleep patterns and circadian stability can evolve throughout adolescence.

Previous studies have mainly focused on adult or university-aged female athletes, with a gap in understanding of how biological processes influence adolescent female athletes with high training loads. Therefore, the purpose of this study was to identify and find answers to the four main research questions. The first goal was to examine the reliability of subjective and objective sleep measures in adolescent females during the two main phases of the menstrual cycle. Secondly, we aimed to compare objective and subjective sleep measures, and then use these measures to understand how the follicular and the luteal phases affect sleep quality, sleep duration, and sleep onset latency in adolescent athletes. Finally, we aimed to identify any differences in sleep measures during the menstrual phases between different pubertal maturation stages. The results from our study quantify the reliability of commonly assessed sleep measures across the menstrual cycles and this information can be used to inform the effectiveness of sleep intervention in this under-studied cohort. There were clear differences between objectively and subjectively measured sleep metrics, such that self-reported sleep duration significantly overestimated the objectively assessed data. The results from our study provide novel preliminary evidence that subtle reductions in sleep quality and increases in sleep latency occur throughout the luteal phase. Additionally, participants who were categorised in the mid-late pubertal stage showed results of longer sleep duration and shorter sleep latency than the participant who were categorised into the early-mid stage, indicating that maturation stages may also impact sleeping patterns.

Overall, the data collected indicated that menstrual cycle-related sleep disruption may have significant implications for athletic recovery, performance, well-being, and injury prevention. In addition, understanding and addressing these challenges are important for supporting female athlete

participation and continuation in sports, as bad sleeping patterns and hygiene caused by hormonal changes may be a contributing factor to lower engagement, increased dropout rates, and a decrease in overall enjoyment of sport during the stages of adolescence. Given how important sleep is to athlete health and well-being, as well as adolescent development, the research findings have highlighted the need for more attention to menstrual cycles during the planning of training schedules and recovery strategies. This research can help lay a foundation for future research to investigate how sleep interventions and menstrual tracking could optimise and impact both performance and participation outcomes for adolescent female athletes.

Practical applications

The research has provided key practical applications for those coaches, parents, staff, and athletes who interact with adolescent female athletes. The observed decreases in sleep quality and the increase in sleep latency during the luteal phase indicate that coaches, supporting staff, and parents should consider incorporating menstrual cycle tracking into monitoring athlete programs. This tracking will help predict any potential sleep disturbances and may inform training load adjustments if needed. Recovery strategies such as increasing knowledge and emphasis on sleep hygiene, scheduling lighter training sessions, or providing more recovery time during the luteal phase may help mitigate the impacts of hormonal changes on the overall performance and well-being of female athletes.

Furthermore, knowledge about the impact of pubertal maturation and its effects on sleep patterns is equally as important. Specifically, the data suggests that sleep recommendations should be modified not only to suit the age of athletes but also their biological maturity. Addressing the issues of menstrual cycle sleep disturbances could not only have an impact on recovery and performance but also on female engagement and long-term participation in sports. By understanding and fostering a more knowledgeable athletic environment, coaches, staff, and parents can help retain more female athletes during the stage of adolescence, which is found to be a key stage of life where more dropouts in sports tend to occur.

Limitations

There was a various limitation during this study that we could not control during the entirety of this study, these included.

- The small sample size (n = 10), due to the limited range of equipment needed for this study. Additionally, there was a limited population of adolescent female athletes who participated in water sports that met the inclusion criteria.
- The menstrual cycle phases of our participants were assessed through an application–based self -tracker. This reliance on self-reporting may have resulted in variability or inaccuracy in determining what phase the participants were in relative to hormonal assessments to identify menstrual phases.
- Due to this research being a field–based study, there were a few external variables such as academic stress, screen time, dietary intake, training volume, and sleep environment that were not able to be controlled which may have impacted the participant's sleep measures.
- Sleep measures were recorded via the Fitbit actigraphy, which has shown to be useful for field-based research; however, the Fitbit may lack the precision of gold-standard procedures including polysomnography for identifying sleep stages.
- Another limitation was the potential for reporting bias in the participant's subjective sleep reporting when compared to objective sleep data. Reporting bias is defined as a selective modification of information by participants with the overestimation of their self-reported sleep durations and sleep quality, indicating that participants may have exaggerated their sleep to align with researchers' expectations.
- The sample of participants included athletes specific to water sports and only around the Bay of Plenty area, which may have limited its relevance to the broader adolescent female populations from a range of sporting backgrounds.

Future Research

From the overall results presented throughout the thesis, there are key future research ideas that are suggested below.

- Comparing the adolescent athletes in other sports (for example: endurance-based vs. strength or skill-based sports) could help us understand how the physiological demands of different sports interact with sleep patterns.
- Assessing hormone levels throughout the entirety of the menstrual cycle, in addition to tracking sleep patterns may help enhance the understanding of the mechanisms of specific hormones across the menstrual phases and how they influence sleep.
- Future research should record and take into consideration menstrual cycle symptoms as these symptoms can independently affect fatigue levels, sleep quality, and overall athletic performance.
- How psychological impacts of sleep disturbances, including the effects on mood, perceived stress, and motivation to train could provide more understanding into how sleep and hormonal health can affect engagement and involvement in sports
- Research could also investigate how interventions, such as sleep hygiene education, nutritional interventions, or menstrual health education could be conducted to assess how beneficial they could be in improving sleep measures.
- Using more scientific objective hormonal measures such as blood or salivary hormone testing would allow more accuracy in determining the menstrual cycle phase, rather than solely relying on application-based tracking.
- Examining how competition may affect adolescent athletes' sleep would help improve knowledge of how high-pressure environments may affect sleep measures and compare these results to adult female athletes.
- Finally, future research should include studying the effects of extended device use before bed in adolescent populations.

Final Summary

This research has helped enhanced the understanding of menstrual cycle-related sleep changes in the population of adolescent female athletes, which demonstrated that subjective sleep measures are typically more accurate and more efficient but must be complimented by objective measures for better accuracy in measuring sleep patterns. In contrast to the female adult populations, the luteal phase has a slight negative impact on sleep quality and sleep latency but not duration in this adolescent female athlete population. Additionally, pubertal maturation has a significant impact on sleep behaviours highlighting the need for age and developmentally appropriate tailored strategies in monitoring and supporting adolescent female athlete sleep, recovery, and overall well-being. All findings from this study have practical implications for coaches, parents, athletes, and health professionals and the reliability data can help to inform meaningful changes. Adolescent female athlete health, performance, and well-being can be supported by more individualised training and recovery programs that consider the effects of age, hormonal changes, and pubertal development on sleep behaviours.

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GLOSSARY

Adolescent	The time after the start of puberty when an individual transitions from a child to an adult
Eumenorrheic	Normal menstrual cycle typically ranges from 25 to 35 days and follows a predictable pattern.
Follicular Phase	The first phase of the menstrual cycle, during which follicle-stimulating hormone (FSH) and estrogen stimulate the growth of fluid-filled sacs called follicles in the ovaries.
Generalisability	The extent to which the results of a study can be generalised to other situations or populations
Luteal Phase	The period between ovulation and the start of the next menstrual cycle. During this phase, progesterone is produced by the corpus luteum (the structure left behind after an egg is released), thickening the uterine lining to prepare for a potential pregnancy.
Menarche	The first menstrual period in a female adolescent
MPOA	It is a part of the sympathetic nervous system (SNS), and neurons that express leptin R transmit and relay information about energy expenditure to the peripheral brown adipose tissue (BAT).
Oestradiol/ Oestradiol	The primary form of estrogen found in women, playing a key role in reproductive and overall health
Oestrogen/ Estrogen	A hormone made by the body that helps develop

	and maintain female sex characteristics and the growth of strong bones.
Ovulation	The process in which a mature egg is released from an ovary
PMDD	Premenstrual Dysphoric Disorder (PMDD) is a very severe form of PMS that can affect a female’s daily life and mood.
PMS	Is a change in mood emotions, physical health and behaviour that occurs between ovulation and the start of your period, these could include mood swings, bloating, depression etc.
POA	Is a region compromising the medial and lateral parts of the preoptic nucleus, the anterior hypothalamus, and nearby regions of the septum.
Post Menopausal	The stage after menopause, defined as the time when a woman has not had a menstrual cycle for over a year
Post Pubertal	The period following puberty, during which full sexual maturity has been reached
Pre- Menopausal	The transitional phase leading up to menopause, characterised by hormonal fluctuations and irregular menstrual cycles.
Pre-Pubertal	The stage just before puberty, often marked by rapid growth and physical development
Progesterone	A steroid hormone released by the corpus luteum that helps prepare the uterus for pregnancy by thickening the uterine lining
Reliability	The consistency and accuracy of a measurement, calculations, or assessment.

REM sleep	A sleep stage that occurs in cycles throughout the night, characterised by rapid eye movement and increased brain activity, often associated with vivid dreaming.
Sleep Duration	The total amount of time a person spends asleep
Sleep Hygiene	A set of habits, behaviours, and environmental factors that contributed to better sleep quality
Sleep Latency	The amount of time it takes to fall asleep after turning off the lights
Sleep Quality	An individual's overall contentment with their sleep quality, duration, and experience

Appendices

Appendix A: Ethics Application

Research Ethics Application – Cover Sheet

Principal Investigator:	Naia Anderson
Division / School / Faculty / Institute:	University of Waikato (Tauranga)
Email address:	naiagrace@outlook.com Na171 @students.waikato.ac.nz
Preferred phone number: Office phone number (if applicable):	0273759281
Student ID (if applicable):	1569760
Proposed start date of data collection/field research: Proposed project end date:	Expected start date: 01/08/2024. Expected end date: 01/03/2025
This is an application for approval of: (indicate all that apply)	Staff research project: No PhD research: No Master's research: Yes Other: No
Name of degree/paper (if applicable):	Master of Health, Sport, and Human Performance
Supervisor name:	Tracey Clissold
Supervisor's approval signature:	

Funding sources (if applicable):	Not applicable
Project sponsors (if applicable - e.g. equipment):	University of Waikato - equipment
Research locations (if outside UOW facilities):	Tauranga Girls college Mount Maunganui college. Omanu School Papamoa College Omanu Swim club
Associated/linked Applications (provide other applications' approval code and title):	Not applicable
Has the application received approval from other institutions? If so, please talk to the HREC Chair before proceeding as this Committee may only need to ratify the already approved application.	Not applicable

I request approval for this research or related activity and attach all relevant documentation necessary for evaluation under the Ethical Conduct in Human Research and Related Activities Regulations. https://calendar.waikato.ac.nz/research-assessment-graduation/ethical-conduct

I have read and complied with the University's Ethical Conduct in Human Research and Related Activities Regulations.

Principal Investigator's signature: Date: 10/05/2024

Project Overview

Please provide the following information about your project

1. Project Title: The menstrual cycle's effect on sleep in school-aged female athletes.

2. Briefly outline the research topic, research questions, and/or research objectives (boxes will expand as you write)

Research topic (20-50 words)	How the menstrual cycle affects sleep in school-aged athletes?
Research questions (Bullet point)	• Is there a difference in sleep quantity between thew two main phases of the menstrual cycle for school aged athletes? • Is there a difference in sleep quality between the two main phases of the menstrual cycle for school aged athletes? • Is there a difference in sleep onset latency between the two main phases of the menstrual cycle for school aged athletes?
Research objectives (Bullet point)	To understand and investigate if the menstrual cycle can affect sleep.

3. What specific research activities are you planning to undertake? ***Briefly*** respond to this question by LISTING research activities. Please note this application focuses on Human research. You will be asked to provide further details under Q.18. NB: delete examples

Research activity	Brief comment (10-30 words per item)
Fitbit charge 5	School- aged female(n=10), will sleep with readibands to track sleep during the two phases of their menstrual cycle.
Sleep diaries	10 school- aged female students will record their sleep quality during the two phases of their menstrual cycle.
Fitbit app	10 school-aged female students will record and track their menstrual cycle and the phases using the Fitbit app where they can track their cycle

4. Justify your project. Provide a summary of the research, its methods, anticipated academic benefits, value, and/or contribution to the field.

(a) Research summary (under 300 words)	The female reproductive cycle is one of the most important biological processes, and the menstrual cycle is known to be a prime example of a bio-psycho-social process (Brown et al., 2021). The menstrual cycle is a reliable indication of a female's health (Sports New Zealand, 2023). Eumenorrheic menstrual cycles are those that occur regularly and last between 21 and 35 days (Carmicheal et al., 2021), and are divided into two major phases, these two phases have been known to be linked with fluctuating hormone levels: the follicular phase and the luteal phase (Brown et al., 2021). It is to be understood that oestrogen and progesterone receptors, which are the female reproductive hormones, are found in the sleep-regulating areas of the brain (Hrozanova et al., 2021), which allows for a substantial hormonal influence on sleep in women (Hrozanova et al., 2021). The role of sex hormones on circadian rhythm identifies sleep disparities between men and women (Silvia et al., 2019). One article by Baker & Driver (2004) shows that 71 % of women indicated that their sleep was disturbed by menstrual symptoms, such as bloating, sensitive breasts, headaches, and cramps. Most women report experiencing sleep difficulties both before and during menstruation (Baker & Driver, 2004). Premenstrual symptoms include fatigue, difficulty concentrating, and lethargy (Baker & Driver, 2004). In New Zealand alone, participation and engagement around puberty; particularly among young women aged 12 to 17 have dropped (Sports New Zealand 2023) the study will help us understand if poor sleep hygiene due to the menstrual cycle is to contribute to this trend.
(b) Methods summary (under 300 words)	The inclusion criteria for the participants for this study will be School-aged females (15-18y), who have had no diagnosed sleep issues, regular menstrual cycles and are on no birth control, this will be determined by forms that state the exclusion/ inclusion criteria. These participants will be recruited from local schools and sporting teams with the consent from these places. The participants selected will then be given a sleep diary, period tracker, and wearable sleep tracker (Readiband) which have been used in other studies to analyse sleep/ wake performance measures (Chinoy et al, 2021), which will be used to track and measure the participants' sleep and menstrual phases over a period of 3-4 months or when each participant has gone through at least three menstrual cycles. Once all data is collected Test-retest reliability analyses will occur to determine the reliability and variability of the data-gathering procedures. Statistical analysis will also be carried out to determine how the follicular phase and the luteal phase affect the sleep quality, duration, and latency of our participants.
(c) Anticipated academic benefits/value/ contribution to the	This study seeks to add to the existing knowledge and understanding of the menstrual cycle in our female athletes to help enhance performance. This information can then also be used to allow more research development in not

field summary (max 200 words)	only our female athletes but also in our youth population. This study's investigation of the menstrual phases and sleep patterns can provide useful insights into the physiological mechanisms underpinning sleep regulation in females. It will help develop targeted interventions and sleep management strategies tailored to female athletes' hormonal fluctuations.

The Researcher(s)

Please tell us about you and/or your research team

5. LIST all members of the research team and briefly describe their roles within your research project.

Name	Role
Naia Anderson	*Primary investigator*
Dr Tracey Clissold (PhD)	Primary supervisor/ mentor Academic Staff Member - Sport Toi-Ohomai Windermere campus, Tauranga Tracey.Clissold@toiohomai.ac.nz

6. OUTLINE (250 words max) relevant qualifications to undertake this research.

Qualifications and Prior Experience	The team is composed of scientists and bio mechanists, who have post-graduate qualifications and are strong researchers in the field being investigated. The team has had experience with the equipment being used for the experiment and data analysis.
Training/expertise in relevant research methods	Training in this area and knowledge of female health, sleep and the menstrual cycle is crucial, and all researchers have knowledge in using the instrumentation used in this research and how the data relates back to the research.
Personal knowledge of the topic/area of interest	All researchers in this study are active in the field of women's health and, all have experience and required skills to conduct research in this area. The team all have a personal interest in understanding how sleep affects the two main phases of the

	menstrual cycle in school-aged athletes.
Other…	*Not applicable*

7. What, if any, discipline-specific codes of ethics or professional standards will guide your research? Outline here:

The Sport NZ Safeguarding children's policies will help guide our research about working with children, and the code of ethics of the National Ethics Advisory Committee (NEAC) will be a guide for our research.

Your intended participants

Please provide the following information about your intended participants:

8. Broadly, who will your participants be? (Indicate the broad target population: e.g. approx. 30 young adults (20-25 years old) men and women from Waikato rural communities). *Offer estimates if exact numbers are uncertain. Do not include individuals' names.*

30 school-aged athletes between the ages of (15-18 years old). Female athletes from schools in the Bay of Plenty district. Must have gone through and completed at least one menstrual cycle to be included in the study (6-12 menstrual cycles in a year)

9(a) How will you recruit participants? Summarise your process as a list of actions, in chronological order (no more than 200 words)

Participants will be found from local Bay of Plenty Schools in the Tauranga region, sporting teams and clubs, word of mouth, and social media platforms such as Facebook and Instagram; poster advertisements placed in public locations with permission from schools and sports clubrooms. Recruitment letters will be provided with a questionnaire to determine whether participants meet the inclusion/ exclusion criteria. These will be handed out or sent via email to potential participants and their parents/ guardians as most of the participants will be under the age of 18 years old.

9(b) Do you need permission from any person or organisation to recruit participants before recruiting participants? If so, please describe this process.

The inclusion criteria are that the participants need to be of school age so 18 and under. I will need to collect parental/ guardian consent from each participant. I will also need consent from the schools and sports teams and clubs to ask permission to send emails to potential participants and put-up posters around the schools and the sports club rooms.

10. How will you inform them about the project and their involvement in it? Summarise your process. Link to relevant attached appendices (e.g. *recruitment emails, posts, posters, information sheets...)*

All participants will be given an information sheet that outlines the research topic, the aims, goals, procedures, benefits, and risks of being involved in the study. They will also be given an informed consent form which will state their rights as participants and allow them to sign to state their participation in the investigation. Since the participants will be school-aged, I will need to collect parent/guardian and participant consent before undergoing any participation in the study and before the collection of personal information. All personal information will be kept in a secure, locked cabinet and each participant will be anonymous to keep their information private throughout the duration of the study. Please see the appendix for the participation information sheet and consent form

11. Are the participants vulnerable?

Yes

(a) in what ways are they vulnerable? Outline

Majority if not all participants who will be recruited will be under the age of 18 years old.

b) Why do you need to involve them in your research? Outline

Discovering why sleep may affect the different phases of the menstrual cycle in school-aged students. Requires the participants to attend school which means most of our participants will be 15-18 years old. Younger females may also not have a full understanding of hormonal contraception therefore, it is easier to find more participants who are not on contraception as being on contraception will affect the study. It is also known that sleep in school-aged children may already be low due to school and sports stress and the study aims to see if menstrual can also impact the younger females' sleep hygiene.

c) How will you protect them from harm? Outline

The research team will ensure that all participants and their parents/ guardians understand and are fully informed of the study objectives, methods, potential risks, and benefits before consenting to participate. Confidentiality rules will be carefully followed throughout the entirety of the study, ensuring participants' privacy and anonymity. Participants will be allowed to withdraw from the study three weeks after data collection and will be notified that this is their right and there will be no consequences to follow. Regular monitoring and check-ins will be conducted to ensure that the participants feel supported and to check on their well-being during the study. Parents or support personnel will be able to attend the information sessions and a female researcher will be present during the duration of the meeting sessions and the collection of the data. We understand that during this time and young women's journey through their menstrual phases can be painful, emotional, and upsetting and we acknowledge this with support information for participants to use if they become distressed

12. Will you select participants based on:

Ethnicity: No	Iwi: No
Culture: No	Disability: No
Gender Yes	Ethical belief: No
Religion No	Sexuality: No

If yes to any of the above:

(a) State how you will inform participants about the selection criteria.
When talking to the female students about the project I will inform them of the selection criteria, I will also add this to the information sheets I will provide to the schools and sports teams/ clubs, and I will also add this to the participation consent sheet once more.

(b) Are your participants likely to come from a particular ethnic group or other distinct population even if you are not selecting them on that basis? If so, please discuss the implication of this for your research.
No, only relevant to one gender.

(c) What cultural and other competencies do you have to work with your selected participant group (e.g. language, membership, professional training)?

The participants chosen for this study will not be selected from any certain social or cultural background. The only exclusion criteria this study will be using only using female participants who play sports. The participants will be shown full respect and care by the researchers and will ensure that cultural and social requirements are met during the commencement of the study. If there are certain needs or wants from the participants, then the researchers will try their best to assist in any way they can. The participants will be able to consult with family or guardians before and during the data collection process if desired.

13. Do you have any type of relationship with your participants already (e.g. employer/employee, supervisor/worker, personal relationship)? No
No participants will not have any connection to the main researcher.

If yes, then you will have a dual role in the research, both as a researcher and, for example, as a friend or family member. Therefore:
How will your pre-existing relationship affect your role as a researcher? Outline and address potential ethical issues associated with your pre-existing relationship with your project.

Not applicable

14. Will participants receive any form of compensation or incentive for participation? (See guidelines on compensation and note that reimbursement for travel expenses can be stated, but does not need justification)

No, participants will not receive any compensations or incentives for their participation in the study, on request from participants they will be allowed to receive a summary of the results from the study.

If yes, what will they receive? (e.g. vouchers, prizes, shared refreshments, course credits, etc.) Outline.

Not applicable

Consent

Please provide the following information about consent processes:

15. How will you gain informed consent from your participants? Outline methods for this consent process

I will give each participant a detailed information sheet about the study, with my contact details to allow any participants to ask questions about the study if necessary. I will also ensure each participant has a full understanding of the study before signing off a consent sheet.

(a) Who will gain consent from participants? *Note that where dual roles exist (Q.13 above), coercion to participate may be avoided by asking a third party to undertake the informed consent process.*

I will need to gain parental written consent, in addition to the children's written consent.

(b) At what point do participants give their consent? *NB: Ensure you attach a copy of the participant consent forms. If you intend to seek oral consent, include a procedure sheet to describe the process by which consent will be negotiated.*
Participants will give their full written consent, once they have read the information sheet about the study and they have a full knowledge of their participation in the study.

(c) If vulnerable, are your participants able to give informed consent?

Yes, the participants involved in this study will be vulnerable due to most of them being under the age of 18 years old. I will need not only consent from the participants but also from parents/guardians.

16. Except for participants who are anonymous to the researcher, participants have the right to withdraw entirely or in part from the research. Please explain how and by when participants can withdraw: (*e.g. three weeks after data collection, or receipt of a transcript*) and ensure this is consistent with what is included in the Participant Information Sheet and Participant Consent Form.

The participants for the study will have the right to withdraw from the study up to three weeks after the research has been conducted, if they do not wish to continue with their participation without any consequences, however after the study has been conducted, they will have to email the primary researcher about the withdraw 3 weeks after the research has been conducted.

17. Data collection activities may be planned for off-campus locations. Please list all non-UOW locations where you will engage in data collection.

Each participant will be able to collect data in the space of their own home.

Data collection can occur in the comfort of their own home and their data can be emailed or if participants want to give their data physically, the participants can email me, and data will be collected at the Adams Centre.

If you need consent or permission from any organization, community representative, and/or anyone other than the individual participants Please list the required permissions, consents, and/or approvals in chronological/process order.

Many participants will be recruited from schools and sports teams therefore the primary investigator will need to visit these places to gain permission to recruit participants.

How and when will you gain these permissions, consents, and/or approvals? *Ensure you attach any statements, letters, or emails of permission or approval that have been secured in advance of your application to the Human Research Ethics Committee.*

I will phone or email the schools and sporting clubs before the commencement of the recruitment giving them a brief understanding of what I need for my study and why I am conducting this study. If I get permission I will go into the schools and sport clubs and then obtain the correct permission from the schools and clubs before participating in recruitment.

Research design

18(a) Please outline what you intend your participants to do *e.g. semi-structured interviews of 12 FASS academic staff members about their experiences of xxx e.g. anonymous online survey of all University of Waikato staff members about xxx* ...
NB: *Attach to the end of the application as part of a single pdf, all research instruments that you intend to use to collect data. (e.g. interview schedules, questionnaire/survey items). Indicate whether the research instruments are drafts or final versions. Later final versions of research instrument versions must be lodged with the committee before data collection.*

The participants who have met the inclusion criteria will be asked to come into the University of Waikato Adams Centre or familiarisation sessions where 1-1 sessions with the lead researcher, participant and any support party will go through what the participants will need to do and what needs to be completed, these 1-1 sessions will be used to keep anonymity among other participants. During this session, the participants will be asked to enter menstrual cycle data onto their Fitbit charge 5 watches where they will be able to track their cycle and their phases via the Fitbit application. Therefore, all participants can track their menstrual cycle on the same app. The participants will all be given one Fitbit charge 5 each. Where they will be shown how this works how to put it on and when to wear it. After this, the participants will also be shown how to create and set up a sleep diary, where they can track their sleep quality/ hygiene. The participants will complete three menstrual cycles where they will track their sleep latency, sleep duration, and sleep quality during the follicular phase and the luteal phase of their periods. The participants each week will be asked to email through their sleep diaries, their Fitbit results, and a picture of their Fitbit app, where the researcher can then take this information and start conducting their analysis of the results.

(d) How will participants benefit from their involvement in the research?

The participants may not find any direct benefit from participating in the research; however, they will have helped contribute to the understanding of how the different phases of the menstrual cycle affect sleep. The participants will be able to receive the outcome and a summary of their results which they can use in the future to help enhance their athletic performance.

19(a) Could participants be harmed in your research?

During the study, there should not be any harm or threats placed upon the participants.

(b) Could concerns arise regarding the health and well-being of anyone participating in your project?

Participants will be conscious of their participation in the study, this may cause worry and anxiety in some participants, affecting their sleep quality or menstrual cycle.

20. How will you analyse participant data?

The data we will first be gathering; sleep quality, sleep duration, and sleep latency during the follicular phase and the luteal phase will be collected and categorised accordingly. Descriptive statistics such as standard deviations, means, and distributions of data will help provide an understanding of sleep characteristics during each phase. Statistical tests, such as t-test and/or ANOVA will be used to assess whether there are significant variations in sleep measures between the two menstrual cycles. To test the test - retest reliability an Intraclass Correlation Coefficient (ICC) will be used. ICC less than 0.40 will be deemed poor, 0.40 – 0.75 will be deemed fair, values between 0.75 – 0.90 will be good and anything over 0.90 will be excellent (Murray et al., 2018). A coefficient of variation under 10 % will be considered acceptable and a CV over 10% will be considered suboptimal (Murray et al., 2018). A typical error will also be measured to test the reliability, therefore a typical error of 5% or less will be shown to indicate better reliability (Sports Sci, 2023.)

Will your research involve comparing one group to another? No

(a) If yes, then explain the process for this comparison, addressing:
    (i) How the participants are categorized into specific groups
    (ii) Why is it important to do this?

21. Does your research involve any deception of participants?

Not applicable

22. Will the identity of the researcher(s) be concealed from participants at any time during the research? (Such research is called ‘covert research.’)

Not applicable

Cultural safety

Te Whare Wānanga o Waikato, the University of Waikato, through its official *Charter,* has an explicit commitment to partnership with Māori, to kaupapa and tikanga Māori, and the interests of New Zealand-born and Island-born Pacific people.

The *Ethical Conduct and Human Research and Related Activities Regulations* stipulates that researchers are required to respect the cultural, social, and language preferences and sensitivities of participants. Therefore, when you apply for ethical approval, you should demonstrate an awareness of social and cultural differences, consult advisors regarding the appropriate conduct of your research, and present the outcome of any consultation in your ethics application.

Two resources important to refer to when undertaking research at the University of Waikato are:

- *Te Ara Tika – Guidelines for Māori Research Ethics*
- *Pacific Health Research Guidelines*

23. Does the research project have relevance or potential implications for Māori, and/or other social and/or cultural groups? No

Do you have at least one cultural advisor for this project?

No

Provide their name(s) and specific role(s):

Not applicable

Outline how you will show respect and sensitivity towards participants (*such as: inviting their support persons to be present during interviews; using interpreters if you are not fluent in the participant's language; being vouched for by elders; using appropriate gestures and greetings; dressing appropriately; participating in cultural ceremonies or rituals...)*:

Participants from all ethnicities and social backgrounds who match the inclusion criteria will be invited to participate in the study. The participants and their parents/ guardians who may be involved in the study will be treated with kindness and respect and they will be made to feel supported. The participants should feel no pressure to consent to participate and they will understand that their participation is completely voluntary. All participants will be supported and if any questions, wants, or needs arise from the participants, the researchers will do their best to understand and accommodate those. During the meeting sessions, the participants will be allowed friends or a family member there as a support person during the breakdown of the study if desired. The subjects will also have the right to withdraw from the study up until three weeks after data collection for any reason.

How will participants' identities (and their communities and/or organisations where relevant) be represented in the research?

Is it important to maintain the confidentiality of participants (and their communities/organisations where relevant) in the research reporting?

If yes, outline how you intend to preserve confidentiality:

During the study, the researchers will know who the participants are, however, the identity of the participants will be kept anonymous using numbers assigned which will be used for obtaining and analysing the data collected. However, a copy of the participant's name and assigned number will be kept in a secure place where only the researchers can access it. This will only be used if the participants wish to view their results. Consent forms will also include a statement that will describe to the participants that their identities will be anonymous. Anonymity will occur and the identities of the participants will only be made available to the lead researcher and the secondary investigator/ supervisor (Dr Tracey Clissold).

All data will be stored in a computer file that will only be accessed using a strong password. The only people who will have access to this information will be the lead researcher and the secondary investigator (Dr Tracey Clissold)

It is important to note that participants will be informed about the potential privacy risks when using the Fitbit app for this research. The app collects personal information such as (Name, email, age, and location), health and activity data (such as heart rate, sleep, and menstrual cycle), and device data (such as IP address). Each participant will be given a special ID number and an email address only known to the lead investigator and the secondary investigation/ leading supervisor (Dr Tracey Clissold). This will help keep anonymity amongst the participants and keep information such as their identity hidden.

26. In addition to the researcher(s) listed on this application, who else will see the information that participants provide?

Will anyone else see the participants' data?	No, all participants will be de-identified and be referred to as a number during the entirety of the study to conceal the identity of the participants.
Outline why they need to see it:	Not Applicable
Will any shared information be linked to participants' names?	No

Will data/names be anonymised before sharing? *It may be appropriate to ask additional parties (e.g. student researchers, transcribers) to sign a confidentiality agreement. Attach the confidentiality agreement that you intend to use.*	A confidentiality agreement will be signed if any other parties (e.g., research assistants) become involved in the study, head researcher will ensure all third parties who become involved have receive or have suitable ethical training.

Research Reporting

28. Identify all the anticipated research outputs for the project

Thesis	Yes
Conference papers	No
Journal articles	Yes
Book chapters	No
Media releases	No
Teaching and learning materials	Yes
Other	Yes List: Oral/ poster presentation.
Sharing outcomes with participants	
Outline how you provide participants with this information:	Participants will be notified in the consent form and the participant information sheet that upon request, they will be provided their results through oral, poster, or thesis presentations by email to the lead researcher

29. Research data must be stored for a minimum of 5 years after the completion of a research project. Where and how will you store your data after the project has been completed? NB: *Supervisors are responsible for storing research data on behalf of their students.*

Where you will store it How you will store it	Paper forms will be stored in a file cabinet either in the lead investigator's office or the secondary investigator's office (Dr Tracey Clissold). The primary and secondary investigators will be the only two investigators who will know where this data is kept and will be the only ones who will have access to these files. The cabinet will always be locked and secure. Electronic data will be kept in a protected file, which will be secure using a strong password. Where only the primary and secondary investigators will have access to the data.

Archiving after 5 years: Where? Under what conditions?	Not applicable
Choosing to destroy data after 5 years. Outline how this will be done safely	*Electronic data will be deleted, and any paper forms or data will be torn up and thrown out immediately*

Legal Issues

30. Ownership of Human Research Data

It is usual to state that participants own the data that they provide, and that the researcher will use the data for the specified purposes, with the consent of participants. Please explain any variation from this arrangement.

Not applicable

31. Copyright

The researcher's ownership of scholarly publications and other forms of research outputs is governed by the University of Waikato's Intellectual Property Rights Policy. Crucially the policy states in Clause 8 that, *"the University recognises and endorses the traditional academic freedom of staff to publish research and scholarly documents and to produce creative and artistic works without restriction; the University does not assert ownership of the copyright of such works (e.g. books, journal articles, conference papers, artworks, and musical recordings) unless specified in clauses 12- 18 of [the] policy."* Please explain any variation from this policy.

Not applicable

Clause 9 states: *"When dealing with intellectual property that includes Mātauranga Māori, and in the context of the WAI262 claim report, the principles of Te Tiriti o Waitangi will be applied by the University".*

(a) Is any intellectual property related to this project subject to the principles of Te Tiriti o Waitangi?
Not applicable

32. Other legal or ethical issues. Describe any other legal or ethical issues related to this project. Consider particularly relationships between members of the research team, and project funders, sponsors, or other stakeholders.

Not applicable

Appendix B: Ethics Approval

The University of Waikato
Private Bag 3105
Gate 1, Knighton Road
Hamilton, New Zealand

Human Research Ethics Committee
Roger Moltzen
Telephone: +64021658119
Email: humanethics@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

11 September 2024

Naia Anderson
HECS
By email: Na171@students.waikato.ac.nz

Dear Naia

HREC(Health)2024#36: The menstrual cycle's effect on sleep in school-aged female athletes

Thank you for your responses to the Committee feedback.

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 C: Participant Information Sheet

Participant Information Sheet

The effects of the menstrual cycle on sleep in school – aged athletes.

An Invitation:

My name is Naia Anderson, and I am a master's student at the University of Waikato Tauranga. I am conducting a research master's thesis to understand and consider how the menstrual cycle affects sleep quality, sleep duration and sleep latency in school – aged female athletes. I am looking for individuals to investigate how different phases of the menstrual cycle can affect several factors of sleep. Your participation in this study is entirely voluntary, and you may withdraw at any moment prior to the completion of data collection with no penalty. The data and evidence from this study may allow for more effective suggestions for managing sleep issues and overall well-being during the different phases of the menstrual cycle, as limited research has been done for this population in the space of sleep and the menstrual cycle.

What is the purpose of this research?

This research looks at how the different phases of the menstrual cycle, like the follicular phase and the luteal phase, affect sleep in school-aged female athletes. We want to understand how these phases impact how long you sleep, the quality of your sleep, and how quickly you fall asleep.

Many girls experience sleep problems before and during their period, and these problems might be linked to the hormones that change during the menstrual cycle. These sleep issues could also be a reason many young women in New Zealand stop participating in sports and physical activity, especially around puberty.

By understanding how sleep and the menstrual cycle are connected, we hope to find ways to improve sleep and help girls stay active and healthy.

Am I eligible to participate in this research?

You are invited to participate in this study if you meet the eligibility requirements.

- Be female
- Be between the ages of 10 – 18 yrs.
- Participate in any sporting activity
- Completed/ have a regular menstrual cycle (6 -12 menstrual cycles in a year)
- Be on no birth control, sleep medication or any medication that could affect a menstrual cycle or sleep.

What will happen in this research?

If you have met all the inclusion criteria, you will be contacted and asked to attend an information session where you will become familiarised about what you need to complete and do for us to collect data. You will be given a Fitbit (sleep tracking device) where you will track your sleep during different phases of your menstrual cycle. You will also be asked to create a sleep diary where you will track the quality of your sleep. You will need to complete three regular menstrual cycles where we will be tracking sleep latency, sleep duration and sleep quality during the follicular phases and the luteal phase of your menstrual cycle. You will be required to email your sleep diary results, readi band results and a picture of your menstrual tracking app, for us to start analysing data.

Familiarisation & Data Collection:
Each participant will be able to collect data in the space of their own home. Data collection can

occur at Omanu Swim Club, where each participant can physically provide the researcher with their data or email a copy of their data.

Data collection:

1. Sleep quality
2. Sleep duration
3. Sleep onset latency
4. Written informed consent form

Measurement of your sleep quality

Your sleep quality will be measured using a sleep diary. The sleep diary will be used to record details about your sleep each day. You will be required to note down what time you went to bed and when you woke up, also jotting any other factors that might have influenced sleep, such as, daily activities, stress levels, last time of meal, also a ranking from 1-10 of how you felt your sleep was.

Measurement of your sleep duration and sleep onset latency

We will use a Fitbit charge 5 to monitor your sleep duration and sleep onset latency. This wearable band is specifically developed to precisely measure your sleep patterns. You will be required to wear the Fitbit charge 5 around your wrist while sleeping. It uses sensors to track your movements and recognise when you fall asleep and wake up.

Measurement of your menstrual cycle

To measure how the two different phases of the menstrual cycle phases may affect your sleep, we will use a period- tracking app. This app will allow you to record information about your cycle, such as the beginning and the end of your period dates as well as any symptoms or changes you see. By examining this data together with your sleep patterns, we will be able to understand how different phases of your cycle may affect your sleep quality, duration, and onset latency.

What are the benefits of my participation in this research?

- As a participant, you may not find any direct benefits from participating in the research; however, your participation will help contribute to the understanding of how the different phases of the menstrual cycle can affect sleep. You will be able to receive the outcome and a summary of your results, which can be used in the future to help enhance your athletic performance.

What are the discomforts and risks and how will they be alleviated?

During the study, there should not be any harm or threats placed upon the participants. Participants will be conscious of their participation in the study; this may cause worry and anxiety in some participants, affecting their sleep quality or menstrual cycle.

It is encouraged you to share any questions or concerns you may have with the researchers, and we remind you that you have the right to withdraw from the study at any time up until the data collecting ends.

How will my privacy be protected?

Your privacy will be maintained throughout the entirety of the study

- You will be allowed to withdraw from the study up until three weeks after data collection has occurred.
- Your details will be kept anonymous using numbers assigned which will be used for obtaining and analysing the data collected.
- All data will be stored in a computer file that will only be accessed using a strong password. The only people who will have access to this information will be the lead researcher and the secondary investigator (Dr Tracey Clissold).

What are the costs of participating in this research?

No cost for participating in the research only your time, patience, and effort.

What opportunity do I have to consider this invitation?

It is with the researcher's intention to start collecting data for the study in October, November, and December 2024. If there are any queries or questions including, any cultural needs, please do not feel hesitant to contact or enquire about these. Please remember your participation is voluntary and, up until the completion of the data collection period, you may withdraw from the study without any consequences.

How do I agree to participate in this research?

If you meet all the requirements to participate in the study, please read and sign the consent form by October the 5th and hand/email it to Naia Anderson.

Research Student: Naia Anderson
naiagrace03@outlook.com
M. 0273759281

This research project has been approved by the Human Research Ethics Committee (Health) of the University of Waikato under HREC(Health)2024# 39. Any questions about the ethical conduct of this research can be addressed to the Ethics Committee at humanethics@waikato.ac.nz, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240. • Consent/Assent Form: These appear to be missing.

Appendix D: Participant Consent Form

Research consent form.

Project Title: The effects of the menstrual cycle on sleep in school-aged athletes.

Research Student: Naia Anderson
naiagrace03@outlook.com
M. 0273759281

Research Overview:

The purpose of this research is to understand the relationship between hormonal fluctuations during the different phases of the menstrual cycle and sleep. Thus, research will examine how these different phases of the cycle impact sleep quality, sleep duration and sleep onset latency. This research can help lead to improved support systems for youth athletes, helping them maintain optimal health and performance throughout their menstrual cycle.

If you agree to participate in this study, you will first be required to sign a written consent form. The investigators will next arrange an information session to familiarise you with the instrumentation used in this study.

There is minimal to no risks associated with this study. While this study will afford no individual benefits, your participation will help contribute to the understanding of how the different phases of the menstrual cycle can affect sleep.

Declaration of consent

1. Do you understand the purpose of this study and the procedures involved as provided in the Participant information sheet?
2. Do you understand that you can ask questions and the research has answered any questions about the study to your satisfaction?
3. Do you understand that all personal data and responses will be kept confidential and used solely for the purposes of this research?
4. Are you aware of any potential risks or discomforts associated with this study, such as privacy concerns related to discussing menstrual health or potential emotional discomfort?
5. Do you understand that you can withdraw your data from the study at any time?
6. Do you understand that your participation is voluntary and that you are free to withdraw from the study at any time, without having to give a reason and without any consequences?

I agree/ do not agree to take part in the above study.

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Name of Participant	Date	Signature
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Name of Parent/guardian	Date	Signature
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Name of Researcher	Date	Signature

Appendix E: Recruitment Poster

Appendix F: Recruitment Letter

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

The menstrual cycle's affects on sleep in school-aged female athletes

Purpose of the study

The purpose of this study is to understand and investigate how the different phases of the menstrual cycle; follicular phase and the luteal phase, affect sleep duration, sleep quality and sleep onset latency in school- aged female athletes. By examining the relationship between the menstrual phases and sleep, this study hope to identify any significant differences in sleep duration, quality and latency experienced by the athletes

Inclusion Criteria

You are invited to participate in this study if you meet the eligibility requirements.

- Be female
- Be between the ages of 13 - 18 yrs.
- Participate in any sporting activity
- Completed/ have a regular menstrual cycle (6 -12 menstrual cycles in a year)
- Be on no birth control, sleep medication or any medication that could affect a menstrual cycle or sleep.

Participant benefits and requirements

If you have met all the inclusion criteria, you will be contacted . You will be given a Fitbit charge 5 (sleep tracking device) where you will track your sleep during different phases of your menstrual cycle. You will also be asked to create a sleep diary where you will track the quality of your sleep. You will need to complete three regular menstrual cycles where we will be tracking sleep latency, sleep duration and sleep quality during the follicular phases and the luteal phase of your menstrual cycle (At no cost).

Contact

If you meet all the requirements to participate in the study, please email Naia Anderson with your expression of interest for more information about the study.

Research Student: Naia Anderson: email: naiagrace03@outlook.com or M.0273759281

Project supervisor: Tracey Clissold: email: tracey.clissold@toiohomai.ac.nz or M. 0212097022