A comparison of pop-up velocity between younger and older recreational surfers

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David Enticott

Abstract

Background: The pop-up is the physiological task that places a surfer on a wave. The aim of every recreational surfer is to catch as many open-faced, rideable waves as possible with pop-up velocity being crucial to this. Recent research shows a clear trend of an aging surfing demographic all of whom have the potential to experience an age-related reduction in their pop-up velocity. A slower pop-up would likely limit wave-riding options for these older surfers; therefore, the primary purpose of this study was to determine if age reduces pop-up velocity in intermediate recreational surfers. We hypothesised that pop-up velocity between younger and older recreational surfers would exhibit no statistically significant difference as a result of older surfers having developed efficient movement patterns and skill sets over many years that offset any age-related muscular decrement **Methods:** Fourteen intermediate recreational surfers (13 males and 1 female) were placed into two groups based on age, a younger group (25.2 ± 9.0 years old, 9.7 ± 10.9 years of surfing experience) and an older group (51.8 ± 6.6 years old, 30.0 ± 9.1 years of surfing experience). The cohort had at least two years surfing experience and did not follow a specific dry-land resistance training programme. Participants completed a simulated pop-up in a controlled laboratory setting with pop-up velocity captured by dual Kistler force plates. A countermovement jump test was also completed by each participant to assess lower-body power and velocity. The intraclass correlation coefficient (ICC), coefficient of variation (CV0, and typical error (TE) were calculated to determine inter-group reliability between the older and younger surfers' pop-up velocity tests and between pop-up tests featuring simulated paddling strokes and those without. An independent samples t-test was conducted to examine the differences between the two age groups' pop-up velocity and between pop-up tests featuring simulated paddling strokes and those without. The strength of correlation between surfer age and relative maximal power was assessed with Pearson's *r*. **Results:** The test showed *good* (ICC 0.75-0.90) reliability and no apparent difference between paddle and non-paddle and the older and younger cohorts; however, the CVs all exceeded 10%. The younger group demonstrated significantly quicker surf pop-ups (1.12±0.16 vs 2.03±0.52 s; $p = 0.0009$; $d = 2.21$ [1.10, 4.20]) and relative maximal power (53.8±12.9 vs 41.2±2.2 $W \cdot kg^{-1}$; $p = 0.0252$; $d = 1.28$ [2.84, 0.23]) than the older group. Interestingly, the negative coefficient (slope) that described the overall relationship between age and leg power observed (m= -0.53) was attenuated when looking at surfers over the age of 35 (m=-0.10). **Discussion:** Loss of pop-up velocity can be expected in older surfers but the typical age-related decline in muscle capability may be offset by surfing. The incorporation of dry-land resistance exercise including power and strength training is recommended to improve pop-up velocity and thus wave wave-catching ability and enjoyment in older surfer. These findings demonstrate positive ramifications of participation in surfing and can support longevity in older recreational surfers. **Conclusion:** Age clearly had a negative influence on pop-up velocity.

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It is difficult to convey the effect an undertaking such as this has had on those closest to me.

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Abbreviations

CMJ – Counter Movement Jump

FP – Force Plate

VJH – Vertical Jump Height

RMP – Relative Maximal Power

TTP – Time to Pop-Up

ROS – Recreational Older Surfers

ICC – Intraclass correlation coefficients

CV – Coefficient of Variant

NP – Non-Paddle

PU – Pop-Up

N – Newtons

RMF – Relative Maximal Force

ATP – Adenosine Tri-Phosphate

RYS – Recreational Younger Surfers

P - Paddle

TE – Typical Error

SP – Simulated Paddle

R – Correlation of Coefficient

ATP-PC - Adenosine Tri-Phosphate – Phosphocreatine

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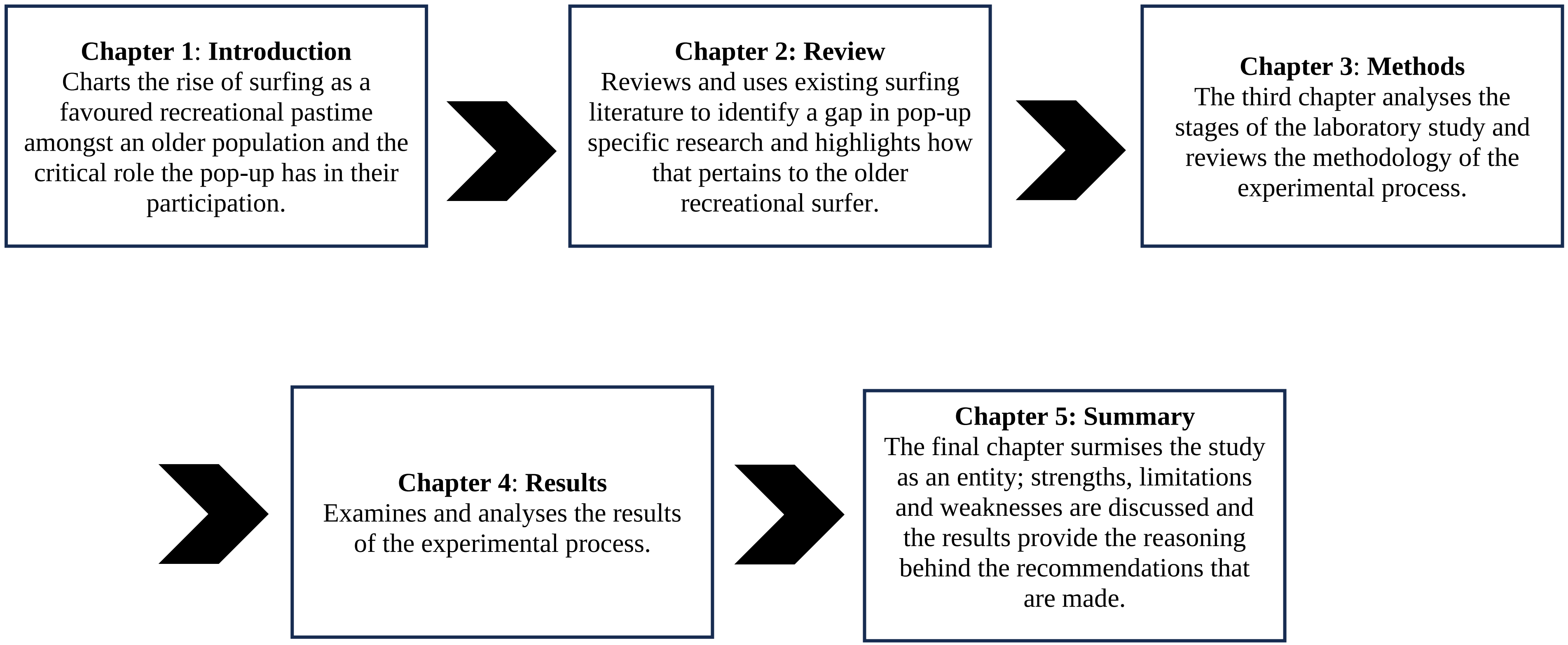

Figure 1: Thesis Outline

Chapter 1: Introduction

Global participation in ocean surfing is increasing, with estimates placing the number of worldwide participants at 37 million (Remnant et al., 2020) up from an approximate 25 million in 2009 (Agurre, 2009). Internationally, the rise of informal lifestyle sports including surfing, come with an assumption that these sports are the domain of youth; a hedonistic, counter-culture pursuit (Wheaton, 2004). Contrary to this typical perception, and as part of the growing popularity of surfing, there is an increasing visibility of older (or 'silver') surfers (Wheaton, 2017) who lack adequate performance measures to reference. Forsyth et al., (2020) suggested that evidence-based recommendations as to how to perform surfing manoeuvres are sparse in contemporary scientific literature with the focus to date predominately on paddling performance. Arguably, the single most important manoeuvre in surfing is the pop-up as it places the surfer on the wave face. The pop-up is a physiologically challenging, highly advanced motor skill combining neuromuscular control, muscular strength, power, coordination, and balance. To our knowledge, a very limited number of research studies into the pop-up exist (Eurich, 2008; Eurich et al., 2010; Hammer et al.,2010; Parsonage et al., 2020; Borgonovo-Santos et al., 2021; Boergers et al., 2023) and none explore the effect of age on pop-up power.

Quantifying how many of the 315,000 surfers in Aotearoa New Zealand (McArthur et al., 2020) are older (over 45) is difficult, an issue prevalent in all lifestyle sports (Wheaton, 2008). It is less difficult to examine the drivers of rising participation in this demographic. In addition to surfing's inclusion the Olympic Games, specific reasons that facilitate surfing whilst ageing include: technological advancements in surfboard construction (providing improved buoyancy and stability), the increased availability of time and disposable income associated with older adults, and the desire to adopt a recreational lifestyle practice (Olive, McCuaig, and Phillips 2013; Beaumont and Brown 2015).

An issue facing older surfers as they take up surfing is that “limited information is available with regard to the long-term physiological adaptations of participating in surfing” (Frank et al., 2009, p.31). This issue was still prevalent almost a decade later with more recent literature highlighting a paucity of research (Farley et al., 2017) and a lack of refinement in the research that exists (Sheppard et al., 2013). Clearly, there is a need to examine distinct categories of surfing performance beyond the existing broader measures in order to enhance the older surfers experience. Meir et al, (1991), Farley et al., (2012) and Mendez-Villanueva et al. (2005) all identified the cornerstone of surfing activity as paddling (55% of a 60-minute surf session) with remaining stationary (35%), wave riding (5%) and miscellaneous activities (5%) accounting for the remainder of the activity. A specific activity not listed is the pop-up which is surprising considering that “wave riding is the essence of surfing” (Borgonovo-Santos at al., 2021, p.21) and mastering the pop-up can be considered the key to unlocking that wave riding experience.

As is often the case, the best interpretation of what the pop-up is, and what it involves, is a simple one. Eurich et al., (2010) stating “it is the need to move 75% of their (the surfers) body weight off the surfboard in less than a second” (p. 2823). That said, no standardised start and completion points of the pop-up have been used across existing research. Parsonage et al. (2020) defined the start of the pop-up as the chest leaving the board with completion being when the front foot has landed on the board. In contrast, Borgonovo-Santos et al. (2021)

determined that the beginning of the pop-up was the point when at least one hand touched the surfboard with the finish of the pop-up characterised by the point at which the surfers stabilised themselves on the surfboard. This ‘point of stabilisation’ is characterised by the force plate reading returning to the surfers starting body weight.

Essentially, the pop-up is an expression of power. A number of studies have explored upper-body strength and power in relation to the pop-up and found surfers who have a greater rate of force development, greater upper body muscle mass, and greater maximal strength are able to pop-up faster (Eurich et al., 2010; Fernandez-Gamboa et al., 2020; Parsonage et al., 2020). During the push-up phase, when initiating the change from a prone to a standing (or wave-riding) position, forces generated have been shown to be equivalent to the surfers full-body weight (Borgonovo-Santos et al., 2021). The lower-body demand of the pop-up appears to be centred around the distribution of landing forces between the forward and back foot (Borgonovo-Santos et al., 2021) with the fore-aft distribution of a surfers bodyweight being 60% and 40% respectively. Frank et al, (2009) found muscle force fluctuations were significantly lower in male recreational surfers with 40 or more years of surfing experience. These authors identified efficient neuromuscular function, specifically balance, joint position sense, and body sway control as critical to becoming stable in the wave-riding position in the moments after the pop-up is complete, thus reducing the prevalence of falling.

It appears that relative upper-body power decline can begin as early as the 20’s in women and 30’s in men (Metter et al., 1997). Similarly, Alcazar et al., (2020) found relative, absolute and specific lower-body muscle power began to decline above the age of 40 in both women and men when testing maximal voluntary leg extension power. Metter et al. (1997) go on to declare that "the independent effect of age on power argues for the importance of movement speed, coordination, and other factors in power generation" (p. B275). In adding dynamic and maximal strength and balance to movement speed and coordination, we identify the critical factors that exemplify an effective surf pop-up.

Therefore, the aim of the current study is to investigate the effect of age on pop-up performance with the primary research question observing any differences in pop-up velocity between younger and older surfers. The study will explore the theory that older surfers will offset the loss of pop-up power associated with aging via their engrained neuromuscular patterning. The technical prowess that older surfers have acquired as a result of performing the pop-up action with more frequency than their younger counterparts might ensure no statistically significant difference in the pop-up velocity between the two cohorts is observed. As such, the null hypothesis is that no statistically significant difference exists in surfing pop-up velocity between younger and older recreational surfers ($H_a = H_0$). The alternative hypothesis is that age-related physical differences will result in differences in pop-up velocity ($H_a \neq H_0$). To the authors knowledge this will be the first study to evaluate surfing pop-up velocity between two independent groups of different ages and surfing experience levels.

Chapter 2: Literature Review

Introduction

Internationally, the rise of informal lifestyle sports, such as surfing, mirrors the decline in traditional sports (Wheaton, 2017) as exemplified in Aotearoa New Zealand by the decreasing participation amongst secondary school children in rugby (Gall, P., Leach, M., 2021). This phenomenon is confounded by the 'attractiveness' of surfing, particularly in Aotearoa New Zealand, where the pristine natural environment speaks to important national discourses about Kiwis as outdoor people (Wheaton, 2017).

Determining the factors that have driven rising participation in surfing amongst those forty years of age and above is fundamental to the motivation and need for this research. As discussed in the introduction, the generic drivers of increased participation in 'lifestyle sports' go some way to explaining the rising interest in surfing by those over forty. It is however, important to understand the more specific reasons that make surfing so appealing. Technological advancements in surfboard construction (providing improved buoyancy and stability), the increased availability of time and disposable income associated with older adults, and the desire to adopt a recreational lifestyle practice (Olive, McCuaig, and Phillips 2013; Beaumont and Brown 2015) enable us to understand why there are an increasing number of 'Silver Surfers' (Wheaton et al, 2017). The notion of how blue spaces, such as the ocean (Olive & Wheaton, 2021), are positively related to well-being, is highlighted as an additional reason for surfing participation that is less likely to be a motivating factor for younger surfers. Interestingly, this is a trend replicated in competitive surfing with Mendez-Villanueva and

Bishop (2010) noting that “current world-class professional surfers are consistently older than 25 years ago, probably reflecting the required years to refine mastery in surfing performance and competitive skills” (p. 59).

These definable mechanisms of participation change, expose surfing’s immature structure; it was only in 1976 that “a collection of disparate unaffiliated pro-surfing events around the world were combined into a professional body” (*WSL History 1976-1982*). Surfing’s elevation from subculture to the mainstream is highlighted by the lack of structured performance measures for the recreational surfer, in stark contrast to typical Aotearoa New Zealand sports such as rugby, cricket, and swimming. An early formative study referencing surfing performance noted that "limited information is available with regard to the long-term physiological adaptations of participating in surfing” (Frank et al., 2009, p.31), an issue still prevalent over a decade later. Forsyth et al., (2020) suggested that evidence-based recommendations as to how to perform surfing manoeuvres are sparse in contemporary scientific literature. There exists a need to identify potential physiological barriers to continued participation and enjoyment of surfing by the aging recreational surfer. If specific assertions can be made regarding age-related muscular power changes (and the subsequent effect on the pop-up), then targeted dry-land training recommendations can be put forward. The recreational surfing experience would benefit from data-driven, and informed training programmes that enhance both enjoyment and continued participation as the surfer ages.

In identifying why surfing research is essentially playing ‘catch up’, it is important to note that the open environment setting of the sport makes field-based data collection difficult.

This paucity of research (Farley et al., 2017) and lack of refinement (Sheppard et al., 2013) is somewhat offset by upwards of ten laboratory studies and two systematic reviews in the past five years. These data arguably contradict the observation regarding a dearth of literature made by Forsyth (2020); however, the focus of the majority of contemporary surfing research is on competitive surfing that is judged and scored. Whilst the pool of research may remain small, its depth is increasing, the works of Márcio Borgonovo-Santos et al., (2021), Parsonage et al., (2020), Furness et al., (2018), Parsonage et al., (2017), Farley et al., (2017) and Forsyth (2020) have built on pioneering research since 1980 such as that of Lowden (1980), Meir (1991), Mendez-Villanueva and Bishop, (2005), Frank et al., (2009), Farley et al., (2012) and Barlow et al., (2014). This paper continues in that same direction by identifying a knowledge gap in one of the more nuanced physiological demands of surfing that is a key performance measure for recreational surfers: the pop up. In spite of its importance to surfing performance, the pop up remains relatively unexplored; therefore, this thesis investigates the different characteristics of the pop up between younger and older recreational surfers.

Identifying the broad physiological demands of surfing

The research highlighted above has been specifically identified for its prevalent use of recreational surfers as study participants, as opposed to competitive surfers partaking in competition-style time-restricted trials. The establishment of key factors for the recreational surfer to consider when seeking to maintain and enhance participation and enjoyment begins with the identification of the predominant physical requirements needed during a typical surf session. Given that a recreational surf session is arbitrary in length, unlike competitive surfing, it is expected that a range of physiological demands will be placed on the surfer. Meir et al, (1991) identified the cornerstone of surfing activity as paddling, taking up approximately 45-

55% of a 60-minute surf session. The remaining time was broken down as follows: approximately 35% is spent stationary, approximately 5% is spent riding waves, and 5% categorised as miscellaneous activities. In contrast, Farley et al., (2012) report that the duration of time spent wave riding, performing miscellaneous activities, and paddling for a wave represented 8%, 5%, and 4% of surf sessions, with Mendez-Villanueva et al. (2005) suggesting that wave riding accounted for just 3.8% of the time, with miscellaneous activity accounting for approximately 2.5%. It is the activities that make up these miscellaneous categories that represent the more nuanced performance measures of surfing. Activities in this category include duck diving under white water, recovering and getting back on the surfboard after falling, walking, running, or wading up the beach (Meir et al. (1991). Farley et al., (2012) adds to this list with "slow one-arm paddling action aiming to maintain position in the take-off zone" (p.1889). A specific activity not explicitly listed that presumably falls into the 'miscellaneous' category is the pop-up. The pop-up is a quick transition from lying prone to standing on the surfboard, requiring significant upper and lower-body strength (Eurich et al., 2010; Fernandez-Gamboa et al., 2020). A powerful and efficient pop-up allows a surfer to get onto the wave faster, allowing for better positioning on the wave and offering a longer ride along the wave (Eurich et al., 2010; Fernandez-Gamboa et al., 2020). This gap in knowledge about this particular fundamental physiological element of surfing highlights a lack of understanding as to what this specific movement means for recreational surfers and their enhanced participation and enjoyment of surfing.

In contrast, the undeniable importance of paddling as a broad performance measure for recreational surfers has directed research into its specific physiological demands. These studies inform the recreational surfer of the specific training practices to adopt in order to improve their surfing. Early limitations when attempting to analyse paddling and record data, included video recording from the shoreline with a camcorder and heart rate (HR) monitors placed in bags to prevent saltwater damage. These methods have since evolved with both technology and time improving the efficacy of these instruments. The introduction of global positioning systems (GPS) has added another dimension to the analysis activity and while the method of data collection may have evolved the result has not changed. Research across relevant studies in the 20 years since (Mendez-Villanueva and Bishop, 2005; Farley et al., 2012; Klingner 2021) all conclude that paddling should be a key performance measure.

Recreational surf sessions can be as long as several hours (Secomb et al., 2014) making it seem that aerobic capacity would be the primary factor in paddling effectively. The early adopted HR, GPS, and time motion measures did not provide true aerobic performance markers. Measuring peak oxygen consumption ($\dot{V}O_2$ max) is considered the gold standard for determining aerobic capacity (Furness et al., 2018) and several studies have utilised this measure. The work of Meir et al., (1991), Shepherd et al., (2013) and Barlow et al., (2014) established $\dot{V}O_2$ max with a variety of instruments such as prone paddling ergometers and modified kayak ergometers and demonstrated that higher $\dot{V}O2$ max was significantly associated with better surfing ability.

Furness et al., (2018) utilised a swim bench ergometer to analyse the largest sample of recreational surfers (n=47) and established a significant difference between the $\dot{V}O_2$ max of professional and recreational surfers. Specifically, the identified $\dot{V}O_2$peak and peak anaerobic power were significantly greater in the competitive surfers than in recreational surfers (M = 40.71 vs. 31.25 ml·kg^{-1}·min^{-1}, $p < 0.001$; M = 303.93 vs. 264.58 W, respectively) although the ages of these recreational surfers was not reported. When Alamraz et al., (2014) compared $\dot{V}O_2$peak power with recreational runners (M = 45.34 ml·kg^{-1}·min^{-1}), cyclists (M = 39.92 ml·kg^{-1}·min^{-1}), and swimmers (M = 46.82 ml·kg^{-1}·min^{-1}), it appears that recreational surfers have lower $\dot{V}O_2$peak then participants in more ‘typical’ endurance sports. It is worthwhile to note that none of the surfing studies reported featured surfers over the age of thirty-nine. The age range of the older cohort in the current study is novel in that recreational surfers in the forty-five to sixty-five year old age bracket have not yet been subjected to surf-specific physiological testing.

In analysing aerobic demands, the relevance of anaerobic capacity becomes apparent. Breaking down the 45-55% of time spent paddling reveals the emergence of a pattern whereby surfing consists of very short (1-20 second) bursts of ‘sprint paddling’ (Shepherd et al., 2013 p.491). These short bursts account for 80% of all paddling activity (Farley et al., 2012). Thus, in addition to the aerobic demands, recreational surfing is revealed to be a sport requiring multiple, short-duration intermittent paddle efforts (Mendez-Villanueva and Bishop, 2005; Meir et al., 1991). This notion of anaerobic intervals serves as a performance measure for the recreational surfer. Minahan, et al., (2016) suggested that “a surfer’s capability to produce a high rate of energy anaerobically may be better able to differentiate surfers of varying ability than peak aerobic power” (p. 810). This insight informs the recreational surfer that specific energy metabolism training, such as interval training, will likely improve performance. Both Minahan, et al. (2016) and Farley et al. (2012) concluded that a surfer with higher peak power production will have both greater rate of energy output and sprint paddle velocity across the aforementioned key time frame of 1-20 seconds.

To date, the combination of aerobic and anaerobic capacity are typically understood to be the cornerstones of the entry speed a surfer carries into a wave (Farley et al., 2016; Fernandez-Gamboa et al., 2020; Sheppard et al., 2012; Tran et al., 2015). Herein, we argue for the inclusion of pop-up velocity as the third key element of entry speed; without it, the speed acquired as a result of a surfers aerobic and anaerobic capability is potentially lost if it isn't harnessed by a fast and efficient pop-up. For the competitive surfer, combining aerobic and anaerobic capacity with efficient pop-up velocity increases the likelihood of success in a competition heat by allowing them to catch more waves. During a heat, surfers look to "lock in their two highest-scoring waves -- both out of a possible 10 points for a possible 20-point heat total" (WSL, n.d., para. 4). For the recreational surfer, catching more waves feeds the notion of being 'stoked', an 'intense awareness of the moment' (Stranger 1999, p. 269), and being 'at one' with the environment (Taylor 2007; Wheaton 2007).

Refining surf specific performance elements

It is the smaller yet crucial, physiological components of surfing that form the focus of this thesis. Paddling is the primary physiological activity (45-55% of a surf session time) and the strategies to adopt to improve this major performance measure have been identified. The second most prevalent activity in a surf session is remaining stationary while waiting for waves, accounting for as much as 52±12.4% of a surf session (Secomb, 2014). It should be noted that this was across a two-hour surf session which can explain the discrepancy of the findings to those of Meir et al., (1991) who focussed on one-hour sessions (35% of time stationary) and Farley et al., (2012) who studied thirty-minute competition heats (30±6.0% of time stationary). Whilst remaining stationary does not pertain to be a performance measure for the competitive surfer, it is certainly influential in the participation and enjoyment experienced by the recreational surfer. Research suggests that age and ageing are powerful signifiers of how we are seen, and how we see ourselves (Hockey and James, 2003) and that older surfers seek out surfing as it offers a lifestyle that gives participants 'a particular and exclusive identity'

(Wheaton, 2004: 4). Surfing – even when stationary in the water – equates to time spent in a natural environment, specifically a "blue space" which has been shown to positively impact a multitude of factors including connection with mental health, physiological well-being, learning, obesity, and physical activity (Wheaton et al., 2017)

The aforementioned work of Meir, Farley and Secomb establishes measures that the recreational surfer can leverage in order to maintain surfing participation and enjoyment as they age. The other identified miscellaneous activities are disregarded as they are performance measures with a specific association to competitive surfers participating in time-restricted heats. These include: running up the beach, recovering the surfboard in the white water after falling, and slow one-arm paddling to maintain a stationary position (Meir, 1991: Farley, 2012: Mendez-Villanueva and Bishop, 2005: Secomb et al., 2014). The amount of time actually spent riding a wave is small, with approximations ranging from as much as 8±2% (Farley et al., 2012) to as little as 3.8% (Mendez-Villanueva and Bishop, 2005). It is logical to explore the pop-up as it is the singular, physiological element that places a surfer in a position to ride a wave; it could be described as the most important performance factor for a recreational surfer. A slow pop-up action will limit the wave-riding options (Secomb et al., (2015). Simply put, increased entry speed to a wave will give the recreational surfer more time on the wave. As discussed, this is arguably the ultimate aim of every recreational surfer.

The pop-up as a fundamental task for the recreational surfer

Wave riding is dependent on executing the pop-up with neuromuscular control, muscular strength, power, coordination, and balance, all combining in this complex motor skill. To frame the pop-up as a critical factor in facilitating improved performance, participation and enjoyment in the recreational surfer, it needs to be understood. It can then be used to answer the question as to the effect, if any, of age on the pop-up. A concise definition of the pop-up is that once a surfer paddles with requisite speed to catch a wave they then jump explosively to their feet (Everline, 2017). A more technical interpretation comes from Lowden and Patman (1980) who suggest that "rapid movement responses to an external stimulus is an important determinant of surfing skill, due to the significant correlation ($p < 0.05$) found between placement in a professional contest and movement time response." There are two issues with this; the first is that the perspective of this thesis is of relevance to recreational, not professional `surfers. Secondly, as pointed out by Mendez-Villanueva and Bishop (2005), Lowden and Pateman did not provide any details about the testing protocol, rendering this information as anecdotal at best. As is often the case, the best interpretation of what the pop-up is and what it involves lies somewhere in between with Eurich et al., (2010) simply stating "it is the need to move 75% of their (the surfers) body weight off the surfboard in less than a second" (p. 2823). In spite of its relevance as a fundamental task in both competitive and recreational surfing relatively few scientific articles (Eurich et al., 2010; Hammer et al., 2010; Parsonage et al., 2018; Parsonage et al., 2020; Borgovov-Santos et al., 2021; Monoco et al., 2023) have specifically investigated how surfers perform the pop-up. To our knowledge, no research to date has considered or characterised the effect of surfer age on the pop-up.

In an early study, Hammer et al., 2010 highlighted the prevalence of low back pain in a single-subject case study reported by a female recreational surfer in her thirties (exact age not reported) during the pop-up. These authors identified that acceleration and the corresponding forces and torques required during the pop-up as the likely causes of the low back pain. The authors went on to suggest an alternative to the prone pop-up is the kneeling pop-up where the starting position is kneeling and described the reduced acceleration and corresponding forces experienced by surfers during the kneeling pop-up. Specifically, as measured by specific kinematics, maximum lumbar spine extension angle, maximum lumbar spine flexion angle, peak flexion velocity, and peak flexion acceleration were stated to "probably associate with much lower stresses" and therefore less low back pain.

Eurich et al., 2010 examined male (28.0 ± 5.50 years old) and female (26.5 ± 5.93 years old) kinematic differences in recreational surfers when performing a simulated surfing pop-up movement. Their results demonstrated that men exhibited significantly greater relative force (M = 9.56 ± 1.25 $N \cdot kg^{-1}$, W = 8.15 ± 0.98) and relative power (M = 16.39 ± 4.22 $W \cdot kg^{-1}$, W = 9.98 ± 2.58) when compared to women ($p < 0.05$). As with the Eurich study, Parsonage et al., (2018) sought to explore kinematic sex differences in the pop-up between male (n=9, age: 30.3 ± 7.3 y) and female (n=8, age: 25.5 ± 5.2 y) competitive surfers as measured by force plates. Normalised peak force (PF) of an isometric push-up, dynamic push-up, and force plate pop-up were significantly greater in males (p < 0.05), with males recording significantly quicker (d = 1.35, $p = 0.01$) time to pop-up (TTP). The authors concluded that greater normalised isometric and dynamic strength in males resulted in greater sports-specific peak force application and a faster TTP. From this data, the authors concluded that "it would appear favourable that female surfers improve their maximal strength to facilitate sports specific pop-up performance".

Parsonage and colleagues (2020), went on to investigate the reliability of the isometric push-up (IPU), dynamic push-up (DPU), and force plate pop-up (FP POP) as measures of upper-body isometric and dynamic strength qualities in both male (n=9) and female (n=9) surfers who had at least 10 years of experience. In addition, the study aimed to compare pop-up performance between stronger and weaker surfers. The study did not state the specific surfing performance level of the participants; however, the average age of the participants was 28.1 ± 6.4 years. The results suggest improvements in pop-up performance may be elicited by improving dynamic strength for stronger surfers, whereas pop-up performance in weaker surfers may be elicited by improving maximum strength.

Borgovov-Santos et al., 2021 aimed to measure kinematics and ground-reaction forces (GRF) during a simulated pop-up motion, and to relate these variables with anthropometric characteristics in experienced recreational surfers (28.4 ± 10.1 y; 12.4 ± 8.9 y experience). They concluded that most anthropometric-related variables showed no relationship with performance variables, with the exception of an inverse relationship between muscle mass and pop-up total duration, suggestive of a benefit of training to improve lean body mass. These authors also observed no differences in upper- and lower-body kinematics between the dominant vs. nondominant hands and among surfers who preferred a regular vs. “goofy-foot” (right foot forward) stance. Finally, the force profiles between hands were similar and symmetric, while the lower extremities during the reaching phase were different, with the front foot applying greater force than that of the rear foot.

The most recent study involving the pop-up (Monoco et al., 2023) investigated the effects of a sport-specific, land-based-home exercise programme on sport-specific assessments related to surfing performance in recreational surfers (34.27 ± 10.45 y), including the pop-up.

Although non-significant, the land-based-home exercise programme group decreased their pop-up time with a large effect size when compared to the control group. The authors concluded that exercises that mimic the pop-up (i.e. a push-up with leg movement) are “noteworthy for SCCs (Strength and conditioning Coaches) to utilise specific training aspects to improve this critical phase for recreational surfers” (p. 368).

Much like the aerobic and anaerobic demands of paddling, the physiological requirements of an efficient pop-up have been identified. Ground reaction force (GFR), as per Newton’s third law, is the force exerted on the surfboard by the upper body, during the pop-up measured in Newtons (N). Relative to the difficulty of obtaining such measurements in the field, controlled, laboratory studies using force plates are the primary resource for assessing pop-up GRF for surfers. Several studies (Parsonage et al., 2020: Eurich et al., 2010: Márcio Borgonovo-Santos et al. 2021) have established a relative (to bodyweight) scale ranging from 0.99 ± 0.10 N/kg BW to 9.56 ± 1.25 N/kg BW. Whilst all surfers in these studies were recreational and relatively evenly matched in experience level and age, their height, anthropometrics, and gender varied.

The work of Joanna Parsonage and her research team (Parsonage et al., 2020) is the only study that identified two key factors will improve GRF in surfers – maximal strength (as measured by the isometric push-up) and dynamic strength (as measured by the clap push-up). Parsonage et al., (2020) identified a threshold whereby stronger surfers would not improve their GRF by further increasing their strength and conversely, weaker surfers would not improve their GRF by increasing their dynamic strength either. The strength a surfer can produce when in motion, paddling for a wave, is dependent on velocity (Newton et al., 1997), and this directly impacts the power relationship (work/time), and subsequently increases pop-up quickness or TTP.

Prior research has reported TTP in recreational surfers, including Parsonage et al., 2020 (0.62 ± 0.09 s), Eurich et al., 2010 (<1.0 s), and Márcio Borgonovo-Santos et al. 2021 (1.20 ± 0.19 s). Hammer et. al (2010) reported a pop-up time of 1.3 s from start to stabilisation in their single participant case study. The sum of this information allows recreational surfers to make very specific decisions as to where their training focus needs to be relative to their current training status. Evaluating muscle performance and its potential for application in sports should always include measures of strength such as peak force, rate of force development, and power (Vossen et al., 2000). These are essential guidelines to the recreational surfer seeking to improve pop-up, and by extension, surfing performance. Pursuing positive changes in power, supported by improved strength, aerobic and anaerobic conditioning, should form the basis of the recreational surfers training programme.

Potential effect of age on pop-up efficiency

When examining the pop-up as a surfing performance measure relative to the older recreational surfer, it is logical to assume that time TTP will decline with age. Power is defined as the rate of force/work over time (Lorenz, 2011; Tillin & Bishop, 2009) and it plays a significant role in surfing performance. In older adults, skeletal muscle power has been demonstrated to be a stronger predictor of functional limitations compared to other physical capabilities such as muscle strength or maximal aerobic capacity (Foldvari et al., 2000, Martinikorena et al., 2016). In addition, maximal muscle power has been observed to decline from an earlier age and at a faster rate than muscle mass and strength. The age-related decline in maximal strength and dynamic strength will concurrently reduce peak force and rate of force development, and power; and these decrements will likely manifest themselves in slower TTP.

A large body of research into muscular strength and power loss with age exist, but few are longitudinal; the Baltimore Longitudinal Study of Ageing (BLSA) was one of the first. This study's relevance to the current study is not only attributed to its length (a longitudinal study over 25 years) but also its depth *(n* = 993 males, *n* = 194 females). In addition, its specific focus on strength and power decline in the upper body ensures it is directly relevant to the pop-up. Parsonage et al. (2020) showed that upper body power was significantly correlated to a quicker pop-up time, while high levels of upper-body force production within a time constraint is critical for successful surfing (Shepherd et al., 2012). Mettler et al., (1997), state that maximal strength declines (34% decline) at a slower rate than power (42% decline) in men from the age of 20 to 80. This highlights an approximate 10% greater decline in power across a 60-year period of power relative to strength loss. These researchers go on to declare that "the independent effect of age on power argues for the importance of movement speed, coordination, and other factors in power generation" (p. B275).

A second, critical feature of the surfing pop-up is general lower-body strength and power. Fernandez-Gamboa et al. (2017) observed that higher ranked competitive surfers had superior counter-movement jump (CMJ) performance to their lower-ranked peers whilst elite junior competitive surfers had higher vertical jump capabilities than their non-elite counterparts (Tran et al., 2015). Whilst both the Tran and Fernandez-Gamboa studies looked at competitive surfers, this study is novel in that it investigates lower-body power in recreational surfers, a novelty extended by the age of the surfers involved (45-65 y). Interestingly, there appears to be a delay in power loss in the lower-body with Alcazar et al., (2020) finding that 40 years and above is the threshold for decrements in both women and men, as opposed to the decline in upper-body power beginning in the early 20's to 30's as asserted by Metter et al., (1997). That said, a direct comparison between upper- and lower-body power decline can be difficult given the strength-power relationships between the upper and lower body have been shown to be only moderate (Bemben & McCalip 1999) indicating some independence between measures of strength and power for different muscle groups.

Ultimately, these studies and the data they produced were used to inform the age range criteria for both the older and younger groups in the current research of 18-35 and 45-65 y respectively. To our knowledge, the dual power capacities of pop-up velocity and lower body power have not been reported nor compared in younger and older recreational surfers. Further, this current study is novel in the fact that it examines pop-up velocity and lower body power in surfers aged 45-65 years old. To date, the eldest cohort of either recreational or competitive surfers that the current literature has assessed, is 34.27 ± 10.45 years (Monoco et al., 2023).

Research Questions

Firstly, this research will seek to identify any differences between the participants TTP when performing a simulated paddling action and when not performing a simulated paddling action. This potentially helps inform future studies in to best practice when analysing the pop-up by aiming to answer the question:

- Does the ecology or familiarity of the paddling stroke, as performed in the water, influence the validity and reliability of TTP velocity?

Secondly, the study also seeks to examine the relationship between age and power among older surfers versus the older general population. As a result, the data will be analysed to attempt to answer the question:

- Does recreational surfing and its associated physiological and psychological influence mitigate the known rates of power decline in older adults?

The older surfer cohort data can be compared with the normative values of power loss with age as described by both Metter et al., (1997) and Alcazar et al. (2020). Identifying how older recreational surfers fare in their capability to retain muscular power versus non-surfers can give valuable insight to the role surfing might play in arresting expected age-associated power decline.

The study will explore the notion that, as the surfing pop-up involves and replicates a 'jumping' action, there potentially will be a reduced likelihood of a strong association between aging and a decline in countermovement jump height amongst older surfers. A comparison of the strength of association between power and TTP in both cohorts will be considered to attempt to answer the question:

- What is the relationship between lower-body power and TTP?

Given the rising popularity of, and participation in, recreational surfing amongst those of 40 years old and above, it is pertinent to try and understand the effects of aging on the ability of these surfers to participate in, and continue to enjoy, surfing. Therefore, the primary research question explored in the current study is the following:

- are there statistically significant differences in TTP between a younger (18-35) and older (45-65) cohort of recreational surfers?

If significant differences can be identified relevant training strategies can be discusses to potentially offset those differences. In addition, the study will explore the theory that older surfers will offset the loss of pop-up strength and power associated with aging via their engrained neuromuscular patterning. The technical prowess that older surfers have acquired as a result of performing the pop-up action with more frequency than their younger counterparts might ensure no statistically significant difference in the TTP between the two cohorts is observed.

Chapter 3: Methodology

Research Design

The experimental study utilised a parallel group design with fourteen intermediate-level recreational surfers being randomised into two cohorts based on their age; a younger group, aged 18-35 and an older group aged 45-65. Both groups were tested for their pop-up velocity and counter-movement jump power.

Sample size calculations

A priori power analysis was conducted with G* power using a significance criterion of α = 0.05 and power = .80, the minimum sample size needed was n = 12 for an independent samples *t* test to detect meaningful differences in pop-up velocity. Fourteen participants were deemed adequate to test the study hypothesis.

Recruitment and Participants

Participants were recruited from across the North Island of New Zealand. Local, regional and national surf clubs and surf schools were contacted via email and/or telephone and asked to display and distribute posters explaining the research to members and gauge their interest in participation. Additionally, local, regional, and national social media surf groups were extensively canvassed.

Convenience sampling resulted in fourteen recreational surfers (13 male, 1 female) who were placed into two groups, a younger group (25.2 ± 9.0 years old, 9.7 ± 10.9 years of surfing experience) and an older group (51.8 ± 6.6 years old, 30.0 ± 9.1 years of surfing experience).

The mean height and weight of the younger group was 177.57 ± 9.45 cm and 72.85 ± 10.80 kg respectively with the mean height and weight of the older group being 177.07 ± 8.42 cm and 81.48 ± 10.03 kg respectively (Table 1). The recruitment and testing of all participants was performed over 24 weeks (October 2022 to March 2023).

Inclusion/exclusion criteria

The inclusion criteria for selection of participants consisted of defining an intermediate recreational surfer as one with a minimum of two years' experience who surfed at least once per week or a minimum of 52 times per year. The participants needed to be able to perform turns and trim (or ride) along the open face of a wave. An additional inclusion criterium was that participants were not permitted to have not performed any regular strength training in the six months prior to testing. Exclusion criteria consisted of any serious musculoskeletal injuries in the six months prior to testing, inability to walk unaided, body mass in excess of 100 kg (due to the custom test rig dimensions and loading capacity) and the participants most commonly used surfboard being longer than 6 feet 6 inches. The focus of this study is the intermediate surfer who predominately uses a shorter surfboard. Essentially, pop-ups are easier to achieve and invariably slower on a longer board relative to their increased buoyancy. As a result, longer, bigger boards are typically used by beginner surfers (although not exclusively).

Table 1. *Descriptive characteristics for recreational younger (RYS) and older (ROS) surfers*

	RYS (*n* = 7)		**ROS (*n* = 7)**	
	Mean ± SD	Range	Mean ± SD	Range
Age (y)	25.2 ± 9.0	18 - 35	51.8 ± 6.6	45 - 65
Height (cm)	177.57 ± 9.45	168 - 192.50	177.07 ± 8.42	161.5 - 188.5
Body Mass (kg)	72.85 ± 10.80	58.7 - 87.3	81.48 ± 10.03*	70.7 - 99.2
Surfing Experience (y)	9.7 ± 10.9	2 - 30	30.0 ± 9.1	15 - 45

*$p < 0.01$ compared to RYS; SD: standard deviation;RYS: *recreational younger surfers;* ROS: *recreational older surfers.*

Informed consent/ethics

The Human Research Ethics Committee at the University of Waikato approved the research and all procedures (ID no. 2022#28, see Appendix A). All participants were given an information letter and were explained the benefits and risks of participation followed by providing their written informed consent before participation.

Equipment

Dual piezoelectric 3D digital force plates (9260AA, Kistler Group, Winterther, Switzerland) were used in a controlled laboratory setting. Two fabricated stools (custom-made) in combination with two surfing shortboards, one lower volume at 32 litres (DHD Ltd, Gold Coast, Australia) and one higher volume at 42 litres (Global Surf Industries, Sydney, Australia) were used to perform all surfing pop-ups). Two canvas straps (FCS Australia) were used to secure the surfboards to the stools.

Experimental procedures

In measuring the velocity of a surfer's pop-up, conclusions are able to be drawn as to the effect of age on the power required to perform this explosive and important surfing manoeuvre. In addition, the two groups CMJ were assessed to obtain a general measure of the participants power to act as a reference and comparison to the specific power requirements of the PU.

Testing took part over seven separate days spanning four-month period. All participants completed their testing inside one hour and were required to visit the laboratory once each. Participants were familiarised with the testing procedures, laboratory setting, and equipment being used. A standardised warm-up (Table 2) and physical preparation phase was undertaken with participants preparing for their simulated pop-up attempts with a five-minute cardiovascular, pulse-raising 'brisk walk' using a treadmill. A short, joint-by-joint mobilisation sequence followed with the combination of these two activities ensuring adequate tissue temperature, neuromuscular awakening, and full joint range of motion was achieved prior to the explosive physiological demand of performing the counter movement jumps and simulated pop-ups.

Table 2. *Warm-up protocol; joint-by-joint-mobilisation and pulse raise.*

Exercise	Duration	Tempo	Sets x Repetitions	Intensity (RPE)
Treadmill Walk	5 minutes	Brisk Walk	N/A	5
Standing BW Calf Raises	N/A	2020	1 x 10	5-6
Leg Swings (Saggital Plane)	N/A	2020	1 x 10 e.s.	5-6
Leg Swings (Frontal Plane)	N/A	2020	1 x 10 e.s.	5-6
Cossack Squats	N/A	2020	1 x 10 e.s.	5-6
Lunge & Rotate	N/A	2020	1 x 10 e.s.	5-6
RB Scapular Retraction	N/A	2020	1 x 10	5-6
RB Overhead Pull Aparts	N/A	2020	1 x 10	5-6
Arm Circles	N/A	1010	1 x 10 forward & backward e.s	5-6

CV = cardiovascular; BW =Bodyweight; e.s. = Each side; RB = Resistance band; 2020 = 2s concentric phase, 2s eccentric phase; RPE = Rate of perceived exertion

Countermovement Jump (CMJ)

The CMJ was performed before the PU. Two Kistler (Kistler Group, Winterther, Switzerland) force plates (FP) sampling at a frequency of 1000 Hz were zeroed before participants took the CMJ start position on the plates. Participants were instructed to place each of their feet on the corresponding force plate (left foot on left force plate, right foot on right force plate) and both their hands on their hip creases. The researcher signalled the participants to initiate the CMJ by flexing at both the hip and knee joints simultaneously in order to squat to a knee joint angle of ninety degrees or until the participants femurs were parallel to the floor. Subsequently, the participant was instructed to explosively jump in a vertical plane as high as possible. The cue for landing was “quietly with soft knees” with the instruction to return to a static standing position before stepping down from the FP. Each participants jump height from take-off (m), relative maximal force (%BW), and relative maximal power (W/kg) were recorded with the best measure of the three attempts retained for data processing and statistical analysis. The participants were provided three minutes rest between efforts to allow for full replenishment of ATP and full recovery of the ATP-PC system, the predominate energy source utilised when performing explosive, power-based movements. After the jump testing, the participant then began their pop-up testing.

Pop-Up Test

Custom-built stools were each placed on the Kistler force plates sampling at 1000 Hz (Figure 3). A surfboard that matched the dimensions of the participants own board was attached to the stools. One stool and force plate was placed directly beneath the front of the surfboard and one stool and force plate directly beneath the back of the surfboard allowing the capture of the surfers pop-up velocity. Padded mats were placed on either side of the rig to ensure participant safety. Twelve pop-up attempts were performed by the participants. The twelve pop-ups alternated in groups of three with the first three performed with no simulated paddling of the arms to ensure an accuracy of baseline force measurement (that being generated by the static participants body mass in N). The force plate was zeroed before participants took the prone position therefore all force measures include the participants body mass. Lying in a prone position with the hands stationary and out to the side, the participant lay as still as possible until signalled to perform the pop-up. In accordance with procedures in Hammer et al. (2010) and Borgonovo-Santos et al., (2021) each pop-up began at the researcher's voice command, "3, 2, 1, go" with measurement commencing at the point at which at least one hand made contact with the surfboard. The pop-up was deemed to have ended when the participants body mass force returned to the pre-pop-up reading. The researcher then signalled the participant to "step down from the surfboard" (Figure 2).

Figure 2. *Participant performing a pop-up on the experimental rig*

Again, three minutes rest was allocated to allow for full replenishment of ATP and recovery of the ATP-PC system used to power the pop-up. A second set of three pop-ups were then performed, this time consisting of three simulated paddling stroke of the arms. The simulated paddling strokes improved the ecological validity of the pop-up as it represented a more accurate movement pattern relative to an in-water pop-up. Each set of three pop-ups were performed twice (six with and six without simulated paddling) for a total of twelve pop-ups per participant. Of the twelve simulated pop-ups, the effort with the quickest velocity (s) was retained for data processing and statistical analysis. The experimental protocol is presentedbelow in Figure 3. Time was set aside at the end of each test to discuss any relevant issues that arose and answer any questions, queries, or concerns the participants had.

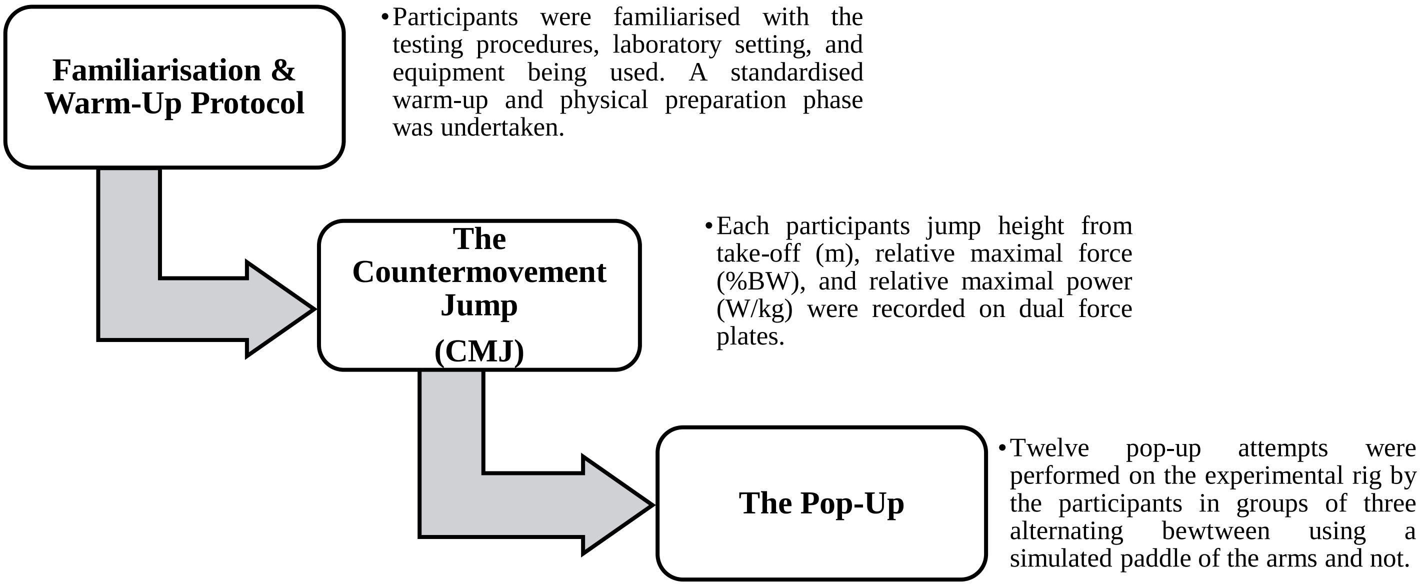

Figure 3. *Schematic Diagram of Experimental Process.*

Data processing

All data was analysed with MARS software version 2.2 (Kistler Group, Winterther, Switzerland), Excel 2016 (Microsoft Corp., Redmond, WA, USA) with the Real Statistics Resource Pack (Charles Zaiontz) and Jamovi Statistical Platform (Sydney, Australia). A representative force/time trace of surfing pop-up is presented in Figure 4 below.

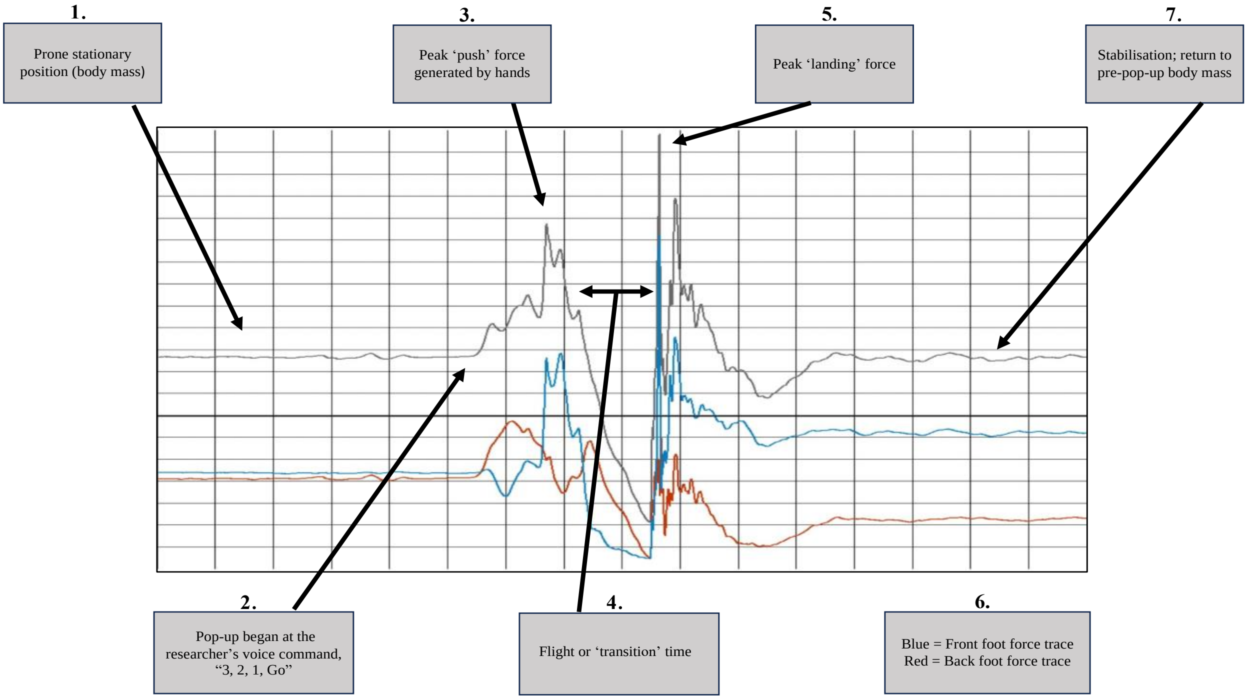

Figure 4. *Force/time trace of surfing pop-up*

Statistical analysis

Descriptive statistics were performed for calculation of the means and standard deviations of all variables. Inferential statistical analysis including an independent sample *t*-test to determine whether there was a significant difference in metrics derived from the CMJ (height, relative maximal force, relative maximal power) and pop-up velocity between the younger and older surfers. Additionally, dependent *t*-tests were performed to establish any within-group differences between pop-up velocity with an without the simulated paddle strokes. For all tests, statistical significance set at $p \leq 0.05$. The magnitude of differences was evaluated by calculating effect sizes (Cohen's *d*) with 95% confidence intervals. Magnitude of effect size was based on the following criteria: ES=0–<0.20 *trivial* effect; ES≥0.20–<0.60 *small* effect; ES≥ 0.60<1.20 *moderate* effect; ES≥1.20–<2.0 *large* effect, and *very large* ES<2.0 (Hopkins, 1997). Intraclass correlation coefficients (ICC), typical error (TE) and coefficient of variation (CV) with 95% confidence intervals were calculated to compute relative and absolute reliability of measures. The reliability according to ICC was interpreted as poor (< 0.5), moderate (0.5-0.75), good (0.75-0.9) and excellent (> 0.9) (Koo and Li, 2016). The reliability according to CV was considered as excellent (< 5%), good (5-10%), acceptable (10-15%) and unacceptable (> 15%) (Shechtman, 2013). The Pearson correlation coefficient (*r*) was calculated to assess the degree of relationship between age and leg power and quantified as follows; ±0.0 to 0.2 (very weak/no association), ±0.2 to 0.4 (weak association), ±0.4 to 0.6 (moderate association), ±0.6 to 0.8 (strong association) and ±0.8 to 1.0 (perfect positive/negative association).

Chapter 4: Results

Reliability Study

The inter-group reliability for the older and younger surfer's pop-up velocity test and simulated paddle and non-paddle pop-up velocity test are presented in Table 3. The ICC showed *good* overall reliability highlighting no apparent difference between paddle and non-paddle and the older and younger cohorts.

Table 3. *Reliability Statistics for the Younger & Older Surfers Pop-Up Velocity Test and Paddle & Non-Paddle Pop-Up Velocity Test*

		Reliability Statistics	
	TE (Raw units)	**CV%**	**ICC**
Younger Cohort	**0.28** [0.24, 0.35]	**18.9** [14.5, 27.7]	**0.48** [0.24, 0.74]
Older Cohort	**0.56** [0.48, 0.71]	**18.9** [14.6, 27.8]	**0.47** [0.23, 0.74]
Paddle	**0.43** [0.36, 0.53]	**18.9** [14.5, 27.7]	**0.81** [0.66, 0.93]
Non-Paddle	**0.47** [0.39, 0.58]	**19.4** [14.9, 28.5]	**0.75** [0.56, 0.90]

Observational Study

Counter-Movement Jump

The comparative measures for the older and younger surfers for the CMJ are presented in Table 4.

Table 4. *Descriptive and inferential statistics for comparative measures of RYS and ROS CMJ height, CMJ relative maximal force and CMJ relative maximal power.*

	RYS (n=7), Mean ± SD	ROS (n=7), Mean ± SD	% difference	Cohens *d*, 95% (CI)	Effect Size (ES)	*p-value*
CMJ						
Jump height (m)	0.391 ± 0.115	0.267 ± 0.026*	31.7	-1.39 ‡ [-3.00, -0.34]	large	0.0170
® Relative Maximal Force (% BW)	225.9 ± 30.50	213.1 ± 17.62	5.7	-0.48 ‡ [-1.77, 0.61]	unclear	0.355
Relative Maximal Power * (W/kg)	53.82 ± 12.86	41.21 ± 2.230*	23.4	-1.28 ‡ [-2.84, -0.23]	large	0.025

◆ *$p > 0.05$, * wattage per kilogramme, ‡ negative d figure is as a result of the order in which the two group means were calculated.*

Correlation

The data showed a *strong association* (R^2 = 0.6184) between aging and a reduced CMJ height. Whilst *a moderate association* (R^2 = 0.5722) between aging and a decline in relative maximal power existed across all the surfers there was *no association* (R^2 = 0.0080) between surfers aged 45 to 65 and a decline in relative maximal power. A *weak association* (R^2 = 0.2541) existed between aging and a decline in relative maximal force.

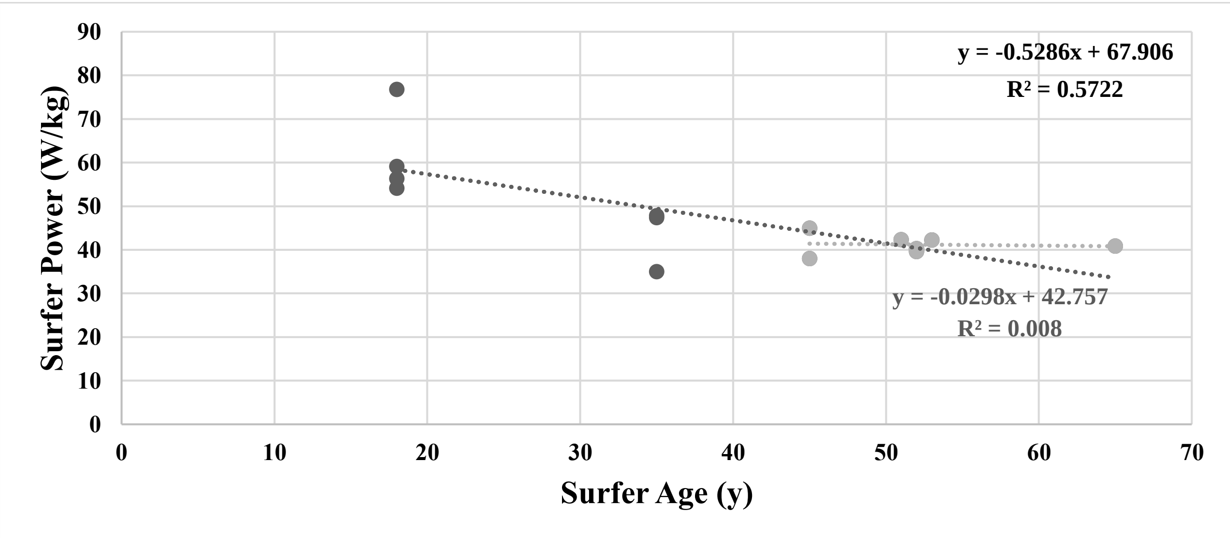

Figure 5. *Surfer Age and Relative Maximal Power.*
Light grey circles represent the older cohort

Pop-Up Velocity

The younger group, *M* = 1.12 s, *SD* = 0.16, 95% CI [0.96, 1.27], demonstrated a significantly quicker surfing pop-up velocity, *t*(12) = -4.37, *p* = .0009) than the older group *M* = 2.03 s, *SD* = 0.52, 95% CI [1.54, 2.51]. The effect size was determined to be *very large (d* = 2.21, 95% CI [1.10, 4.20]).

Simulated Paddle vs Non-paddle Pop-Up Velocity

The non-paddle pop-up velocity, (*M* = 1.63 s, *SD* = 0.69), was not significantly quicker than the simulated paddle pop-up velocity (*t*(12) = 2.1603, *p* = .1895, *M* = 1.7 5s, *SD* = 0.62) and the effect size was determined to be *small (d* = 0.37).

Correlation

The data showed a *very weak association* (R^2 = 0.0266) between younger surfers' relative maximal power and pop-up velocity. There was a *no association* (R^2 = 0.0088) between older surfers' relative maximal power and pop-up velocity.

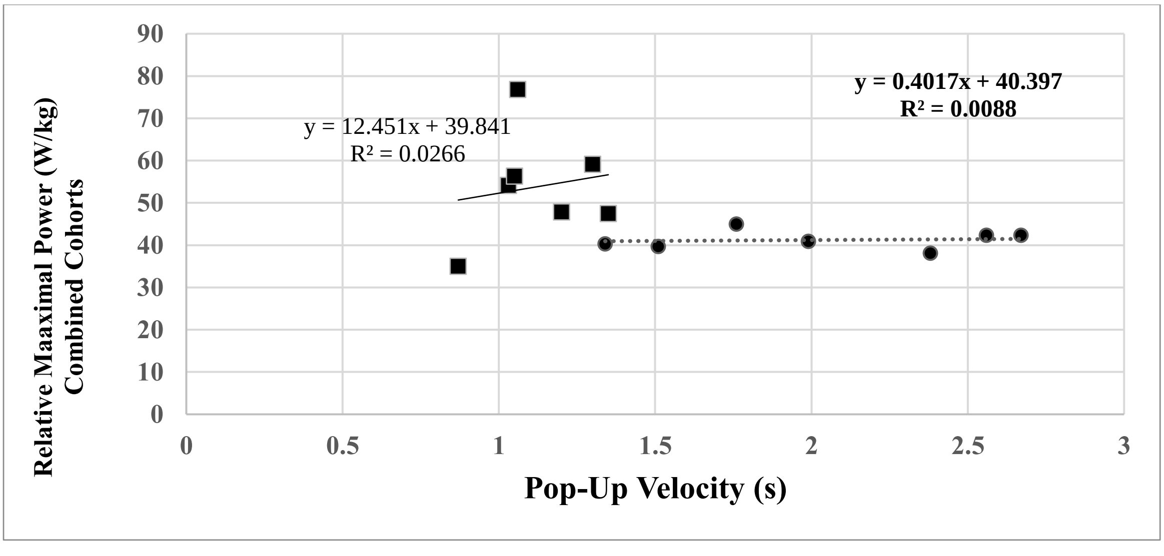

Figure 6. *Surfer Pop-Up Velocity and Relative Maximal Power*
Circles represent the older cohort

Chapter 5: Discussion

The aim of this thesis was to investigate the effect of age on pop-up performance with the primary research question investigating whether any differences were observed in pop-up velocity between younger and older recreational surfers. The results showed that the difference in pop-up velocity between younger and older recreational surfers is statistically significant and that older recreational surfers can expect their pop-velocity to decline as they age. These findings correlate with previous studies (Metter, 1997; Gava et al.; Alcazar, 2020) that the power decline threshold in both men and women is approximately 40 years old. The null hypothesis is rejected, as is the researchers notion that a sufficiently engrained neuromuscular task will supersede the detrimental effect of age on muscular power.

The results challenge previous studies that the pop-up requires surfers to move 75% of their body mass in less than a second (Eurich, 2010). In both cohorts, the average TTP in the current study exceeded this sub-second threshold, albeit against different criteria as to the specific start and end point of the pop-up. There is a need in any future work to establish a consensus as to a definitive beginning and end point of the pop-up (when using force plates as a measuring instrument) as to date two schools of thought exist. The first is that the pop-up begins when the hands or chest of the surfer leaves the surfboard and ends with them standing (Eurich, 2010: Parsonage et al., 2020) . The second concludes that the pop-up begins when the hand(s) first contact the deck of the surfboard and the ends with the surfer stabilised in their stance (Hammer et al. 2010: Borgonovo-Santos et al., 2021). Stabilised in this instant refers to the surfers body mass force returning to the pre-pop-up reading. We are in agreement with Borgonovo-Santos et al. that stabilisation is a more reliable marker for the end of the pop-up and have adopted the same pop-up start/finish criteria for this research. Our justification being that an argument can certainly be made that without stabilisation, the surfer lacks the requisite control to successfully complete the pop-up and will subsequently miss the wave. As stated by Fernandez-Gamboa et al., 2020 “The execution of the pop-up should not jeopardize the stability of the board” (p. 49).

In addition to slower pop-up velocity, counter movement jump height and counter movement relative maximal power were also significantly lower in older recreational surfers. A novelty existed in the comparison of the younger and older surfers relative maximal force in that there was no significant difference between the two groups. It is accepted that there are a multitude of determinants of both muscular force and power output including muscle and fibre size and length, the angle and architecture of muscle tendons and the force production capabilities of muscular cross-bridges (Fitts et al., 1991). It may be concluded that older recreational surfers, with their more mature muscular development, are more likely to have the tissue architecture and dimensions described above. In saying that, no association between lower body power and pop-up velocity was found across both the older and the younger cohorts indicating the counter-movement jump is not a particularly valid method of assessing surfing pop-up velocity. Further conclusions can be drawn when discussing the reliability and validity of utilising a simulated paddle stroke when testing pop-u velocity. It appears that attempting to improve the ‘ecology’ of the test by incorporating simulated paddle strokes did not decrease the reliability of the test. This is an important consideration for any future work studying the pop-up.

Whilst the data show that relative force production is maintained by the older surfers, it is likely that the ability to produce this force rapidly is severely compromised. The work of Pedejnic et al. (2012) and Vossen (2000) suggests that the neural and muscular factors underlying movement velocity may be more compromised with age than those underlying force production. It is noted that the Pedeinic study took account of muscle size while this research used the surfers body weight rather than lean muscle mass. Therefore, it is important not to interpret this lack of significant difference in relative force between the younger and older groups in this study as an indication that the older surfers necessarily have similar lean muscle mass. Standardising power output using lean muscle mass, rather than body mass as was performed herein may provide further insight. Given that muscle and bone mass decrease with age it is important not to necessarily conflate the similar relative force outputs between the cohorts with muscle 'quality'. Additionally, it is relevant to consider the complexity of the pop-up as a movement as a further contributing factor to slower pop-ups in older recreational surfers. Khuo et al., 2006, (as cited in Alcazar et al., 2020) stated that "the functional reserve of various physiologic systems, such as the neuromuscular system negatively affect the ability of aged individuals to perform motor tasks" (pp. 1369). Interestingly, the data showed that surfers aged 45-65 maintained their power when compared with the power of non-surfers in the same age range. This would indicate that surfing is beneficial in offsetting the typical age-related degeneration in muscle power.

Limitations

Almost by virtue of the fact they still surf regularly, the older surfers maintain a relatively healthy body mass which could explain their ability to produce a comparable about force as a percentage of their body weight as the younger surfers. Whilst it could be considered a potential limitation of this study is that body composition or anthropometrics as physical characteristics of the participants were not recorded, the work of both Frank (2009) and Lowden (1983) suggest that excessive leanness does not offer a performance advantage in surfing. Additionally, no correlation between body characteristics and the surf pop-up have been found (Borgonovo-Santos, 2021). In contrast, Eurich et al., (2010) determine that surfers with greater muscle mass relative to their body size have an advantage in lifting their own bodies, a key component of the pop-up.

As ever, a larger sample size would have facilitated more generalisable results; additionally, future research would benefit by categorising the surfers based on their gender as well as ages. Naturally, the biological sex differences between males and females creates a physiological discourse exemplified by characteristics such as neurological efficiency, coordination, reaction times, and hormonal and neuromuscular modulation (Metter et al., 1997). As discussed above, there has been no association found between body characteristics and the surfing pop-up (Borgonovo-Santos, 2021), but there is clear association between body characteristics and power decline with age. Body mass index, muscle fibre ratios, and lean muscle mass have all been shown to influence different rates of power decline in men and women (Alcazar et al., 2020).

Future research

The direction of future studies into surfing pop-up velocity could consider comparing younger and older recreational surfers who already followed a power-based dry-land training programme. Additionally, a comparison of untrained younger and older recreational surfers before and after a specific strength and power training intervention. The direction of such studies, whilst not necessarily unique, would be beneficial in building on the work of studies such as this one. Perhaps of greater benefit would be the exploration of a different type of training intervention from the typical strength and power interventions. As discussed above, movement and coordination are critically important factors in pop-up velocity, therefore, research that examines the effects of a movement and/or coordination based intervention on aging recreational surfers would be of interest. Rate of force development as it pertains to the older surfer is certainly relevant to explore in further depth . This is particularly true egiven the older surfers in this study did not experience a significant decline in relative maximal force compared to the younger surfers despite the clear differences in TPP. Further, given the relative lack of association between surfer relative maximal power and pop-up velocity the argument can be made that, as lower body power doesn't appear to influence TTP, an analysis of the relationship between upper-body power and pop-up velocity warrants exploration.

Previous research has tended to agree that absolute power decline is linear from the age of 40 to 80 (Metter et al., 1997: Skelton et al., 1994: Reid et al., 2014) with Metter et al. reporting a 3% and 1.7% rate loss in relative muscle power men and women respectively every year. Interestingly, the results of this study only show a moderate association between the older surfers decline in relative maximal power and pop-up velocity. This warrants further investigation as it may indicate that older surfers do indeed offset the natural decline in power as experienced by a general population and that the anticipated linear decline can be arrested to some degree. In contrast, Alcazar at al., (2020) identify a steeper drop off in absolute muscle power from the age of 60 in men. This curvilinear trend in men differs in women who experience a more linear decline in their power up to the age of 75. Therefore, this knowledge could allow specific training recommendations based on gender and specific age groups to be made; untrained male recreational surfers between the ages of 40 and 65 could potentially benefit from a power-based, dry-land training regime; whereas untrained female surfers over 40 appear to have a larger natural window in which they will retain power and potentially, pop-up velocity. That said, there is some ambiguity around these age thresholds.

It is important to note that relative muscle power is viewed as a determinant of an individual's ability to perform daily activities (Skelton et al., 1994). Given that the data presented in this study suggests that older surfers may mitigate the expected rate decline of muscle power (when compared to a general population) an argument can be made that surfing positively impacts quality of life as participants age. As previously discussed, this physiological benefit is supplemented and enhanced by the psychological benefits of surfing. With contemporary thinking defining age as a period of time where individuals feel it is increasingly necessary to remain fit, both physically and mentally (Millington 2011), surfing may provide an avenue to do both.

As evidenced in this study, the pop-up is a specific and complex activity that all recreational surfers need to execute as efficiently as possible to enhance both their performance and enjoyment of surfing. Therefore, it would be interesting to compare recreational participants in other sports that have complex, power-based movement patterns such as the drive in golf, the serve in tennis, and the tumble turn in swimming. Future studies should consider not only gender but tighter age ranges for more targeted and specific results. Additionally, Edwen et al., 2013 concluded that factors affecting both muscular force and muscular contractile velocity contribute to power decline with age. In particular, they found that muscular contractile velocity, as measured during the stretch shorten cycle (SSC), converges between males and females with age. The researchers found a 50% greater decline in the SSC in men than women making maximum contractile velocity arguably the better predictor of pop-up efficacy. Future pop-up studies could consider utilising this measure in gender specific research.

Finally, there is potential for future studies to explore curve analysis given the force trace of the pop-up and the wealth of information that could be extracted, rather than just peak values and overall time to complete the skill. Examining data such as front foot versus back foot contributions to pop-up velocity and its relationship to power and force generation across age cohorts, could also yield further insights.

Chapter 6: Conclusion

Key points

Whilst strength and power assessments have been frequently implemented in sports settings to assess the neuromuscular qualities of athletes and are representative of sports-specific performance (McGuigan et al., 2016), a comparable body of evidence for recreational sports participants, particularly surfing, lacks depth. Therefore, measuring pop-up velocity is an important tool in informing the recreational surfer as to which type of additional training should be encouraged to maintain pop-velocity with age and subsequently enhance their surfing experience.

All recreational surfers of both genders can expect their surfing pop-up velocity to decrease with ageing. The difference between the pop up velocities of younger recreational surfers aged 16-35 and older recreational surfers aged 45-65 is statically significant ($p<0.05$). That said, surfing appears to markedly offset the typical age-related decline in power; the known rates of power decline in adults are mitigated. It is likely of benefit for recreational surfers to retain as much lean muscle mass as possible as they age so a concurrent strength and power training regime to compliment and enhance their time in the water is recommended. Power training should supersede strength training if time and lifestyle restraints do not allow both. There does not appear to be a relationship between lower body power and pop-up velocity in recreational surfers. Encouraging simulated paddling when conducting pop-up velocity testing may produce a more reliable result than testing without the simulated paddle.

Practical implications

The argument can be made that strength training alone does not suffice. The 10% increase in power decline versus strength decline experienced by both men and women (Metter et al., 1997) indicates that power specific, not strength specific, training should be the primary focus of the aging recreational surfers training regime. A distinction between strength decline and power decline must be made and used as the basis for pop-up specific surf training programmes. This is particularly relevant when considering time as factor in designing a training programme; decisions can now be made as to what is potentially superfluous to a pop-up specific training programme and what can have the biggest impact on surfing performance and enjoyment. It could be suggested that upper-body power training should be prioritised over lower body power training given the lack of relationship between lower body power relative maximal power and pop-up velocity.

Take home message

We can conclude that 'just surfing' isn't enough to maintain pop-up velocity. The independent effect of age on power, force, velocity, strength, movement and coordination supersedes gender, muscle mass, muscle size, and body size (Metter et al., 1997). In order to preserve their pop-up velocity as much as possible, aging recreational surfers should engage in a dry-land training programme that focusses predominantly on power based training. Secondary training elements that could be included in such a programme are strength, balance, and coordination training. This is especially relevant to recreational surfers over 45.

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Appendices

Appendix A: Ethics Application

Research Ethics Application – Cover Sheet

Human Research Ethics Committee
Postal Address: The Secretary, Human Research Ethics Committee
Private Bag 3105
Hamilton 3240
E-mail: humanethics@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Name of Principal Investigator:	David Enticott
	drenticott@gmail.com
	+64 22 1690 765
School / Faculty / Institute:	**Te Huataki Waiora School of Health, The University of Waikato.**

Email address:
Phone number:
Office:

Student ID (if applicable):	1618701
Proposed start date of field research / data collection:	July 2022
This is an application for approval of: (indicate all that apply)	y/n Staff research project
	y/n PhD Research
	y/n Masters Research
	y/n Other
Name of degree / paper (if applicable):	Master of Health Sport & human Performance

Supervisor's name (if applicable): Supervisor's approval (signature): Martyn Beaven

Funding sources:

Project sponsors (e.g. equipment sponsors): N/A

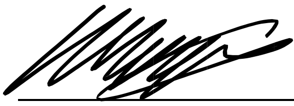
Research locations (if not within University of Waikato facilities) N/A

Associated Applications (provide the associated N/A application code and title):

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. http://calendar.waikato.ac.nz/assessment/ethicalConduct.html

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

Principal Investigator's signature:



Date: 11/07/2022

Project Overview

Please provide us with basic information about your project.

1. Project Title:

   'A comparison of pop-up velocity between younger and older recreational surfers'

2. Briefly state the **research topic, research questions** and/or **research objectives**.

   There exists a fundamental lack of research in the broad topic of surfing performance measures for recreational surfers. This becomes more apparent when seeking information about the specific elements of surfing that are crucial to performing successfully; in this research, that is the pop-up manoeuvre and vertical jump height. We will determine how and why the pop-up is such a critical performance measure for recreational surfers and compare and contrast pop-up velocity and vertical jump height between younger and older recreational surfers. The primary aim is to determine if any statistically significance exists in the pop-up velocity between younger and older recreational surfers. Secondary to this, we will explore the hypothesis that an older surfers experience with the pop-up offsets the natural decline in power, strength, speed and velocity that comes with age. The older recreational surfers will not be significantly slower than younger recreational surfers as a result of the engrained neuromuscular efficiency brought about by performing the pop-up for longer. The vertical jump measure may help us validate this theory, that is, if the older surfers pop-up velocity is not significantly slower than the younger surfers but the vertical jump height is significantly different, it may indicate that engrained neuromuscular efficiency could offset typical power decline as recreational surfers age.

3. What specific research activities are you planning to undertake? Respond to this question with a list of research activities. You will be asked to provide further details under Q.18.
   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
   ...

   This is a controlled laboratory study utilising Kistler force plates to record and analyse the movement and velocity with which subjects performing the surfing pop-up and vertical jump. The average pop-up times and vertical jump heights for both age groups will be analysed and compared using an independent samples *t* test. An observation will be made to determine if there is any statistical significance in the pop-up velocity and vertical jump heights between the two groups.

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

   Global participation in stand-up ocean surfing is increasing, with estimates placing the number of worldwide participants at 35 million. As a result of the inclusion of surfing in the 2021 Tokyo Olympic games it is anticipated that number will soon reach 50 million with approximately 340,000 of those being recreational surfers here in Aotearoa New Zealand.

   Internationally, the rise of informal lifestyle sports, such as surfing, mirrors the decline in traditional sports exemplified in Aotearoa New Zealand by the decreasing participation amongst secondary school children in rugby. This is confounded by the 'attractiveness' of surfing, particularly in Aotearoa New Zealand, where the pristine natural environment appeals to Kiwis as a collective. New Zealanders seem to inherently gravitate to the outdoors, in particular the ocean. An assumption often made regarding surfing is that it is the domain of youth; a hedonistic, counter-culture pursuit of, predominantly male, participants. Contrary to this typical perception, and as part of the growing popularity of surfing, there is an increasing visibility of older surfers. Surfing's elevation from subculture to the mainstream has highlighted the lack of structured performance measures for the recreational surfer, in stark contrast to typical Aotearoa New Zealand sports such as rugby, cricket and swimming. An early formative study referencing surfing performance noted that limited information is available with regard to the long-term physiological adaptations of participating in surfing. Evidence based recommendations as to how to perform surfing manoeuvres are sparse in contemporary scientific literature. There exists a need to continue to refine distinct categories of surfing performance measures for those who have no intention of operating within the strict scoring boundaries of competition. The recreational surfing experience would benefit from quantifiable performance measures.

This study will take the singular, physiological element that places a surfer in a position to ride a wave, the pop-up, and compare performance between younger an older surfers. In spite of its importance to surfing performance, the pop-up remains relatively unexplored which merits further investigation as it could be described as the most important performance factor for a recreational surfer. A slow pop-up action will limit the wave-riding options. Simply put, increased entry speed to a wave will give the recreational surfer more time on the wave. Arguably, this is the ultimate aim of every recreational surfer. This study will observe what, (if any) effect aging has on pop-up effectiveness.

The Researcher(s)

Please tell us about your research team.

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

   David Enticott under the supervision of Martyn Beaven

6. Outline your qualifications to undertake this research. Include such things as prior experience, training in relevant research methods, and/or personal knowledge of the subject

   I've been a recreational surfer for 10+ years, currently operating at an intermediate level and worked as a lifeguard with experience in rescue techniques whilst studying at an undergraduate level. On completion of my Bachelor's degree I travelled and surfed extensively across the globe. As a student of the Masters of Health, Sport & Human Performance course, this research is being undertaking as a continuation of knowledge and experience gained from the Research Methods and Advanced Human Performance Science papers.

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

   This research is guided by the University of Waikato's Ethical Conduct in Human Research and Related Activities Regulations.

The Participants

Please provide the following information about your potential participants:

8. Broadly, who will your participants be? (Indicate the population, not the names of participants) How many participants will there be? Provide an estimate if you are unsure of exact numbers.

   The participants will be two groups of recreational surfers, both male and female. The first group will be aged 18-30 and the second group will be aged 45-60. There will be eight surfers in each group (4 men and 4 women) totalling 16 participants in all.

9. How will you recruit participants? Summarise your process.

   Participants will be recruited from the local surfing community in the Mount Maunganui/Tauranga area. Specifically, local surf clubs, surf schools and prominent figures in the surfing community will be contacted via email and/or telephone and asked to display and distribute posters explaining the research to members and gauge their interest in participation. Travel vouchers will be offered to reimburse petrol and public transport costs to and from the testing centre.

10. How will you inform them about the project and their part in it? Summarise your process.

    An information sheet will be distributed to all potential participants fully informing them as to the specific process involved in the research. A clear breakdown of the experiment, it's physical demands and the time required will all feature as part of the information sheet. The rights of the participants to withdraw from the study up until one week following the laboratory pop-up session, or to decline to answer any questions in the study will be reiterated prior to the testing session.

    In spite of its importance to surfing performance, the pop up remains relatively unexplored which merits further investigation as it could be described as the most important performance factor for a recreational surfer. A slow pop-up action will limit the wave-riding options. Simply put, increased entry speed to a wave will give the recreational surfer more time on the wave. Arguably, this is the ultimate aim of every recreational surfer. This study will observe what, (if any) effect aging has on pop up effectiveness.

    Force plates will be used to record and analyse the movement and velocity with which participants in each cohort perform the surfing pop up. The participants in each group will be instructed to perform the surfing pop up on a surfboard that matches the dimensions of the board that they most frequently ride. The surfboard will be strapped to two slightly elevated platforms (securely placed on top of the force plate) to allow for simulated paddling strokes prior to the pop-up to replicate the open environment and movement associated with an in-water pop up as closely as possible. After completing a warm up, participants will be instructed to perform the surfing pop up three times with the quickest time being recorded.

    Participants may withdraw from the study at any time without having to give a reason up until one week following the laboratory pop-up session.

    Please find the information sheet attached.

    ***Attach** a copy of the information sheets for participants. Ensure that the content of the information sheet is written in language suited to the relevant participants.*

    ***Attach** a copy of any recruitment emails, posts, posters or similar.*

11. Are the participants vulnerable? No   If yes, then:
    In what ways are they vulnerable? N/A

Why do you need to involve them in your research? N/A
How will you protect them from harm? N/A

12. Will you select participants on the basis of their ethnicity, iwi, culture, gender, sexuality, religion, ethical belief or disability?

No

If yes, then specify the basis for selection, and state how you will tell participants about the selection criteria.

N/A

Are your participants likely to be from a particular ethnic group or other distinct population even if you are not selecting them on that basis?

No

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

As a recreational surfer with 10 years' experience I have an understanding of the language, the mindset and culture associated with surfers and surfing. I appreciate the importance of any information that may help surfers retain the physical ability to continue to surf regularly as they get older.

13. Do you have any type of relationship with your participants already (e.g. employer/employee, supervisor/worker, personal relationship)?

No

If yes, then you will have a dual role in the research, both as researcher and, for example, as friend or family member. How will your pre-existing relationship affect your role as a researcher?

N/A

Consider potential ethical issues associated with your pre-existing relationship. How will you address these issues in your project?

N/A

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.)

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

Participants will be reimbursed for their travel costs with petrol and/or public transport vouchers.

Consent

Please provide the following information about consent processes:

15. How will you gain informed consent from your participants?
Each participant will give their consent via the completion of a specific informed consent form (attached) prior to participation. All participants will be given an information sheet that fully explains the benefits and risks of participation, allowing them to make an informed decision prior to signing the consent form.

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.

As no relationship of any type exists between the researchers and the participants we will obtain consent from the participations ourselves.

When will participants give their consent?

Upon the completion and returning of the informed consent form.

How will you record their consent?

As described, via the use of an informed consent form, securely stored on a password and fingerprint encrypted laptop. Please find consent form attached.

If vulnerable, are your participants able to give informed consent?
N/A

If no, then:
How will you obtain consent from their proxy?
What steps will you take to ensure that their participation is voluntary at all times?
N/A

16. With the exception of participants who are anonymous to the researcher, participants have the right to withdraw entirely or in part from the research. Please provide the following information:
How long will participants have to withdraw? (e.g. three weeks after data collection, or receipt of a transcript)

Participants may withdraw from the study at any time without having to give a reason up until one week following the laboratory pop-up session.

How will they withdraw? (e.g. by informing the researcher)

By contacting the lead researcher, David Enticott, using the contact information provided on the information sheet.

17. Data collection activities may be planned for off-campus locations. Please list all off-campus location where you will engage in data collection. N/A

Do you need consent or permission from any organisation, community representative, and/or anyone other than the individual participants? If yes, list all the required permissions, consents, and/or approvals. N/A

How and when will you gain these permissions, consents and/or approvals? N/A

Research design

Please tell us about what you will be asking your participants to do.

18. What will participants be doing and how long will each activity take? Please provide these details for each of the items on your list in Q.3 above.

The inclusion criteria for selection of participants consisted of defining an intermediate recreational surfer as one with a minimum of five years' experience who surf at least once per week or a minimum of 52 times per year. They need to be able to perform turns, and trim (or ride) along the open face of a wave. They need to be currently free form injury and not participate in regular dry-land resistance based training. Participants will be split into two test groups of eight recreational surfers; a younger cohort (18-30 years old) and an older cohort (45-60 years old). Each group will consist of four female and four male recreational surfers. Force plates will be used to record and analyse the movement and velocity with which participants in each cohort perform the surfing pop-up and vertical jump. The participants in each group will be instructed to perform the surfing pop-up on a surfboard that matches the dimensions of the shortboard (less than 6'6) they most frequently ride. The surfboard will be securely strapped to two, slightly elevated, small platforms. Our aim us to replicate the open environment and movement associated with an in-water pop up as much as possible. After completing a warm up, participants will be instructed to perform the surfing pop up three times with the quickest time being recorded. We anticipate the testing process for each participant to take about 40 minutes, broken down as follows:

0-10 minutes – Introduction and familiarisation; participants will meet the researchers and will be shown the equipment being used and receive a brief rundown of how it works. Participants will be shown where they will perform their pop-up and vertical jump attempts and then they will commence a warm up.

10-20 minutes – Warm up and physical preparation; participants will prepare for the pop-up attempts with a five minute cardiovascular, pulse-raining activity using either a stationary cycle or treadmill. This will be followed by a short, joint by joint mobilisation sequence; the combination of these two activities will ensure adequate tissue temperature is obtained, neuromuscular awakening is achieved and joints have been worked through their full range of motion prior to the explosive physiological demand of preforming a pop-up.

20-35 minutes – After a check that all systems are working and receiving information as they should, the participants will assume a prone position on the surfboard followed by the first of three pop-up attempts. Three minutes rest will be allocated to allow for full replenishment of ATP (Adenosine Triphosphate) and full recovery of the ATP-PC system used to power the pop-up. The same process will be repeated for the vertical jump.

35-45 minutes – Quick debrief; time to discuss any relevant issues that arise with the participant and answer any questions, queries or concerns.

How will participants benefit from their involvement in the research?

The participants will benefit from their involvement in the research in two distinct ways:

`1 – Participants will learn of the effect, if any, of aging on one of the most important and fundamental elements of recreational surfing performance, the pop up. Specifically, participants will learn if the time to pop-up increases with age which will inform training focus for the participants. They will learn what specific training methods, such as power and strength, to employ to offset the natural decline in pop-up velocity expected with age.

2 – The participants will also understand the effect, if any, of surfing experience on the popup. They will potentially know that repeated and ongoing pop-up repetitions will maintain velocity and efficacy in spite of aging as a result of neuroplasticity.

19. Could participants be harmed in your research?

There is potential risk in performing any physical activity, particularly those that require explosive or powerful movement of load or weight. The surf pop-up comes with some inherent risk relative to this.

If yes, please describe all potential harms to your participants.

There is risk of soft tissue injury when performing the pop-up relative to the requirement to move load with speed in a non-linear fashion. Specifically, hamstrings, calves (and Achilles tendon) and lower back.

How will you minimize the risk of these harms occurring?

Participants will conduct a two stage warm up: five minute of low intensity (RPE 5/6) cardiovascular exercise (walking on a treadmill or cycling on a stationary bike) followed by a joint by joint mobilisation sequence of bodyweight movements. This is followed by three recorded pop-up and vertical jump attempts with the fastest and highest being used.

What will you do if a participant is harmed? Describe your processes in detail.

There will be a first aid kit on hand throughout the experiment for initial treatment as the injury is assessed and decisions made about any further treatment, for example, transport to a medical clinic, hospital or a return home.

Is it likely that concerns could arise regarding the health and wellbeing of your participants, through their participation in your project? How will this be managed?

No – there is no atypical or extraordinary risk involved.

20. How will you analyse the data that you collect from your participants?

The process to analyse the data collected involved establishing an inclusion criteria consisting of recruiting intermediate recreational surfer defined as:

- One with a minimum of five years' experience who surf at least once per week or a minimum of 52 times per year.
- One that can perform turns and trim (or ride) along the open face of a wave.
- One that is currently free from injury and not participating in regular, dry-land resistance based training.

Convenience sampling groups the participants by age, a younger cohort of 18-25 year olds and an older cohort of 45-60 year olds. The research or dependent variables are the velocity of the pop up and vertical jump height, both ratio scales of measurement. The age of the participants is the independent variable. As such, an independent sample t tests will be utilised to establish whether or not age has a statistically significant effect on pop-up velocity and vertical jump height.

Will your research involve comparing one group to another?

Yes.

If yes, then explain how the comparison will be done.

The data produced by the two groups will be analysed and compared to conclude whether or not there is any statistically significant difference between the two sets of data.

How are the participants categorized into specific groups?

The participants (who are all recreational surfers meeting the criteria as described above) will be categorised into two groups; an older cohort of 45-60 year olds and a younger cohort of 18-30 year olds.

Why is it important to do this?
It is important to compare two groups in order to establish whether statistical differences occur between those two groups as a result of a particular variable. In this instance, whether or not age is factor in pop-up velocity and vertical jump height for recreational surfers. This information can then potentially be extrapolated to make assumptions across a broader population. This in turn can allow for recommendations to be made as to how to treat, diagnose or solve a particular problem. It informs the efficacy of a particular intervention and therefore allows a strategy to be developed to manage the issue.

21. Does your research involve any deception of participants?

No.

If yes, then describe the deception.

N/A

Why is it necessary to deceive participants? How and when will participants be told of the deception?

N/A

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

No.

If yes, then describe the concealment.
Why is it necessary?
How and when will participants be told of the concealment?
If never, then, explain why the concealment will not be disclosed to participants.

N/A

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 to the interests of New Zealand-born and Island-born Pacific people.

Through the *Ethical Conduct and Human Research and Related Activities Regulations*, researchers are required to respect the **cultural, social** and **language preferences** and **sensitivities** of participants. When applying for ethical approval, researchers should demonstrate an awareness of social and cultural difference, consult advisors regarding the appropriate conduct of their research, and present the outcome of consultation in their ethics application.

Two resources that are particularly relevant to research at the University of Waikato are *Te Ara Tika – Guidelines for Māori Research Ethics* and the *Pacific Health Research Guidelines.*

23. Does the research project have particular relevance or potential implications for Māori, or for other social and cultural groups?

As the research is aimed at determining the effect of age on the ability of older surfers to perform the surfing pop-up, then there are implications for this group (surfers aged 45-60). These implications include recommendations for specific dry-land training to help manage the potential decline in pop-up velocity that this demographic may experience. We also hope to determine how much velocity is lost with age allowing assessments to be made as to how much of an impact a slower pop-up has on the surfing experience of 45-60 year olds.

If yes, then please provide the following information about your consultation processes:
Who are the stakeholders? (That is, whom do you have to consult?)

N/A

What are the results of your consultation with them so far? (e.g. describe advice taken on appropriate procedures and approaches to research, decisions made about appropriate ways to return research findings)

N/A

Do you have at least one cultural advisor for this project? Please provide their name(s) and specific role(s).

N/A

24. Describe how you will show respect and sensitivity towards participants (e.g. having support persons present during interviews, having an interpreter if you are not fluent in the language, being vouched for by elders, using appropriate gestures, dressing inoffensively, or participating in cultural ceremonies or rituals).

N/A

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

No names, identities, or identifying information from participants will be reported in this study. Individual information will remain confidential at all times and only shared between the investigators of this project. Raw data will also not be reported; rather it will be analysed for summaries, conclusions recommendations.

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

Yes.

If yes, how will you preserve confidentiality?

Participants will be given a pseudonym so that research data can be de-identified. Participant identity (Consent Forms and pseudonym code) will be stored on a password protected computer separate to the research data.

26. In addition to the lead researcher(s), who else will see information provided by the participants? Will any of the shared information be linked to the participants' names, or will it be anonymised before sharing?

The data collected will be shared with the research supervisor; as the supervisor is likely to be in the laboratory as the experiment is conducted the participants names will be known to the supervisor.

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.*

27. How and where will the data be stored and protected **during** the research project?

The data will be stored on a password and finger print encrypted laptop.

Research Reporting

28. List all the anticipated research outputs for the project (e.g. thesis, conference papers, journal articles, other sorts of presentation, book, media release, pedagogic materials).

The output for the research will be a thesis and, if published, a scientific journal article. Other outputs may include a presentation and a conference poster.

What provision is there to provide participants with information about the outcomes of the research?

All participants will be eligible to receive a copy of all information gleaned from the study upon its completion. This will be in the form of a thesis and/or scientific journal.

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? Supervisors are responsible for storing research data on behalf of their students.

The research supervisor will arrange secure storage of all data for the minimum 5 years required.

If archiving is appropriate for your project data, where will you archive the data and under what conditions?

There is no plan to archive the data.

If you do not intend to store your data indefinitely, how will you ensure that your data is safely destroyed?

All paper records will be shredded and securely disposed of, all electronic records with be transferred to an external drive which will be physically destroyed.

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.

There is no variation from this arrangement.

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 copyright of such works (e.g. books, journal articles, conference papers, art works and musical recordings) unless specified in clauses 12-18 of [the] policy."*

Please explain any variation from this policy.

There is no variation from this policy.

Clause 9 states that, *"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".*

Please indicate if intellectual property is subject to the principles of Te Tiriti o Waitangi.

N/A

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.
There are no other legal or ethical issues relative to this research. There is no sponsorship, no relationships between researcher(s) and any participants. There are no other stake holders.

Appendix B: Confirmation of Ethics

The University of Waikato
Private Bag 3105
Hamilton, New Zealand, 3240
0800 WAIKATO (924 528)

HECS Human Ethics Committee
Brett Langley
Telephone +64 77 838 4060
Hecs-ethics@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

29 July 2022

David Enticott

Martyn Beaven

Re: HECS Ethics Approval of Application HREC(HECS)2022#28 "A comparison of pop-up velocity between younger and older recreational surfers"

Dear David

Thank you for submitting your application HREC(HECS)2022#28 for ethical approval.

We are pleased to provide formal approval for your project, including the following activities:

- Recruitment of 16 participants (8 men and 8 women surfers in 18-30 and 45-60 age groups) to perform surfing pop-up and vertical jump trials.
- Use Kistler force plates to record and analyse the movement and velocity for subjects performing the surfing pop-up and height for vertical jump.
- Laboratory sessions should take approximately one hour to complete. Participants will be reimbursed for travel.
- Participants may withdraw at any time during, and up until one week following data collection without reason.

Please contact the committee by email (hecs-ethics@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.

Kind regards,

B Langley

Brett Langley, PhD
Chairperson
HECS Human Ethics Committee
University of Waikato

Appendix C: Participant Information Sheet

Participant Information Sheet

Study Title:

'A comparison of surfing pop up velocity between younger and older recreational surfers'

Location/Institution:

Adams Centre for High Performance,
University of Waikato

Lead Researcher:

David Enticott

Research Supervisor:

Martyn Beaven
martyn.beaven@waikato.ac.nz

Contact:

022 1690765/ drenticott@gmail.com

This research project has been approved by the Human Research Ethics Committee at the University of Waikato as HREC20XX#XX. Any questions or concerns about the ethical conduct of this research may be sent to the Secretary of the Committee, email humanethics@waikato.ac.nz, postal address, Human Research Ethics Committee, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.

Introduction

My name is David Enticott, and I am a Master of Health, Sport & Human Performance student at the University of Waikato. As part of the degree, I am undertaking a research project that investigates the relationship between age and the surfing pop-up. We are seeking recreational surfers of an intermediate level aged between 18-30 and 45-60 to participate in the study. It is anticipated that it will take approximately 40 minutes of your time on one day only to participate this study.

What is the purpose of the study?

Global participation in stand-up ocean surfing is increasing, with estimates placing the number of worldwide participants at 35 million. As a result of the inclusion of surfing in the 2021 Tokyo Olympic games it is anticipated that number will soon reach 50 million with approximately 340,000 of those being recreational surfers here in Aotearoa New Zealand.

Internationally, the rise of informal lifestyle sports, such as surfing, mirrors the decline in traditional sports exemplified in Aotearoa New Zealand by the decreasing participation amongst secondary school children in rugby. This is confounded by the 'attractiveness' of surfing, particularly in Aotearoa New Zealand, where the pristine natural environment appeals to Kiwis as a collective. New Zealanders seem to inherently gravitate to the outdoors, in particular the ocean. An assumption often made regarding surfing is that it is the domain of youth; a hedonistic, counter-culture pursuit of, predominantly male, participants. Contrary to this typical perception, and as part of the growing popularity of surfing, there is an increasing visibility of older surfers. This study will take the singular, physiological element that places a surfer in a position to ride a wave, the pop-up, and compare performance between younger an older surfers.

In spite of its importance to surfing performance, the pop up remains relatively unexplored which merits further investigation as it could be described as the most important performance factor for a recreational surfer. A slow pop-up action will limit the wave-riding options. Simply put, increased entry speed to a wave will give the recreational surfer more time on the wave. Arguably, this is the ultimate aim of every recreational surfer. This study will observe what, (if any) effect aging has on pop-up effectiveness.

In examining the pop-up as a surfing performance measure relative to the older recreational surfer, it is logical to assume that time pop up velocity will decline with age. Age-related decline in maximal strength and dynamic strength conversely reduces peak force, rate of force development and power that manifest themselves in a slower pop up.

What are the potential benefits and risks of this study?

We hope this study will provide you, as recreational surfers, the following two specific benefits:

`1 – Participants will learn of the effect, if any, of aging on one of the most important and fundamental elements of recreational surfing performance, the pop-up. Specifically, participants will learn if the time to pop-up increases with age which will inform training focus for the participants. They will learn what specific training methods, such as power and strength, to employ to offset the natural decline in pop-up velocity expected with age.

2 – Participants will also understand the effect, if any, of surfing experience on the pop-up. They will potentially know that repeated and ongoing pop-up repetitions will maintain velocity and efficacy in spite of aging.

Potential risks - There is potential risk in performing any physical activity, particularly those that require explosive or powerful movement of load or weight. The surf pop-up comes with some inherent risk relative to this. There is risk of soft tissue injury when performing the pop up relative to the requirement to move load with speed in a non-linear fashion. Specifically, hamstrings, calves (and Achilles tendon) and lower back.

What will my participation in the study involve and how long will it take?

As a participant you will be asked to attend the Adams Centre for High Performance in Mt Maunganui on one weekend day, either Saturday or Sunday. You will be required for approximately 40 minutes with the time broken down as follows:

0-10 minutes – Introduction and familiarisation; you'll meet the researchers and we will show you the equipment being used and give a brief rundown of how it works. You'll be shown where you will perform your pop-up attempts and then you will warm up.

10-20 minutes – Warm up and physical preparation; you'll prepare for the pop-up attempts with a 5 minute cardiovascular, pulse-raining activity using either a stationary cycle or treadmill. This will be followed by a short, joint by joint mobilisation sequence; the combination of these two activities will ensure adequate tissue temperature is obtained, neuromuscular awakening is achieved and joints have been worked through their full range of motion.

20-35 minutes – After a check that all systems are working and receiving information as they should, the participants will assume a prone position on the surfboard followed by the first of the pop-up attempts. Three minutes rest will be allocated to allow for full replenishment of ATP (Adenosine Triphosphate) and full recovery of the ATP-PC system used to power the pop-up. The same process will be repeated for the vertical jump.

35-45 minutes – Quick debrief; time to discuss any relevant issues that arise with the participant and answer any questions, queries or concerns.

Who pays for the study?

Participation in this study is free. We will provide you with a travel voucher to reimburse you for your fuel/public transport costs to and from the test centre.

What are my rights?

Your participation is entirely voluntary and you are free to withdraw at up until one week following the laboratory pop-up session. You have the right ask any question relating to the study at any time. You also have the right to not answer any question or perform any activity you do not feel comfortable with. Your identity, personal information and data will be kept confidential at all times and will be securely stored on a password and finger print encrypted computer. The data collected form the study will be used to in thesis and potentially a published article in a scientific journal. You will receive a copy of any and all documents that the data is used to produce. The output for the data that is produced will be a thesis and, if published, a scientific journal article. Other outputs may include a presentation and a conference poster. It may be necessary to photograph and/or video record elements of your participation in the study however your identity will not be disclosed with your face and any distinguishing features being obscured. Any use of your obscured image in the study will only occur with your permission.

Can my data be withdrawn from the study once it has been submitted?

Yes, you may withdraw from the study at any time without having to give a reason up until one week following the laboratory pop-up testing session. As per University of Waikato regulations, research data will be stored for 5 years in a restricted access University of Waikato secure drive after which time it will be destroyed.

Who do I contact if I have any questions or concerns?

Please feel free to contact David Enticott, the lead researcher if you have any questions or concerns at any time:

Phone – 022 1690 765

Email – drenticott@gmail.com

If you would prefer to contact a different member of the research team then please get in touch with my research supervisor:

Martyn Beaven

Email – martyn.beaven@waikato.ac.nz

Appendix D: Participant Consent Form

Consent Form for Participants

Human Research Ethics Committee
Te Huataki Waiora
School of health

Hamilton 3240
Phone +64-7-8384737
Email contact-hecs@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

A comparison of pop-up velocity between younger and older recreational surfers

Consent Form for Participants

I have read the **Information Sheet for Participants** for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study up until one week following the laboratory pop-up testing session, or to decline to answer any questions or perform any activity in the study. I understand it may be necessary to photograph and/or video record elements of my participation in the study and I understand that my identity will not be disclosed and my face and any distinguishing features will be obscured. Any use of my obscured image in the study will only occur with my permission.

I agree to provide information to the researchers under the conditions of confidentiality set out on the Information Sheet.

I agree to participate in this study under the conditions set out in the **Information Sheet** form.

Signed: ____

Name: ____

Date: ____

Researcher's Name and contact information:

David Enticott
Phone 022 1690 765
Email *drenticott@gmail.com*

Supervisor's Name and contact information:

Martyn Beaven (martyn.beaven@waikato.ac.nz)

Appendix E: Recruitment Poster

Appendix F: Recruitment Email

Recruitment email

Hi (insert name/organisation/contact),

My name is David Enticott and I'm Masters student at the University of Waikato. I'm part of a team conducting a research study into the effect of aging on the pop-up in surfing and I'm writing to you to ask for your help in recruiting participants. As someone with close links to the local Mt Maunganui and Papamoa surf communities, we're hoping you can display the attached poster, circulate it among your members and pass this information on to any potential participants.

Fundamentally, a slow pop-up action will limit the wave-riding options. Retaining or even increasing entry speed to a wave will give the recreational surfer more time on the wave. Arguably, this is the ultimate aim of every recreational surfer. This study will observe what, (if any) effect aging has on pop up effectiveness. Our goal with this new study is to specifically measure change in pop-up speed (or velocity) in intermediate level recreational surfers as they get older. We hope this information will inform surfers as to how much their pop-up will change as they age allowing them to make conscious and specific decisions regarding the focus of their training.

We hope you would like to help advance our understanding of what it takes to maintain or improve performance in recreational surfers. As passionate (aging!) surfers ourselves we have an innate interest in trying to hold on to our fundamental surfing skills for as long as possible – we hope you share that interest.

All the relevant information can be found on our participant information sheet:
Participant Information Sheet.docx

Please let me know if you have any questions we could answer. Thank you for your contribution to the advancement of surfing performance knowledge.

Kind regards,

David Enticott
UOW Master of Health, Sport & Human Performance Student