Effects of Eccentric Cycling as Part of a Warm-Up Protocol on Various Athletic Performance Measures Among Recreationally Active Individuals

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Table of Contents

List of Tables

List of Figures

Appendix

ATTESTATION OF AUTHORSHIP

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

The respective contributions of both me and the co-author to the paper are explicitly detailed at the outset of the thesis. Furthermore, I confirm that all co-authors have granted their approval for the inclusion of our collaborative work in this Master's thesis.

Signature:

Date: 15/8/2024

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ABSTRACT

Warm-ups play a crucial role in any physical activity regimen, significantly impacting performance outcomes. By engaging in a warm-up routine before engaging in exercise or sports, individuals can effectively prepare their bodies for optimal performance while reducing the risk of injuries. A well-designed warm-up typically includes activities such as light cardiovascular exercise, dynamic stretching, and drills specific to the upcoming event (Zentz et al., 1998; Bishop, 2003; Fradkin et al., 2010). Eccentric cycling, a form of resistance training where the muscles lengthen under tension, has gained attention for its potential benefits in sports performance (Elmer et al., 2013; Elmer et al., 2017; Beaven et al., 2014). Unlike traditional concentric exercises where muscles shorten as they contract, eccentric cycling focuses on the controlled lengthening of muscles, which can result in greater force production and muscle hypertrophy (Elmer et al., 2017). Studies have shown that eccentric training can lead to significant improvements in muscle strength and mass, and it is particularly effective when performed at high intensities (Roig et al., 2009). Despite this, there is limited research on investigating the acute effects of eccentric cycling as part of a warm-up on sports performance. Chapter 2 of this thesis includes a literature review on 1) the effects of warm-up for athletic performance, and 2) the effects of eccentric exercise on athletic performance. Chapter 3 consists of a cross-sectional study conducted on recreationally active individuals. This study aims to evaluate the effects of a single session of eccentric cycling as a part of the warm-up on various performance metrics, including 30-meter sprinting performance, standing long jump ability, shoulder internal and external rotation, sit and reach, and 20-second hopping frequency. By examining these effects, the study seeks to determine the efficacy of eccentric cycling as a part of the warm-up protocol and its potential benefits in enhancing athletic performance. The analysis revealed no significant differences between the eccentric cycling protocol and the traditional warm-up for sprinting, jumping, and sit and reach. Alternatively, there was a significant difference in shoulder rotation compared to the traditional warm-up, with a mean difference of 3.0 degrees ($p = 0.005$). Additionally, the sequence in which the warm-up were performed had a large effect on shoulder rotation. However, there was no significant interaction between

the type of warm-up and the sequence in which they were performed, suggesting that the increases in shoulder rotation were primarily due to the eccentric warm-up itself and not influenced by the order of warm-up protocols on different performance metrics. The results indicate that eccentric cycling may offer benefits for certain movements, such as shoulder rotation. Various upper-body and overhead sports could potentially benefit from adding eccentric cycling to their warm-ups. Further research is needed on the effects of upper body eccentric cycling on shoulder range of motion and performance in athletic populations. In fact, the control group outperformed the eccentric protocol group in hopping frequency (2.4 hops/second, $p = 0.04$), highlighting a potential drawback of using eccentric cycling as a part of a warm-up for activities requiring explosive leg power. This difference in hopping frequency may be due to fatigue induced by the eccentric cycling. Consequently, the lack of improvement in sprinting and jumping might also be linked to this fatigue, as these activities similarly demand rapid power generation. Based on the findings in this thesis, practical implications suggest that recreationally active individuals should continue using a traditional warm-up for lower body activities, which include light cardiovascular exercises, dynamic stretching, and sport-specific drills, to optimize performance and reduce the risk of injury. More research is needed on warm-ups with eccentric cycling in athletic populations, especially with an upper-body focus.

Chapter 1

INTRODUCTION AND RATIONALE

Thesis Background

An effective warm-up routine generally consists of light cardiovascular exercise, dynamic stretching, and drills specific to the upcoming event (Zentz et al., 1998; Bishop, 2003; Fradkin et al., 2010). However, it's important to recognize that the effectiveness of a warm-up routine may vary depending on the specific sport, individual characteristics, and environmental conditions. The key to optimal warm-up lies in striking a delicate balance between adequately preparing the body for peak performance and avoiding premature fatigue. This balance is crucial because insufficient warm-up may lead to suboptimal performance and increased injury risk, while excessive warm-up can cause premature fatigue, potentially reducing performance during the actual event.

Eccentric exercise, characterized by muscle lengthening under tension, has unique physiological properties that may offer benefits as part of a warm-up strategy. Previous research has primarily focused on the long-term adaptation to eccentric training, demonstrating improvements in muscle strength, power, and hypertrophy (Roig et al., 2009). Eccentric cycling is a relatively new exercise method that involves the individual actively resisting the backward movement of the pedals, which are driven by an electric motor (Barreto et al., 2020). Numerous studies have shown that eccentric cycling results in lower metabolic demand, lower oxygen consumption, lower cardiorespiratory strain, and lower perceived effort (Chasland et al., 2017; Elmer et al., 2013). Additionally, eccentric cycling has been shown to result in greater improvement in strength and power compared with concentric cycling (Elmer et al., 2017). However, the acute effects of eccentric cycling on subsequent sports performance remain largely unexplored. This thesis aims to bridge this gap in the literature by investigating the potential of eccentric cycling as a part of a warm-up tool. By examining its acute effects on multiple performance metrics among recreational active individuals, this study seeks to determine the efficacy of eccentric cycling as a novel warm-up protocol and its potential implications for enhancing sports performance. To date, there are no studies that have examined the effects of a single eccentric cycling session as a part of warm-up on sports performance. The findings of this research may contribute to the development of more effective and efficient warm-up strategies, potentially influencing pre-competition preparation across various sports disciplines.

1.1 Purpose statement

The primary goal of this thesis was to determine the effects of eccentric cycling as a part of a warm-up protocol on multiple performance metrics among recreationally active individuals, including 30-meter sprinting performance, standing long jump, shoulder internal and external rotation, sit and reach, and 20-second hopping. This investigation was conducted on recreationally active individuals for the following reasons:

1) To date, no known study has investigated the effects of eccentric cycling as a part of a warm-up protocol on athletic performance.
2) To date, no known study has investigated the effects of eccentric cycling as a part of a warm-up protocol in a demographic of recreationally active individuals.

Previous research conducted over seven weeks has found greater improvement in maximal upper body strength and power compared with concentric arm cycling (Elmer et al., 2017). However, the acute effects of a single eccentric cycling session as part of a warm-up on sports performance remain largely unexplored. This thesis attempted to investigate whether eccentric cycling possesses warm-up potential, aiming to determine the potential utility of using eccentric cycling as a warm-up tool.

1.2 Research aims and hypotheses

The preliminary aim of this thesis was to 1) review the literature on the benefits of warm-up on performance metrics and the effects of eccentric cycling on athletic performance. The primary aim was to 2) determine the difference between traditional warm-up methods and eccentric cycling as part of a warm-up protocol on specific performance metrics in recreationally active individuals. Eccentric exercise, particularly eccentric cycling, has shown promising effects on muscle function and performance. Research indicates that eccentric cycling can lead to improvements in muscle strength, power, and structural adaptations with potentially lower metabolic costs compared to traditional concentric exercise (Chasland et al., 2017; Elmer et al., 2013; Elmer et al., 2017). These unique characteristics of eccentric cycling suggest it may offer advantages when incorporated into warm-up routines. Given these potential benefits, we hypothesized that for 2) eccentric cycling as part of a warm-up protocol would lead to better performance outcomes compared to traditional warm-up methods.

1.3 Structure of the thesis

This thesis consists of four chapters including a literature review (Chapter 2) and one experimental study (Chapter 3) to be submitted to journals for publication. References are presented at the end of the final chapter as required by AUT for thesis submission. The structure of the thesis is shown as a schematic in Figure 1.

Chapter 2 of the thesis is a review of the current literature on the warm-up effect on physical performance, and the effect of eccentric exercise on athletic performance.

Chapter 3 of this thesis is an experimental cross-sectional study on the effects of eccentric cycling as a part of a warm-up protocol on multiple performance metrics among recreationally active individuals.

Chapter 4 is the final chapter, and it includes a summary and conclusion of the thesis's overall findings. It also includes practical recommendations, limitations of the present study and potential areas for future directions.

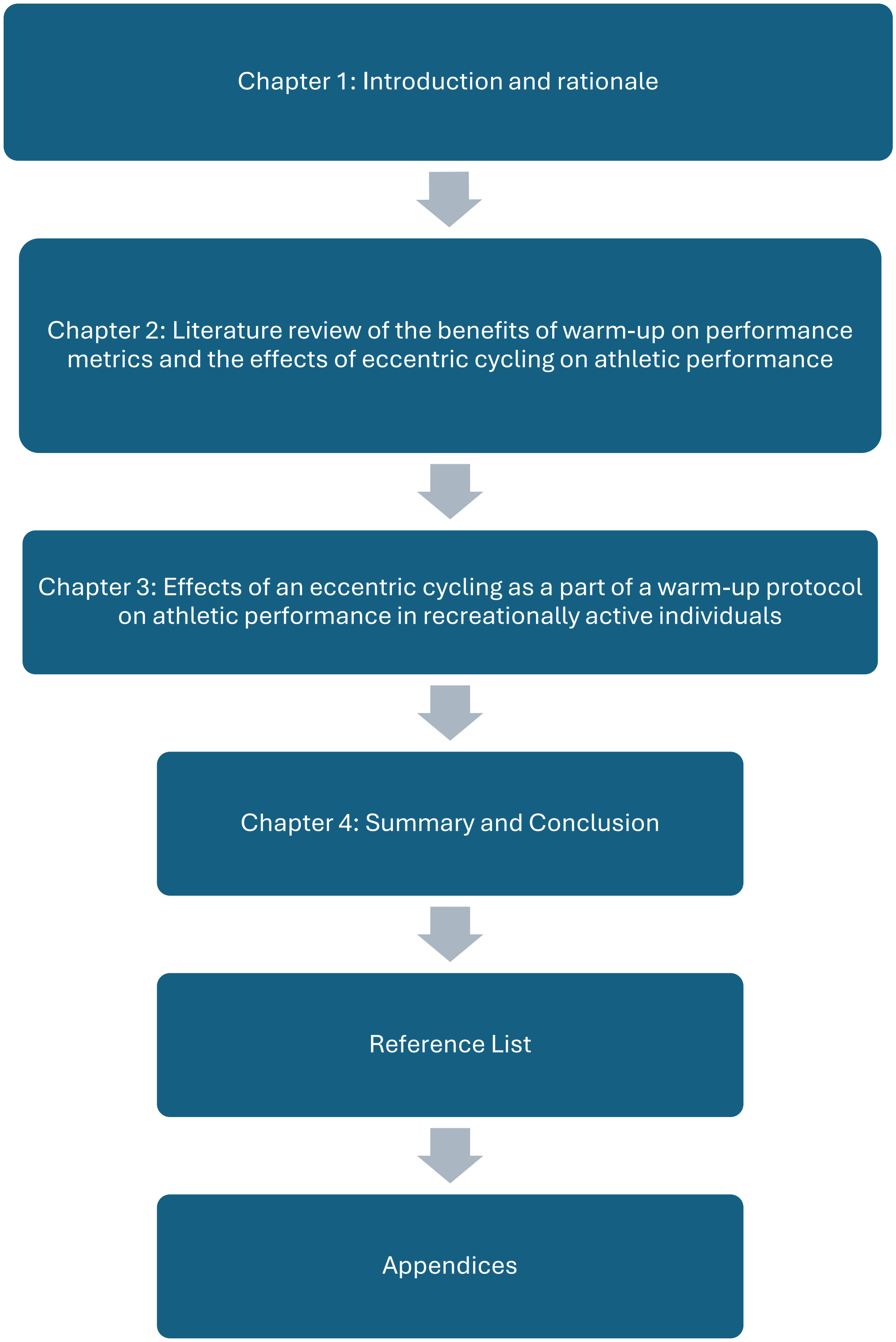


Figure 1. A schematic of the flow of chapters in this thesis

Chapter 2

Literature review of the benefits of warm-up on performance metrics and the effects of eccentric cycling on athletic performance

2.1 Abstract

This review examines the literature on warm-up benefits on athletic performance and the effects of eccentric cycling on athletic performance.

2.2 Introduction

Warming up before exercise is widely known to significantly impact performance outcomes (Rumeau et al., 2023; Seitz & Haff, 2016; McGowan et al., 2015). A well-designed warm-up typically includes activities such as light cardiovascular exercise, dynamic stretching, and drills specific to the upcoming event (Zentz et al., 1998; Bishop, 2003; Fradkin et al., 2010). Engaging in a proper warm-up enables individuals to experience increased blood flow to the muscles, reduced muscle viscosity, stimulation of the nervous system, enhanced flexibility and mobility, and increased force development (McGowan et al., 2015; Bishop, 2003; Marián et al., 2016; Martinopoulou et al., 2022). By incorporating such a routine before engaging in exercise or sports, individuals can effectively prepare their bodies for optimal performance while reducing the risk of injuries (McGowan et al., 2015; Bishop, 2003). Additionally, warm-ups offer a valuable opportunity for mental preparation, enabling athletes to focus their attention and build confidence (McGowan et al., 2015; Shellock & Prentice, 1985; Lochbaum et al., 2022; Fujii et al., 2023; Rumeau et al., 2023).

While there are various forms of warm-up modalities, the use of eccentric muscle actions has garnered increasing attention in recent years. Eccentric muscle actions not only actively generate force as the muscle extends under tension but also absorb mechanical work and generate a high amount of force at a low metabolic cost. Results have shown lower metabolic, cardiovascular, and respiratory demands than traditional concentric and isometric exercise (Harris-Love et al., 2021; Barreto et al., 2021). In many sports, these eccentric actions are crucial as they can serve for dual function, acting as shock absorbers to decelerate or absorb energy during landing and braking movements but also allowing temporary storage and release of elastic energy through the stretch-shortening cycle to augment force production during explosive concentric actions like sprinting and jumping (Vogt & Hoppeler, 2014; Harris-Love et al., 2021).

Eccentric cycling, a relatively new exercise modality, involves backward-moving pedals with an electric motor against which the individual actively resists this backward movement (Barreto et al., 2021). It can be performed in different positions to target the quadriceps, arms (see Figure 2), gluteals (see Figure 3), or hamstrings (see Figure 4). Studies have shown that eccentric cycling may produce similar muscular activation and cardiovascular and metabolic responses compared to concentric cycling when both exercises are performed at a fixed heart rate or oxygen uptake, with eccentric cycling producing a substantially greater workload (Barreto et al., 2021).

Sprinting is an explosive activity requiring maximal power over a short distance (Mero et al., 1992). Athletes need quick acceleration, allowing them to reposition themselves in a match situation to gain tactical advantages on the field or seize scoring opportunities in team sports, such as soccer, rugby, basketball, and netball. Additionally, sprint speed is the primary determinant of success in some track and field events such as 100-meter and 200-meter dashes (Suchomel et al., 2016). Multiple studies have investigated the benefits of various warm-up methods on athletic performance, however, there is a limited amount of research on the warm-up effects of eccentric cycling, particularly in the context of sprinting, especially among recreationally active individuals. Therefore, this literature review aims to critically examine 1) the warm-up effect for athletic performance, and 2) the effects of eccentric exercise on athletic performance.

2.3 Literature review search methods

An electronic-based search was conducted using the search engines Pubmed, Taylor & Francis Online, Google Scholar, Ovid, Scopus, ResearchGate and SPORTDiscus to identify potential articles. The following search terms were used: eccentric cycling, warm-up, rate of force development, post-activation potentiation (PAP), and sprinting. Further literature was obtained from electronic 'related articles' searches and by manually screening the reference lists of the included studies. The specific inclusion criteria included 1) warm-up protocols that assessed athletic performance, and eccentric studies that assessed performance metrics, 2) a detailed explanation of the procedures and methods, 3) written in English, 4) research studies solely conducted with human participants, and 5) observational studies.

2.4 Warm-up effect for athletic performance

Warm-ups are essential to an individual routine before starting any physical activity, to help enhance sports performance, and help prevent injury. Warm-up can be categorized as an active warm-up or a passive warm-up. An active warm-up involves physical activities that increase the heart rate and blood flow. These warm-ups include activities such as jogging, dynamic stretches, and sport-specific drills. Passive warm-ups, on the other hand, increase body temperature without performing physical activities, such as hot baths, heating pads, or wearing blizzard survival jackets (McGowan et al., 2015; Bishop, 2003). According to Bishop (2003), doing a warm-up before any physical activity is believed to help increase blood flow to the muscles, reduce muscle viscosity, stimulate the nervous system, enhance flexibility and mobility, and improve the rate of force development (Bishop, 2003). An active warm-up is more common in most sports since using a passive warm-up before competition is not often practical in the field. Nevertheless, passive warm-ups can be beneficial in maintaining muscle temperature and core temperature during the transition phase, helping to prevent a decline in the temperature and subsequently improving exercise performance (McGowan et al., 2015).

There are several studies that have reported on the influence of warm-ups on athletic performance, including range of motion (ROM), force production, jumping ability, strength, and power production (Behm et al., 2016; Van Gelder & Bartz, 2011). Stewart and Sleivert (1998) showed a significant improvement in ROM for ankle dorsiflexion and hip extension following a dynamic warm-up that included running at various intensities of 60%, 70%, and 80% of VO2max, coupled with three minutes of stretching. However, this improvement was not observed in hip flexion and knee flexion. These findings suggest that both stretching and dynamic warm-up can induce acute changes in ROM, and these alterations are not dependent on the intensity of the warm-up. The probable mechanisms for these enhancements may be attributed to the increase in muscle temperature and the elasticity of connective tissues, which allow muscles to extend to greater lengths (Taylor et al., 1990). Similarly, Magnusson et al. (1996) demonstrated that repeated stretches in human hamstring muscles lead to temporary reductions in stiffness and increases in flexibility, although these effects returned to baseline within an hour. This indicates that dynamic stretching can provide short-term benefits in muscle pliability and ROM. Additionally, dynamic stretching can enhance agility performance, which is crucial for sports requiring rapid changes of direction, such as basketball, soccer, and rugby (Van Gelder & Bartz, 2011). Unlike dynamic stretching, Brusco et al. (2018) observed that even a short duration of static stretch will induce a significant reduction in vertical jump when preceded by a dynamic warmup. Similarly, Chaouachi et al. (2010) found that the order of static and dynamic stretching, as well as the intensity of the stretches, did not significantly affect sports performance. In order to improve sports performance, research suggests that individuals should avoid performing static stretches with maximal tension, long durations (more than 30 seconds), and high volumes (more than 6 repetitions or 60 seconds per muscle). Furthermore, it is advisable to allow a recovery period of more than 5 minutes between static stretching and performance (Chaouachi et al., 2010). As a result, dynamic warm-up has been shown to acutely improve ROM, likely due to increased muscle temperature and connective tissue elasticity (McGowan et al., 2015). As such, research highlights that dynamic stretching can enhance the ROM and flexibility temporarily; static stretching may impair performance when not properly integrated (Behm & Chaouachi, 2011). Therefore, to optimize sports performance, it is essential to carefully balance the types and sequences of stretches, ensuring that static stretches are not too intense, prolonged, or voluminous and allow for sufficient recovery time before engaging in athletic activities.

Multiple studies have found an increase in the rate of force development (RFD) after performing heavy-resistance training programs or explosive-type strength training, which is crucial for improving sprinting and jumping performance (Maffiuletti et al., 2016; Aagaard et al., 2002; Van Hooren et al., 2022; Marián et al., 2016; Martinopoulou et al., 2022). The enhanced RFD allows athletes to generate more force in a shorter period, leading to better performance in explosive activities. Typically, increases in RFD before physical activity are achieved using post-activation potentiation (PAP) methods (Güllich & Sehmidtbleicher, 1996).

PAP refers to the enhancement of athletic performance following a pre-load activity (Lorenz, 2011; Tillin & Bishop, 2009).

PAP is a method commonly used to potentially enhance athletic performance. According to Tillin & Bishop (2009), to achieve the effects of PAP, it must be induced by a voluntary conditioning contraction. Research has shown that greater volumes and intensities of voluntary conditioning contraction will result in greater levels of PAP and fatigue. Although the exact mechanism underlying the effectiveness of PAP is yet to be fully determined, researchers have proposed two main mechanisms (Jeffreys, 2008; Hodgson et al., 2005). The first mechanism involves the phosphorylation of myosin regulatory light chains, which increases the sensitivity of actin-myosin to calcium released from the sarcoplasmic reticulum during subsequent muscle contractions (Lorenz, 2011). The increase in calcium sensitivity facilitates a faster transition from weak-binding to strong-binding sites, thereby enabling a greater number of force-generating cross-bridges during contraction (Hodgson et al., 2005). Consequently, this augmentation leads to increased force in each successive twitch contraction, enhancing muscle force and speed (Blazevich & Babault, 2019). The second mechanism is the increase in neuromuscular activation (Hodgson et al., 2005). Strength training or plyometric training causes synaptic excitation within the spinal cord, subsequently increasing the post-synaptic potentials and the force-generating capacity of the targeted muscle groups (Lorenz, 2011; Jeffreys, 2008). This neuromuscular activation enables the nervous system to recruit a greater number of motor units and synchronize their firing patterns more effectively during subsequent contractions (Blazevich & Babault, 2019).

Numerous studies have provided evidence supporting the effectiveness of using PAP in enhancing athletic performance (Güllich & Sehmidtbleicher, 1996; Maroto-Izquierdo et al., 2020; Rumeau et al., 2023; Jeffreys, 2008; Wilson et al., 2013; Dobbs et al., 2019; Bevan et al., 2010; Petisco et al., 2019). PAP can be achieved through various methods. A systematic review by Seitz and Haff (2016) found that plyometric exercises and high-intensity concentric contractions result in a more significant potentiation effect compared to traditional moderate-intensity exercises and maximal isometric contractions. These two methods, particularly plyometric exercises, are highly recommended for achieving PAP. This superiority may be because plyometrics are associated with the preferential recruitment of type II motor units, which enhances subsequent explosive movements (Seitz & Haff, 2016). However, it is important to note that while PAP can significantly enhance performance, it can simultaneously induce fatigue. When the intensity is too high, the negative effects of fatigue may outweigh the benefits of PAP. Maximizing the benefits of PAP and minimizing fatigue depends on the individual's training status and optimal recovery time, which varies from person to person (Gouvêa et al., 2013; Wilson et al., 2013). Typically, individuals with longer training histories not only experience a more prolonged PAP effect but also require heavier loads to induce this effect, compared to those with less training experience (Chiu et al., 2003; Wilson et al., 2013).

A meta-analysis done by Dobbs et al. (2019) showed that there was a significant improvement in vertical jump performance with heavy loads (≥80% of 1 RM), provided that rest intervals were given between 3 and 7 minutes. Their effect was trivial when the rest intervals were beyond 7 minutes. Additionally, a study by Bevan et al. (2010) found improvements in sprint performance over distances of 5m (with 47% of participants performing best at 8 minutes, 27% at 12 minutes, and the remaining 26% at 4 and 16 minutes) and 10m (where 53.3% showed optimal performance at 8 minutes, with the rest equally distributed between 4 and 16 minutes) following a heavy preload stimulus. Beyond heavy loading, ballistic or plyometric exercises can also serve as effective PAP protocols. These types of movements are beneficial because they activate different muscle fibers and enhance the stretch-shortening cycle (SSC), which is crucial for explosive movements (Seitz & Haff, 2016).

Thapa et al. (2020) demonstrated that a combination of box jumps followed by immediate drop jumps can improve agility test performance. This combination likely potentiates both types of muscle contractions involved in the SSC by engaging diverse muscle fibers simultaneously, thereby enhancing overall athletic performance. This approach shows the broad applicability and versatility of PAP strategies beyond traditional heavy-loading methods.

Table 1

Descriptive of selected PAP studies

Reference	Sample	PAP Intervention	Type of testing	Protocol	Results
Thapa et al. (2020)	12 male university basketball players	BDJ performed by jumping onto the box after a countermovement and then dropping from the box with an immediate vertical jump. 3 sets of 5 BDJ repetitions with a rest of 10secods between repetitions and 60seconds between sets.	15m linear sprint test and modified agility T-test (MAT)	After a 10-minute warm-up, a baseline assessment was conducted for 3 minutes. Following this, participants either underwent the BDJ protocol or walked for 3 minutes. Post-intervention measurements were collected 3 minutes after the intervention.	Significant interaction effect (time x intervention) in MAT with a large effect size MAT performance was also significantly higher after BDJ protocol compare to baseline. No significant effect in 15m linear sprint test.
Bevan et al. (2010)	16 professional rugby players	1 set of 3 repetitions at 91% of subjects estimated 1RM squat.	10m sprint (with a 5-m split)	Subjects completed 5 10m sprint at the following times : baseline, 4,8,12 and 16 minutes after the intervention.	No significant difference with regard to 5 and 10m sprint times. Subjects performed their best sprint times at the 8-minute time point for the 5m and 10m sprint time.
Beato et al. (2019)	10 male athletes	3 sets of 6 repetitions of eccentric overload (EOL) or traditional weightlifting (TW) half squat exercise	Standing Long Jump (SLJ), Countermovement Jump (CMJ), 5m sprint	Subjects perform a warm-up followed by one of the two exercise modalities (EOL or TW). SLJ, CMJ and 5m sprint were performed at 1, 3, and 7 minutes after the interventions.	EOL and TW show increase in SLJ distance and CMJ height but not 5m sprint performance.

Reference	Sample	PAP Intervention	Type of testing	Protocol	Results
Chatzopoulos et al. (2007)	15 healthy males	10 repetitions at 90% of 1RM back squat (HRS)	30m dash (0-10 and 0-30)	Running test were performed 3 times – a) 3 minutes prior the HRS, b) 3 minutes after the HRS, and c) 5 minutes after the HRS (in separated training session).	Running speed was not affected 3 minutes after the HRS, but it increased for both selected running phase (0-10 and 0-30) 5 minutes after the HRS.
Matthews et al. (2009)	12 male athletes	Condition 1 : 5 reps at 85% of a 1RM bench press. Condition 2 : 5 reps of a 2.3kg medicine ball push pass. Condition 3 : Control	Flight time of the basketball push-pass	Pretest, 60seconds rest, followed with either condition (1,2 or 3), 240 seconds rest, post-test.	Condition 1 and 2 show a significant difference in peak power output from pre to post test.
Till and Cooke. (2009)	12 male soccer players	Deadlift (5 reps), tuck jump (5 reps), isometric maximum voluntary contraction knee extensions (3 reps for 3seconds)	3 10m and 20m sprints at 4, 5 and 6 minutes post warm-up and 3 vertical jump (VJ) at 7, 8, and 9 minutes after post warm-up.	After a controlled warm-up, subjects required to performed the PAP treatment protocol. After the treatment, subjects underwent 3 10m and 20m sprints at 4, 5 and 6 minutes post warm-up and 3 VJ at 7, 8, and 9 minutes after post warm-up.	No significant difference in the first 10m and 20m sprints compare between PAP intervention group and control group. No significant difference in performance responses between the strongest and weakest subjects, but large variations in individual responses were found between the subjects.

Reference	Sample	PAP Intervention	Type of testing	Protocol	Results
Sanchez-Sanchez et al. (2018)	7 national level (NL), and 8 regional level (RL) soccer player.	PAP-1 : performed back squats with a load (60% pf 1RM) that allowed a high speed (1m/s) PAP-0.5 : performed a back squat with a load (90% 1RM) that allowed a moderate speed (0.5 m/s). Subjects required complete the repetitions for both PAP until the mean propulsive concentric velocity was reduced by > 10%	Repeated sprint ability test (RSA) (six 20-m sprints with 20s of recovery)	After a traditional warm-up, the athletes underwent either one PAP intervention method. After the PAP warm-up, athletes rested passively for 5 minutes and then performed the RSA test.	No differences between both PAP-0.5 and PAP-1 for the different protocols on the fastest sprint (RSAb) and the mean time of all sprints (RSAm). Compared to control, there is a small effect was observed for the reduction in RSAb after PAP-0.5. NL athletes showed greater RSAb and RSAm performance after PAP-0.5 and PAP-1 compared with RL athletes.
Ahn et al. (2022)	13 resistance trained college	Dynamic resistance (5 reps x 3 sets of 87% of 1RM back squat) Plyometric (5 reps x 3 sets of max voluntary +10% body weight of weighted jump) Isomeric (3sec x 3 sets of 30degree back squat)	CMJ and 20m sprint	After a standardized warm-up, baseline testing of CMJ and 20m sprint was collected. After baseline testing, subjects completed PAP intervention. Post-test were measure on 20s, 4, 8, 12, 16, and 20 minutes after the intervention.	0-20m at the 4,8,12,16 and 20 minutes showed significantly faster compared to baseline and 20s time point. Pairwise comparison for time revealed significantly greater Main effect for time but no main effect for condition or intervention on CMJ.

Reference	Sample	PAP Intervention	Type of testing	Protocol	Results
McBride et al. (2005)	15 Division III football players	Heavy load squat protocol (HS) : 1 set of 3 reps at 90% of 1RM. Loaded countermovement jump protocol (LCMJ) : 1 set of 3 reps at 30% of 1RM.	40-m dash with time measured at 10, 30 and 40m split time.	After a 5 min cycle ride, subjects performed either one protocol (HS,LCMJ or control). After 4 minutes post-warm-up, subjects completed for the 40-m dash.	After HS protocol, subjects ran faster in the 40-m dash in comparison to control protocol. No significant difference were observed in the 10-m and 30-m split times between the 3 conditions.
Baker (2003)	16 rugby league players	6 repetition of bench presses with a resistance of 65% of 1RM	Explosive Bench Press throw power output	Warm-up perform 5 reps of both bench press and bench press throw exercise with resistance of 60 and 40kg. After a 4-minute rest, pretest is measured. After 3 more minute rest, control group performed for post-test, while the experimental group perform the PAP intervention and after that measure for post-test.	No differences were observed between the group in power output, however, at the post-test, significant differences was observed between the groups, showing the experimental group show a greater increase in the power output recorded.
Drury and Twist. (2014)	12 amateur rugby players	105% of concentric 3 repetition maximum (HEL 105%), 110% of concentric 3 repetition maximum (HEL 110%), no pre-conditioning (PC).	Ballistic Bench Press Throw (BBPT) peak power output (PPO)	Follow a warm-up, participants given a passive rest period of 5 minutes before perform their pre-BBPT. After completed the pre-BBPT, a 10 minutes rest was given before performed a (either HEL105%, HEL110% or PC) to induce PAP. After the intervention,participants given rest for 8 minutes, then proceed to post-BBPT measure.	Significant decrease in PPO in the PC whilst increase in PPO from baseline in both the HEL 105% and HEL 110%. Baseline PPO was similar between all the Pre-BBPT conditions.

Reference	Sample	PAP Intervention	Type of testing	Protocol	Results
Baker (2003)	16 rugby league players	6 repetition of bench presses with a resistance of 65% of 1RM	Explosive Bench Press throw power output	Warm-up perform 5 reps of both bench press and bench press throw exercise with resistance of 60 and 40kg. After a 4-minute rest, pretest is measured. After 3 more minute rest, control group performed for post-test, while the experimental group perform the PAP intervention and after that measure for post-test.	No differences were observed between the group in power output, however, at the post-test, significant differences was observed between the groups, showing the experimental group show a greater increase in the power output recorded.
Chiu et al. (2003)	7 athletic (AT) and 17 recreational trained individuals (RT)	5 sets of 1 reps at 90% 1RM in the parallel back squat with 2 minutes rest between sets.	Rebound jump squat (RJS) and concentric-only jump squats (CJS) performed with 30%, 50% and 70% 1RM at 1 minute intervals.	The first post-test were performed 5 minutes following the warm-up and the second will be 18.5 minutes following the warm-up	No significant interactions were found for CJS at all loads. For RJS, significant interactions were seen for average force. (AF), average power (AP), and peak power (PP) at 30% loads. Average force for RJS at 70% load was also significant. AT showed significant difference with RT for CJS at 30% and 50% loads, and RJS at 30% loads. During experimental warm-up condition, AF, AP, PP were significantly greater at 18.5 minutes compare to 5 minutes.

In conclusion, the application of PAP strategies is a well-documented and effective approach for enhancing athletic performance across various sports disciplines. Research consistently demonstrates that PAP, whether induced through heavy loading, ballistic movements, or plyometric exercises, can significantly improve outcomes such as vertical jump height and sprint speed. The key to maximizing the benefits of PAP is understanding the balance between potentiating exercises and the potential for fatigue, which is influenced by the intensity of the activity and individual recovery capacities. Tailoring the recovery periods and intensity of the warmup exercises can help maximize the benefits of PAP while minimizing the risk of fatigue induced by the pre-stimulus. Importantly, the selection of PAP protocols should be tailored to an athlete's specific needs, training history, and physiological characteristics, highlighting the necessity of a personalized approach in sports training regimens.

2.5 Effects of eccentric exercise on athletic performance

Eccentric muscle actions not only actively generate force as the muscle lengthens under tension, but also absorb mechanical work and produce significant force at a lower metabolic cost than isometric and concentric muscle actions (Harris-Love et al., 2021). The eccentric action also favours specific neural patterns, requiring fewer motor units required to generate the same amount of force during a submaximal exercise (Enoka, 1996). This makes them an effective training method for athletes and a beneficial rehabilitation modality for clinical populations (Elmer et al., 2017; Harris-Love et al., 2021).

A study compared concentric-only, eccentric-only and concentric-eccentric resistance training for their effects on muscle strength and hypertrophy (Sato et al., 2022). The results showed that the concentric-eccentric and eccentric groups experienced an increase in maximum voluntary isometric torque, maximum eccentric contraction torque, maximum concentric torque, and muscle thickness. In contrast, the concentric-only group showed a significant increase only in maximum concentric torque. This indicates that eccentric contractions provided a greater stimulus for muscle strength increases and muscle hypertrophy. In addition to the chronic benefits observed in studies like that of Sato et al. (2022), acute research by Beato et al. (2021) compared groups with and without flywheel implementation. Findings from this study showed that the group using the flywheel protocol showed significant improvements in jump height, peak power, impulse, and peak force during the countermovement jump (CMJ), as well as enhanced isokinetic strength in both the quadriceps and hamstrings. This further emphasizes the greater impact of eccentric exercises in enhancing various aspects of muscular performance.

Various training methods have been used to target as eccentric muscle actions, such as eccentric resistance training and flywheel devices. However, it is unclear if eccentric cycling could be effectively adapted for warm-up exercise. Eccentric cycling requires individuals to resist a motor-driven backward-moving pedal. Studies have shown that the metabolic and cardiorespiratory responses of eccentric cycling were lower than concentric cycling (Elmer et al., 2013; Elmer et al., 2017; Beaven et al., 2014). One study compared the physiological measure between concentric and eccentric arm cycling, and the results indicated that eccentric arm cycling resulted in lower respiratory exchange ratio, cardiac output, heart rate, ventilation and blood lactate concentrations compared to concentric arm cycling (Beaven et al., 2014). These findings were supported by Elmer et al. (2013), who found that eccentric arm cycling can be performed at a lower metabolic demand compared with concentric arm cycling. The Vo2 was similar between the concentric and eccentric arm cycling modalities, however, the power was almost three times greater during the eccentric arm cycling. These findings suggest that incorporating eccentric arm cycling into training programs is beneficial for exercising the upper body while minimizing metabolic and cardiorespiratory strain as well as perceived exertion. The reduction in metabolic and cardiorespiratory responses demonstrates the potential of eccentric arm cycling as a less strenuous yet effective form of exercise, suitable for both rehabilitation patients and general populations.

A study done by Elmer et al. (2017) found that after 7 weeks of eccentric arm cycling, participants in the eccentric arm group showed greater improvements in maximal upper body strength and power compared to the concentric arm cycling group. Notably, the eccentric arm cycling group also saw musculoskeletal benefits without an associated increase in peripheral or central arterial stiffness, suggesting that arterial function was not negatively affected. The above findings suggest that an eccentric cycling machine allows lower metabolic costs but higher force production capabilities.

Research on the chronic effect of eccentric cycling has found improvements in muscle strength and hypertrophy, functional capacity, leg explosive strength, aerobic/endurance capacity, absolute and relative anaerobic power output, muscle structure, and maximum cycling power in various populations (Sarkar et al., 2020; Leong et al., 2014; Barreto et al., 2023). However, the acute enhancement in performance of a single eccentric cycling session on sports performance has yet to be determined.

2.6 Conclusion

In conclusion, this review provided an overview of research findings on the effects of warm-ups on sports performance and the benefits of using eccentric cycling. Warm-up routines are crucial for improving ROM, force production and overall athletic readiness, reducing the risk of injury and optimising sports performance. To enhance performance effectively, warm-ups must be carefully prescribed to minimize fatigue. Eccentric cycling, as a form of eccentric overload exercise, demonstrates unique advantages by promoting higher force production at lower metabolic and cardiorespiratory costs. This makes it particularly beneficial not only for enhancing athletic performance but also for rehabilitation and injury prevention. However, there is a lack of research on the use of eccentric cycling as a part of a warm-up strategy. As research continues to evolve, incorporating eccentric cycling into warm-up protocols could offer athletes a competitive edge. Therefore, it is recommended that future research should continue to explore the nuances of these warm-up techniques to fully unlock their potential in athletic performance enhancement.

Chapter 3

Effects of an eccentric cycling as a part of warm-up protocol on athletic performance in recreationally active individuals

Abstract

Background: Warm-up is essential before any physical activity, as it prepares the body and can enhance sports performance. A proper warm-up increases muscle temperature, blood flow, and flexibility, which are crucial for athletic performance and injury prevention. However, it is important to balance the warm-up intensity to avoid fatigue, which can negatively impact performance. Eccentric cycling has been shown to be effective in various contexts, including rehabilitation and muscle strengthening. Despite its benefits, there is a lack of studies specifically examining its impact as a warm-up protocol on athletic performance metrics such as sprinting performance, standing long jump, shoulder internal and external rotation, sit-and-reach test, and 20-second hopping frequency. Such information could provide valuable insights for coaches and individuals to optimize their training routines and enhance overall athletic performance.

Aim: The aim of this research was to determine the effects of eccentric cycling as a part of a warm-up protocol on athletic performance, including sprinting performance, standing long jump, shoulder internal and external rotation, sit-and-reach flexibility and hopping frequency in recreationally active adults.

Methods: After a single familiarisation session, seventeen recreationally active individuals (age: 29.6 ± 4.2 years, height: 173.9 ± 10.6 cm, and weight: 72.4 ± 11 kg) participated in the study, which involved two testing days. Each participant was randomly assigned to either a traditional warm-up or a traditional warm-up plus eccentric cycling on a custom-made machine on the first day. On the second testing day, participants crossed over to the alternate condition, ensuring that all participants experienced both warm-up protocols on different days. The eccentric cycling protocol involved a 6-minute exercise targeting both the upper body (shoulder) and the lower body (glutes, hamstrings).

Each testing session began with a 5-minute jog followed by 10-minutes of joint mobility and dynamic stretches. Participants then followed their assigned protocol. The traditional warm-up group completed a standard warm-up routine followed by three 30-metre (m) sprints at 75%, 80%, and 85% of their maximal speed, with 30-seconds rests between each sprint. The eccentric group, after completing the traditional warm-up, performed an additional 6-minute eccentric cycling session (2 minutes each targeting the upper

body, glutes, and hamstrings), followed by the same three 30m sprints at 75%, 80%, and 85% of their maximal sprint, with 30-second rests between each sprint. After a 4-minute rest, both groups completed five tests in the following order: a 30m sprint time, standing long jump distance, shoulder internal and external range of motion, 20-second hopping frequency, and the sit-and-reach flexibility test.

Results: There were not significant differences between the protocols for sprint times, jump performance or sit-and-reach flexibility. Hopping frequency was significantly greater (+2.4 hops/second, $p = .048$) with the traditional protocol, and shoulder rotation was significantly greater (+3.0 degrees, $p = .005$) following the eccentric protocol. The sequence in which the warm-ups were performed had a large effect on shoulder rotation, but there was no significant interaction between the type of warm-up and the sequence in which they were performed.

Conclusion: Eccentric cycling as part of a warm-up demonstrated significant differences on select performance outcomes, particularly significant increases in shoulder rotation while also reducing hopping frequency. While it didn't significantly impact other performance metrics, such as sprint times, standing long jump distance, and sit-and-reach tests. This indicates that eccentric cycling could be beneficial to include as part of a warm-up for upper-body activities that involve shoulder rotation. More research is needed on the effects of upper-body eccentric cycling on physical performance in athletic populations.

3.1 Introduction

Preparing the body through a proper warm-up routine prior to physical activity has become a widely accepted and deeply ingrained practice among athletes and coaches across all levels and disciplines. This principle is grounded in a substantial body of scientific evidence highlighting the benefits of warm-up exercises on sports performance and injury prevention (Fradkin et al., 2010; McCrary et al., 2015; McGowan et al., 2015; Bishop, 2003; Marián et al., 2016; Martinopoulou et al., 2022; Ding et al., 2022). Warm-up activities prime the cardiovascular and musculoskeletal systems by gradually increasing muscle temperature, heart rate, and blood flow, facilitating more efficient oxygen delivery and enhancing muscle pliability and contractility (Bishop, 2003). The increased temperature also improves muscle elasticity, reducing the risk of muscular strains and injuries. Furthermore, warm-up exercises enhance coordination, proprioception, and reaction times, which are crucial for optimal athletic performance (Nicolini et al., 2021; Behm & Chaouachi, 2011; Kyranoudis et al., 2021). A well-structured warm-up typically includes activities such as light cardiovascular exercise, dynamic stretching, and drills specific to the upcoming event (Zentz et al., 1998; Bishop, 2003; Fradkin et al., 2010; Jeffreys, 2008). While an effective warm-up can enhance performance, it is important to recognize that an overly intense warm-up can lead to elevated fatigue levels, which may subsequently impair performance. Excessive warm-up activities can deplete energy reserves, elevate fatigue levels, and impair subsequent athletic performance which can detract from an athlete's ability to perform at their best during their main event (Tomaras & MacIntosh, 2011). Therefore, it is crucial to balance the intensity and duration of the warm-up to ensure that it prepares the body adequately without causing undue fatigue. In addition to these multifaceted benefits, warm-up routines have become integral to training programs and pre-competition rituals for athletes and coaches.

Eccentric cycling is a unique exercise requiring individuals resist the pedals moving backwards actively (Barreto et al., 2021). Research has shown various benefits, and one notable advantage is that eccentric cycling requires lower metabolic demand and cardiorespiratory responses compared to traditional concentric cycling, making it an efficient training modality that minimizes cardiovascular strain while maximizing muscular benefits (Elmer et al., 2013; Elmer et al., 2017; Beaven et al., 2014). This efficiency allows for higher power outputs at similar oxygen consumption levels, providing a greater stimulus for muscular adaptations (Elmer et al., 2013). Studies by Beaven et al. (2014) also found that compared with concentric cycling, eccentric cycling demonstrated a lower respiratory exchange ratio, cardiac output, heart rate and blood lactate concentrations. These characteristics suggest that eccentric cycling could be particularly beneficial as part of a warm-up protocol. Its lower metabolic and cardiovascular demands may allow athletes to prepare their muscles for greater absolute loads in subsequent performance without inducing significant fatigue.

Sprinting and horizontal jumping are crucial components of athletic performance, as they contribute to an athlete's overall speed, power and explosiveness. Numerous studies have investigated the relationships between these two physical abilities and their impact on various sports (Farley et al., 2024; Soyal et al., 2023; Loturco et al., 2018)). Sprinting is an explosive activity requiring maximal power to run over a short distance. Sprint ability is a key factor in outperforming opponents to win a race or gain an advantageous position in various sports contexts; for example, 100m, and 200m sprints in track and field, and field-based team sports such as American football, soccer, hockey, and rugby (Suchomel et al., 2016). According to studies by Spencer et al. (2005), the mean distance and duration of sprints during soccer were between 10-30m and 2-3 seconds.

Horizontal jumping, such as the standing long jump, is an important measure of lower body power and explosiveness (Meylan et al., 2010). It evaluates an athlete's ability to generate force rapidly and transfer it horizontally. This ability is crucial for various sports, particularly those requiring explosive power, such as basketball, volleyball, and track and field events. Both the 30m sprint distances and horizontal jumping are particularly useful metrics in assessing sport-specific sprint performance.

In addition to sprinting and horizontal jumping, internal and external rotation of the shoulder also plays an important role during athletic performance. Shoulder movement is a crucial component in various athletic activities, particularly those involving overhead motions such as swimming, baseball, cricket, handball, javelin, tennis and volleyball (Oliver et al., 2020). The interplay between shoulder internal and external rotation can significantly influence an athlete's performance and risk of injury (Spratford et al., 2020; Terry & Chopp, 2000; van Den Tillaar & Ettema, 2007). Research suggests that the shoulder internal rotation plays an important role in throwing performance, such as generating the high racket or bat speeds observed in sports like tennis and baseball (van Den Tillaar & Ettema, 2007). This rotational and extension capability enables athletes to produce powerful, high-speed movements that are critical for success in these sports. Effective internal rotation provides the necessary force during the acceleration phase of throwing, while external rotation during the cocking phase allows for the storage of elastic energy, contributing to a more powerful release (Herrington, 1998; Slovák et al., 2023; Wagner et al., 2011). Proper balance and strength between these rotations are crucial for optimizing performance and preventing injuries (Clarsen et al., 2014; Hellem et al., 2019; Nodehi-Moghadam et al., 2013).

Muscle-tendon stiffness plays a crucial role in storing and releasing elastic energy during stretch-shortening cycle activities, which is a factor that potentially influences sports performance (Dalleau et al., 2004; Pearson & McMahon, 2012). Hopping tasks are widely recognized as a method for determining vertical stiffness, offering a representation of the simple spring-mass model in action (Farley et al., 1991). Studies have demonstrated that hopping test can differentiate between athletic groups and are associated with athletic performance (Hobara et al., 2008; Hobara et al., 2010). Addiditonally, research indicated that leg stiffness increase with hopping frequency (Hobara et al., 2013), suggesting that varying hopping frequencies can assess an individuals ability to modulate lower limb mechanics. Hence, a 20-second hopping test was employes to test the lower-limb stiffness.

Given the multifaceted benefits of warm-up routines and the unique characteristics of eccentric cycling, the integration of eccentric cycling as a part of a warm-up modality may offer a promising strategy for enhancing athletic performance. Eccentric cycling has been shown to elicit lower cardiovascular, metabolic, and perceptual strains compared to concentric cycling, while still providing a significant muscular stimulus (Elmer et al., 2013; Elmer et al., 2017; Beaven et al., 2014). This lower physiological demand allows athletes to prepare their muscles for subsequent activity without inducing excessive fatigue. To date, no study has directly investigated the warm-up effects of eccentric cycling on sprinting performance in recreationally active individuals. Therefore, the primary aim of this research is to investigate the effect of eccentric cycling on sprinting performance, standing long jump, shoulder internal and external rotation, sit-and-reach flexibility, and 20-second hopping, when integrated as part of a warm-up protocol. By examining these various performance metrics, this research seeks to provide coaches and individuals with a comprehensive understanding of how eccentric cycling as part of a warm-up influences athletic performance.

3.2 Methods

3.2.1 Study Design

This was a cross-sectional study that aimed to investigate the effects of eccentric cycling as a part of a warm-up protocol on various performance metrics in recreationally active individuals. A randomized cross-over study design (Figure 2) was utilized, where participants completed two separate testing sessions, each involving a different warm-up protocol. In one session, participants performed a traditional warm-up plus eccentric cycling (intervention), while in the other session, they only performed the traditional warm-up (control). After each warm-up protocol, participants rested for 4 minutes before undergoing a series of performance tests. The dependent variables including sprinting performance, standing long jump, shoulder internal and external rotation, 20-second hopping, and sit and reach test were examined immediately after each warm-up. The protocol for the eccentric cycling intervention was a 6-minute training session with the eccentric cycling machine, targeting the arms, hamstrings, and glutes (see Figure 3, Figure 4 and Figure 5).

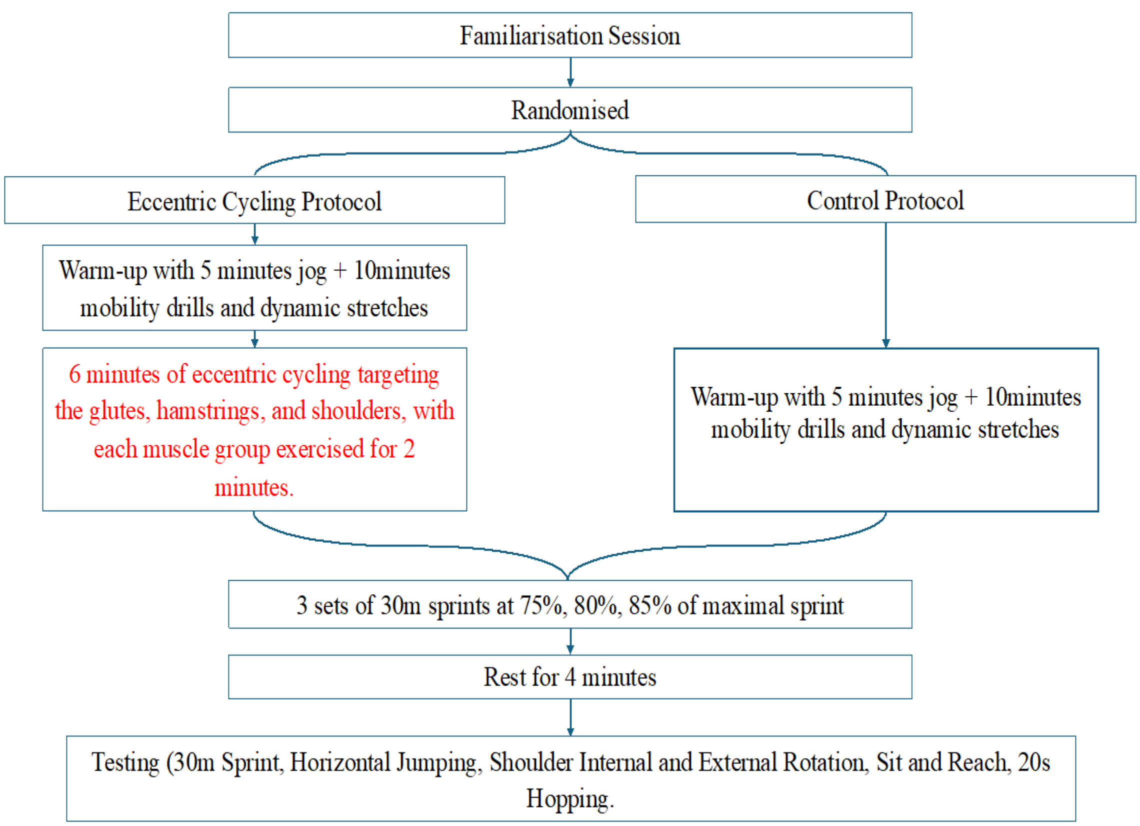


Figure 2. Experimental Design Scheme

3.2.2 Participants

Seventeen participants volunteered to participate in this study (age: 29.6 ± 4.2 years, height: 173.9 ± 10.6 cm, and weight: 72.4 ± 11 kg). Before testing, the study procedures and risks were explained verbally, and written informed consent was obtained from all participants. The inclusion criteria for the study were individuals who had to be aged 18-35 and engaged in recreational physical activity, injury-free for the past six months, and participating in recreational active training at least twice a week. Participants were excluded if they had a current injury or a history of orthopaedic or arthritic conditions affecting their back, knee, foot, or ankle joints.

3.2.3 Ethics Statement

Ethical approval for this research was granted by the Auckland University of Technology Ethics Committee (AUTEC: 23/259), granted 7 Dec 2023.

3.2.4 Procedures

Each participant underwent a single familiarisation session to become acquainted with the eccentric cycling machine. The study was conducted over two testing days, during which the allocation of warm-up protocols (either the control protocol or the eccentric cycling protocol) was randomly determined. Randomization was carried out using an online randomization tool (www. randomizer.org). The intervention protocols were conducted on a custom-made eccentric cycling machine. The eccentric cycling device features a sturdy metal base, which provides a solid foundation. Attached to this base is a motor connected to the pedals. The underside of the base is equipped with spikes, ensuring stability and preventing any unwanted movement during use. The cadence for the eccentric cycling was set at 30 revolutions per minute (rpm) for all positions. The motor drives the pedals in a backward direction, requiring participants to actively resist the pedal movement to achieve the desired eccentric effect. The testing procedure started with a 5-minute slow jog, followed by 10-minutes of joint mobility and dynamic stretches. These mobility drills included shoulder rotations, hip exterior/interior rotations, hip flexion/extension, hip abduction/adduction, pelvic rotations, knee rotations, ankle rotations, lunges, and 30-seconds of body-weight squats.

3.2.4.1 Eccentric Cycling Protocol

After the warm-up, participants proceeded differently based on their assigned protocol for that day. Participants scheduled to undergo the eccentric cycling protocol engaged in a 6-minute training session on the eccentric cycling machine, targeting the arms (2-minutes) as shown in Figure 3, glutes (2-minutes) as shown in Figure 4, and hamstrings (2-minutes) as shown in Figure 5, with a 30-second rest between each exercise. The eccentric cycling cadence was set at 30 revolutions per minute (rpm) for all positions.

For the arms eccentric cycling exercise, participants were required to resist the pedals of the machine while maintaining a high plank position. If maintaining the high plank position became too challenging, they were allowed to modify to a kneeling position, as shown in Figure 3, to complete the 2-minute arms movement.

Figure 3. Eccentric cycling arms position. The subject is required to resist the pedals in an anti-clockwise motion while maintaining this posture.

For the glute eccentric cycling exercise, participants were required to maintain a glute bridge position as shown in Figure 4. Throughout this movement, participants had to keep their hips elevated, ensuring they remained in the glute bridge position the entire time without letting their hips drop.

Figure 4. Eccentric cycling glutes position. The subject is required to resist the pedals in an anti-clockwise motion while maintaining this posture.

For the hamstring eccentric cycling exercise, participants were required to perform a hamstring bridge as shown in Figure 5. Unlike the glute bridge, this exercise required participants to lie with their hips further away from the machine, extending their legs more and lifting their hips to engage the hamstrings. Throughout the movement, participants needed to maintain this extended position to effectively target the hamstrings.

Figure 5. Eccentric cycling hamstring position. The subject is required to resist the pedals in an anti-clockwise motion while maintaining this posture.

Encouragement was provided throughout the entire session. Subsequently, they performed three sets of 30m running at 75%, 80%, and 85% of maximal sprinting velocity with 30-second rests between each sprint. Following this, they rested for 4-minutes before proceeding to the testing phase. Participants not assigned to the eccentric cycling protocol proceeded directly to three sets of maximal sprints after the warm-up and dynamic stretches. Following the sprints, they had a 4-minute rest period before proceeding to the testing phase. Each participant completed the other protocol on a separate testing day.

3.2.4.2 Performance Tests

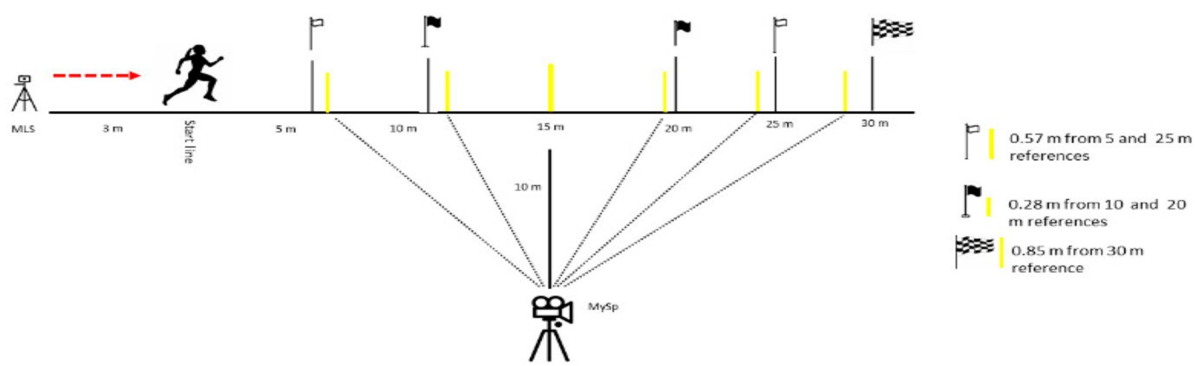
Upon completion of the rest period, both groups underwent five tests, in the following order: 30m maximal sprint, standing long jump, shoulder internal and external rotation, sit-and-reach test and 20-second hopping.

30m Sprint

The 30m test was recorded using an iPhone (13 Pro Max) and the My Sprint App (Figure 6). My Sprint App system utilizes high-speed analysis at 240 frames per second and has been proven to be a reliable and valid method for assessing linear sprint performance. It has shown consistency and accuracy when compared to other reference systems such as timing photocells and radar gun (Romero-Franco et al., 2017). A flat and straight running surface was used, with a 30m distance marked out using markers. Participants were instructed to avoid any backward movement before the start. Once participants indicated they were ready, the researcher started the video recording and then counted down "3, 2, 1," at which point the participants began their sprint from a stationary start, continuing until they crossed the 30m finish line. Verbal encouragement was provided to all participants to ensure they sprinted through the entire 30m distance.

Figure 6.

Experimental setup of the testing sessions for the validation of the MusclelabTM Laser Speed Speed and MySprint app. The yellow lines represent the marking poles as part of the, Mysprint set



Note. 30-meter sprint time analyzed by using the My Sprint App setup. From " Level of Agreement, Reliability, and Minimal Detectable Change of the Musclelab^{TM} Laser Speed Device on Force-Velocity-Power Sprint Profiles in Division II Collegiate Athletes," by Ghigiarelli et al., 2022, *Sports (Basel, Switzerland)*, *10*(4), 57.

Standing Long Jump

Participants began from a standing position, swinging their arms and bending their knees to provide maximum forward drive. A take-off line was marked on the ground, followed by the forward jump. The jump length was measured using a metric tape measure from the take-off line to the nearest point of landing contact (i.e., the back of the heels). Each participant had two attempts.

Shoulder rotation

Participants stood with their back against a wall, ensuring their upper back, head, and hips were all in contact with the wall. For the internal rotation test, participants started in a 90-degree "L" position and rotated their hands as far toward the ground as possible without allowing their scapula to lift off the wall (Figure 7). For the external rotation test, participants stood against the wall with the same contact points as in the internal rotation test and then rotated their hands toward the wall (Figure 8). A goniometer was used to measure the internal and external rotation for each test. For these measurements, the goniometer was positioned with the fulcrum placed at the olecranon. The stationary arm was aligned vertically, while the movable arm was placed along the forearm, using the styloid process of the ulna as a reference point (Cools et al., 2014).

Figure 7. Shoulder Internal Rotation Assessment

Figure 8. Shoulder External Rotation Assessment

Sit and reach test

Participants were required to remove their shoes and sit on the floor with their legs extended and their feet placed flat against the sit-and-reach box. With hands placed one over the other and palms facing downwards, participants slowly reached forward as far as possible. Participants held this position for a 3-seconds and the distance reached was measured in centimetres.

Hopping test

Participants were instructed to hop naturally with both legs for 20 seconds, ensuring consistency in their hopping rather than focusing on achieving maximum height or speed. Their hands were placed on their hips to maintain balance and proper form throughout the test. The total number of hops was recorded during the 20 seconds.

3.2.5 Data Analysis and Statistics

Statistical analyses were performed using the R language and environment for statistical computing (R Development Core Team, 2010). Notably, we used *tidyverse* (Wickham et al., 2019) for data treatment, *lmerTest* (Kuznetsova et al., 2017) for fitting models, *ggeffects* (Lüdecke, 2018) to estimate marginal means, and the *easystats* (Lüdecke et al., 2022) framework (e.g., *performance*, *parameters*, and *effect size*).

Descriptive statistics (mean ± 95% CI) were calculated for all dependent variables extracted from the testing sessions. To address our research question and determine the acute effects of an eccentric warm-up compared with a traditional warm-up on athletic performance, a variety of linear mixed effects models were used. Separate models were developed for sprint times, horizontal jump distance, hopping frequency, shoulder range of motion, and sit and reach. Each model included group (i.e. eccentric and traditional warm-up) with individual participants as random effects. Note that for the model including shoulder range of motion, data from both limbs, and internal and external rotation was all included within the model to increase the number of data points, and due to a lack of clear a-priori hypotheses regarding the directional (or unilateral) effects of the stimulus.

Firstly, during initial data screening an outlier was detected for one participant's measurement of external rotation for the right limb. This value was considerably lower than the rest of the cohort, and the participant's own, and was subsequently removed as a recording error. This decision was bolstered by sensitivity analysis, which showed the subsequent model was substantially a better fit with this point removed ($p = .001$, Akaike information criterion (AIC)= 826.8 vs 803.9, RMSE= 4.529 vs 4.316, for with and without the outlier, respectively). The sequence of treatment (eccentric-traditional conditions, and traditional-eccentric) was added into models, including the interaction between group and sequence. Models were then checked against the raw model (i.e., excluding sequence) for the practical and statistically significant influence of the addition of sequence (e.g., interpreting change in AIC, RMSE, significant contribution within the model, and influence on coefficients). Except for range of motion, sequence was determined to not influence the outcome nor the effect of the condition and excluded. For range of motion, sequence and its interaction with group was retained for further analysis. Before interpretation, model assumptions were tested, with minor violations observed for normality and homogeneity of variance when observing diagnostic plots. Subsequently, the raw models were compared to both robust fits (using *rlmer* from *robustlmm* (Koller, 2016) and when log transforming the dependent. The impact of these violations was judged negligible, and we progressed with the original models. Nonetheless, this should be considered when interpreting the model outcomes.

Raw coefficients with confidence intervals were interpreted from each model. Subsequently, an ANOVA was performed on each model, reporting the F statistic, p-values, and partial omega squared (ω_p^2) values to estimate effect size. The magnitude of the effect was interpreted using the following thresholds: very small ($\omega_p^2 < .01$), small ($\omega_p^2 = .01\text{-}.059$), medium ($\omega_p^2 = .06\text{-}.13$), or large ($\omega_p^2 > .14$). Significance for all tests was set at alpha = .05.

3.3 Results

The results of the study comparing the eccentric protocol and the control protocol are presented in Table 3. For shoulder rotation, the eccentric warm-up group had significantly higher mean shoulder rotation (3.0 degrees) compared to the traditional warm-up group, with F = 7.94, p = .005, and ω_p^2 = .006, indicating a small effect size. The sequence of the warm-ups also had a significant impact on shoulder rotation, with F = 18.65, p = .001, and a large effect size ω_p^2 = .051. The interaction between group and sequence did not have a significant effect on shoulder rotation, as results indicated by F = 1.2, p = .271. Additionally, a greater hopping frequency (2.4 hops/second) was observed with the traditional protocol. A significant difference was observed for the hopping frequency, with the results indicating F = 4.6, p = .048, and a large effect size ω_p^2 = .17.

There were no significant differences observed for the other performance metrics, including the standing long jump, 30-m sprint times, and the sit and reach test.

Table 2

Descriptive statistics for eccentric protocol and control protocol.

Variables	Eccentric Protocol	Control Protocol
Sprint Time (s)	5.66 ± 1.04	5.54 ± 1.06
Standing Long Jump (cm)	187.74 ± 45.69	185.76 ± 42.82
Shoulder Internal Rotation (Left)	86.98 ± 4.44	84.74 ± 4.26
Shoulder Internal Rotation (Right)	88.23 ± 3.56	85.66 ± 5.19
Shoulder External Rotation (Left)	82.71 ± 6.72	81.58 ± 5.26
Shoulder External Rotation (Right)	84.34 ± 5.07	82.55 ± 6.20
Sit and Reach (cm)	31.63 ± 10.05	32.34 ± 9.27
Hopping	45.41 ± 4.15	47.82 ± 5.56

Table 3

Comparison of performance metrics between eccentric cycling protocol and control protocol

	Analysis of Variance											
	Group				Sequence				Group x Sequence			
	F	p	ω_p^2		F	p	ω_p^2		F	p	ω_p^2	
Shoulder Rotation (º)	7.94	**.005**	**.006**	***Small***	18.65	**.001**	**.051**	***Large***	1.2	.271	.000	Very Small
Standing Long Jump (cm)	0.33	0.571	0.00	Small								
30m sprint Times (s)	2.66	0.123	0.08	Medium								
Hopping (Hops/second)	4.6	**0.048**	**0.17**	***Large***								
Sit and Reach (cm)	0.96	0.342	0.00	Very Small								

Mean, $\bar{x}$; 95% confidence intervals, 95% CI; partial omega squared (ω_p^2);. Because there were no significant differences for sequence in any of the models, except for the shoulder rotation, sequence and group x sequence was excluded for all other dependent variables.

3.4 Discussion

An effective warm-up can enhance athletic performance and reduce the risk of injury (Bishop, 2003; Rumeau et al., 2023; Seitz & Haff, 2016; McGowan et al., 2015). This cross-sectional study examined the effects of eccentric cycling as a part of the warm-up protocol on several athletic performance metrics, including sprinting performance, standing long jump, hopping frequency, shoulder internal and external rotation, and the sit-and-reach test. The major finding of this study was that recreationally active individuals showed improved shoulder rotation after the eccentric cycling protocol compared to the control protocol. Additionally, the hopping frequency was better following the control protocol than after the eccentric cycling protocol. For sprinting performance, horizontal jumping, and the sit and reach flexibility test, there were no significant differences between the eccentric cycling and control protocols.

For sprint and standing long jump performance metrics, eccentric cycling as a part of the warm-up protocol showed no significant effect in comparison with a traditional warm-up. A possible reason why the eccentric cycling warm-up did not improve sprint and standing long jump performance may be due to the unique physiological and mechanical characteristics of both measures. Successful sprint and standing long jump performance requires a high RFD and efficient use of the SSC, with the ability to produce high RFD over brief contact times (Walker, 2024; Taber et al., 2016; Slawinski et al., 2010). Eccentric cycling primarily emphasizes the lengthening phase of muscle contractions; hence, it appears that it does not closely mimic the concentric-dominated actions of sprinting and jumping (Aagaard et al., 2002). This is also in line with the findings from Stasinaki et al. (2019), which showed significant increases in RFD and fascicle length in the fast eccentric training group. Based on these results, they suggested that fast eccentric resistance training might be more effective for increasing rapid force production compared to slow eccentric resistance training. In contrast, in this study, the eccentric cycling protocol was performed at a constant velocity of 30 rpm, which appears to limit its effectiveness for rapid force production. While eccentric training methods offer valuable stimuli for enhancing hypertrophy, strength, and power, it is important to note that eccentric training methods are particularly suitable for individuals with higher training age and experience (Suchomel et al., 2019). Eccentric exercise induces muscle damage that leads to substantial and long-lasting changes in motor unit (MU) activity, including lower MU recruitment thresholds, an increase in MU discharge rates, a reduction in MU conduction velocities, and an increase in MU synchronization (Semmler, 2014). These changes negatively impact sprint and jump performance, as they impair the rapid and powerful contractions needed for these activities. Therefore, these neuromuscular alterations might explain why eccentric cycling as a warm-up protocol did not enhance sprint and jump performance in this study.

Linnamo et al. (2003) found differences between isometric, concentric, and eccentric actions in MU activation patterns. Their findings conclude that MU recruitment thresholds may be lower during eccentric actions compared to isometric actions. Additionally, they observed that during the isometric preactivation phase and subsequent concentric action, the mean spike amplitude increased significantly up to 80% of maximal voluntary contraction, supporting the recruitment of bigger and faster MU at high force levels. In contrast, during eccentric conditions, the mean spike amplitude increased only up to 60% MVC, suggesting full recruitment of MU at a relatively lower force level. Instead, in eccentric actions, the mean spike frequency continued to increase even after 60% MVC, whereas in isometric and concentric conditions, the mean spike frequency increased only up to 40% MVC. These findings suggest that eccentric actions rely more on increasing the firing rate of already active motor units rather than recruiting additional motor units, which may not be optimal for activities requiring rapid and powerful contractions. Therefore, the neuromuscular alterations induced by eccentric cycling at a constant velocity of 30 rpm might explain why the eccentric cycling warm-up protocol did not enhance sprint and jump performance in this study. Thus, eccentric cycling is not suitable as part of a warm-up protocol for recreationally active individuals seeking acute improvements in sprint and jump ability; however, elite and intermediate-level individuals still need to be explored.

With regards to the shoulder rotation, the study revealed a significant acute increase following the eccentric cycling warm-up compared to the traditional warm-up (3.0 degrees). This acute improvement in flexibility is notable, as most studies on range of motion (ROM) increase focus on chronic adaptations rather than immediate effects. Additionally, there was a significant difference on the sequence, but no significant difference between the type of warm-up and the sequence in which they were performed. This suggests that the improvements in shoulder rotation were primarily due to the eccentric warm-up itself and not influenced by the order of the protocols.

This improvement in shoulder ROM observed in our study aligns with the findings from Aune et al., (2019), who reported an acute improvement in dorsiflexion ROM following an eccentric exercise protocol, demonstrated that eccentric exercise could lead to acute enhancement in flexibility. However, our findings contrast with Oyama et al. (2011), who reported an immediate decrease in internal and external rotation ROM following a high volume protocol consisting of 9 sets of 25 repetitions, specidically designed to induce muscle damage, which differs from our approach. This discrepancy may be attributed to differences in the specific eccentric exercises performed, the intensity and duration of the protocols, or the populations studied. The immediate increase in shoulder ROM observed in this study may be due to alterations in the viscoelastic properties of the muscle-tendon unit, such as reduced passive stiffness and increased compliance (Taylor et al., 1990; Magnusson et al., 1996). These changes could facilitate greater movement amplitude and reduce resistance during stretching, thereby contributing to the observed improvement in flexibility. While Kawama et al., (2022) focused on passive muscle stiffness, their findings still provide valuable insight into understanding changes in active ROM. They suggested that eccentric resistance that performs at a wide ROM, long muscle length, and long duration with a low to moderate load/volume is the key program for acutely decreasing passive muscle stiffness. Although our study measured active ROM rather than passive stiffness, the underlying mechanisms influencing both measures may be related. The low intensity of our eccentric cycling protocol (30rpm for 2-minute) aligns with the recommendations by Kawama et al., (2022), potentially explaining the observed acute improvement in shoulder ROM. Typically, adaptations in muscle architecture and joint mobility are observed in chronic studies, often spanning several weeks or months (Peviani et al., 2018). For instance, Peviani et al. (2018) reported that sarcomerogenesis, a key mechanism in improving range of motion, was only observed after 15 days of stretching in rat soleus muscles. These findings suggest that significant changes in flexibility and muscle structure generally require prolonged periods of consistent training or stretching. Similarly, several researchers have demonstrated that eccentric exercise can improve flexibility and ROM over longer period (Aune et al., 2019; Vetter et al., 2022; Potier et al., 2009; Nelson & Bandy, 2004; O'Sullivan et al., 2012; Diong et al., 2022). However, most of these studies are chronic in nature and use different methodologies compared to our methodologies. Since this is the first study examining the acute effects of eccentric cycling on shoulder flexibility, a notably unique movement, further research is needed to validate these findings, explore whether similar rapid adaptations can be consistently achieved, and understand the specific processes that contribute to these acute changes in muscle function and flexibility.

The 3.0 degrees improvement in shoulder ROM observed in this study for athletes is noteworthy, especially for overhead throwing athletes. Optimal shoulder flexibility is crucial for movements such as spiking in volleyball, serving in tennis, throwing in javelin, and pitching in baseball (Slovák et al., 2024; Herrington., 1998; Cohen et al., 1994; Fortenbaugh et al., 2009). These movements all involve a critical cocking phase, where the shoulder reaches maximum external rotation, followed by a rapid acceleration phase with internal rotation (Escamilla & Andrews, 2009). Enhanced ROM can potentially improve performance in both the cocking phase and the acceleration phase, allowing for greater power generation during the cocking phase and more efficient energy transfer during acceleration (Whiteley, 2007; Escamilla & Andrews, 2009). While increased shoulder external rotation can enhance ball velocity (Matsuo et al., 2001), it also poses a higher risk of shoulder internal impingement (Whiteley, 2007).

It's important to note that while this 3.0 degree improvement is promising, it should be considered in the context of individual athlete needs and sport-specific demands. Future studies could explore the long-term and cumulative effects of such acute improvements and investigate whether this enhancement in ROM directly translates to improved performance metrics in specific sports. For instance, researchers could examine whether the increased ROM leads to faster serve speeds in tennis or improved pitch velocity in baseball. Simultaneously, it would be crucial to monitor for any potential increases in injury risk associated with these performance gains.

Muscle-tendon stiffness plays a crucial role in storing and releasing elastic energy during stretch-shortening cycle activities, which is a factor that potentially influences sports performance (Dalleau et al., 2004; Pearson & McMahon, 2012). Several studies have examined the relationship between lower limb stiffness and sports performance in activities such as sprinting, endurance running, and jumping（Li et al., 2021; Pearson & McMahon., 2012; Krzysztofik et al., 2023; Hoppeler H., 2016; Douglas et al., 2017; Chelly & Denis., 2001). Research has indicated that hopping frequency also affects lower limb stiffness, with both ankle and knee stiffness being important for optimal performance (Blickhan, 1989; Farley et al., 1991; Hobara et al., 2010). Ankle stiffness is particularly crucial for high frequency hopping, while knee stiffness is more related to frequency hopping with a greater ground contact time (McMahon et al., 2012; Farley et al., 1991; Hobara et al., 2011). To date, there is no study investigating the effects of eccentric cycling as a part of warm-up on lower limb stiffness. Thus, a 20-second hopping test was conducted to investigate the effects of eccentric cycling as a part of warm-up on lower-limb stiffness. It was hypothesised that if the eccentric cycling protocol enhanced muscle function, an improvement in hopping performance would be observed due to more efficient utilization of recoil energy (Lindstedt et al., 2001). Contrary to expectations, our findings revealed a significant decrease in hopping frequency compared to the traditional warm-up. This aligns with Morrissey et al. (2011), who found a significant decrease in achilles tendon stiffness (ATS) in the eccentric training group, with no change observed in the concentric group. Similarly, Krzyztofik et al. (2023) investigated the acute effects of varied back squat activation on muscle-tendon stiffness and jumping performance, finding that ATS significantly decreased after the conditioning activity across all conditions. Moir et al. (2009) examined the acute effects of heavy back squats on mechanical variables during a series of bilateral hops and found no significant difference in vertical stiffness, although some individuals showed acute stimulus increases. These findings collectively suggest that both eccentric and certain concentric exercises can lead to temporary reductions in tendon stiffness.

According to Farley et al. (1991), humans typically select a hopping or running frequency that minimizes the metabolic cost of operating their muscle-tendon springs. This suggests that any disruption in the efficiency of these springs, such as through fatigue or suboptimal conditioning, could lead to changes in movement patterns aimed at conserving energy. In a fatigued state, the efficiency of these springs may be compromised, prompting a decrease in hopping frequency to conserve energy. During hopping, when the elastic energy is dissipated, the muscles must add enough energy to compensate for the loss (Farley et al., 1991). In a fatigued state, the muscles may not efficiently add this energy, leading the body to select a lower frequency to reduce metabolic costs and manage energy loss more effectively. In our study, participants were able to choose their preferred hopping frequency, which might reflect their body's attempt to optimize energy efficiency under the given conditions. Additionally, according to Kubo et al. (2020), active muscle stiffness in sprinters was significantly higher than in untrained men, although no significant difference was observed in tendon stiffness between the two groups. This suggests that while trained individuals may have greater muscle stiffness, their tendon stiffness does not necessarily differ from untrained individuals. In the context of our study, this implies that recreational active individuals, who may naturally have lower muscle stiffness, could experience greater metabolic costs during activities like hopping. Their muscles may not be as efficient in storing and releasing elastic energy, particularly when fatigued, leading to adjustments in movement patterns to conserve energy. Based on Kubo & Ikebukuro (2019), a decline in joint stiffness after repeated hopping exercises is primarily due to changes in active muscle stiffness rather than alterations in tendon properties or neuromuscular activities. Therefore, this suggests that the observed decrease in hopping frequency following the eccentric cycling protocol could be influenced by changes in muscle stiffness.

Moreover, findings by Michaut et al. (2001) found a temporary increase in series elastic component (SEC) compliances after the eccentric exercise. The SEC stiffness and the number of attached actomyosin cross-bridges are closely linked, and it could be hypothesised that the increased SEC compliance associated with the decreased force was due to the reduction in the number of attached cross-bridges (Michaut et al. 2001).

The compliance value increased when the force values decreased, which could impair the muscle's ability to effectively store and release elastic energy, hence leading to reduced force production and performance. In this regard, it shows that eccentric cycling might induce fatigue more than performance enhancement in recreationally active individuals. While this form of exercise can be beneficial for certain adaptations, its impact on muscle-tendon efficiency and overall energy expenditure should be carefully evaluated.

3.5 Conclusion

The main findings of this study were that incorporating eccentric cycling into a warm-up protocol significantly reduces hopping frequency and increases shoulder rotation. However, contrary to the expectations, this warm-up protocol did not yield significant differences in metrics such as sprint performance, standing long jump distance, and sit-and-reach test. This thesis found that, except for hopping frequency and shoulder rotation, the eccentric cycling warm-up protocol had limited enhancement in recreationally active individuals. However, there were no significant decreases in athletic performance with the eccentric protocol, with the exception of hopping frequency. This is also the first known study using eccentric cycling as a part of a warm-up protocol in the current population, with the findings indicating some promise for providing further insights into its applications and effectiveness.

Chapter 4

Summary, practical applications and future research

4.1 Summary

The purpose of this thesis was to review the literature on the benefits of warm-ups for sports performance and the effects of eccentric cycling on athletic performance. Chapter 2 found that performing warm-ups before any physical activity can enhance performance and reduce the risk of injury. However, the warm-up must be appropriate for the individual's fitness level. If the warm-up is too intense, it may cause premature fatigue and reduce subsequent performance during the actual event. Conversely, if the warm-up is insufficient, it may lead to suboptimal performance and an increased risk of injury.

Eccentric cycling, as a form of eccentric overload exercise, demonstrates unique advantages by promoting higher force production at lower metabolic and cardiorespiratory costs. These benefits make eccentric cycling particularly effective for enhancing athletic performance while minimizing fatigue and strain on the cardiovascular system. Therefore, incorporating these advantages, eccentric cycling was selected when designing the methodology for Chapter 3.

To date, this is the first study to examine the acute effects of a single eccentric cycling session on sports performance among recreationally active individuals. Our findings indicate that while the eccentric cycling as a part of a warm-up protocol significantly improved shoulder rotation, the traditional warm-up protocol was more effective in enhancing hopping frequency. Additionally, there was a significant difference on the sequence, but no significant difference between the type of warm-up and the sequence in which they were performed. This suggests that the improvements in shoulder rotation were primarily due to the eccentric warm-up itself and not influenced by the order of the protocols.

Furthermore, the eccentric cycling protocol did not yield significant differences in other performance metrics, such as 30-meter sprint times, standing long jump, and sit-and-reach test. This indicates that while eccentric cycling has specific advantages, its overall effectiveness as a warm-up may vary depending on the specific activity and the individual's fitness level. Importantly, there were no significant decreases in athletic performance with the eccentric protocol, except for the observed difference in hopping frequency, where the traditional warm-up proved to be more beneficial.

4.2 Practical recommendations

This thesis found that an eccentric cycling protocol had limited warm-up effects on sprinting, horizontal jumping and flexibility in recreationally active individuals. However, it did show an acute decrease in hopping frequency and an increase in shoulder rotation. The long term effects remain to be investigated. From a training or competition warm-up perspective, individuals who require overhead movement can consider using this method to improve subsequent performance and possibly reduce the risk of injury.

4.3 Limitations and Future Research

Although this thesis provided some useful insights into the effects of eccentric cycling as a part of a warm-up protocol, some limitations need to be acknowledged. One limitation of this study is the small sample size and the participants' relatively low level of sports background. Participants were recreationally active individuals rather than semi-professional or professional athletes. This may limit the generalizability of the findings to highly trained or elite athletes. Future research should aim to include semi-professional or professional athletes. Another limitation is the lack of randomization in the eccentric cycling exercise protocol, i.e. they all started with the upper body, then the glutes, then the hamstrings. This may have led to fatigue in recreationally active individuals, potentially affecting their performance in the tests. Future studies should consider randomizing the sequence of exercises (e.g., glutes, shoulders, then hamstrings) to minimize fatigue. Although the study found no significant differences in most performance metrics. The significant improvement in shoulder rotation suggests a specific benefit that could be explored further. Future research could investigate the impact of eccentric cycling warm-up on shoulder rotation in athletes involved in overhead sports such as volleyball, baseball, cricket, tennis, badminton, swimming, water polo, and handball, where enhanced shoulder range of motion and force generation are critical for performance. Specifically, studies could examine whether the increased ROM translates to improved performance metrics, such as faster serve speeds in tennis or higher pitch velocities in baseball, while simultaneously monitoring for any potential increases in injury risk associated with these performance gains. Another area of interest could be the comparison of eccentric cycling warm-ups with other warm-up techniques commonly used in overhead sports. By evaluating the efficacy of different warm-up methods, researchers can identify the most effective strategies for enhancing shoulder performance and reducing injury risk. Lastly, exploring different durations and intensities of eccentric cycling warm-ups could provide insights into optimizing protocols for various athletic populations. It is possible that the 6 minutes was too long in duration and caused fatigue. Further research could also examine the long-term effects of eccentric cycling on performance and injury prevention, providing a more comprehensive understanding of its benefits.

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APPENDICES

Appendix 1: Ethics Approval, Auckland University of Technology Ethics Committee

Auckland University of Technology Ethics Committee (AUTEC)

7 December 2023

Matt Brughelli
Faculty of Health and Environmental Sciences

Dear Matt

Re Ethics Application: **23/259 Acute effects of concentric vs eccentric cycling on sprinting performance in netball players.**

Thank you for your responses to AUTEC's conditions.

Your ethics application has been approved for three years until 7 December 2026.

Non-Standard Conditions of Approval

1. Please replace the word "anonymous" with "aggregated" in the feedback section.

Non-standard conditions do not need to be submitted to or reviewed by AUTEC unless requested but must be completed before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC.
2. All public facing documents must have the AUTEC approval number and be of a high standard of spelling and grammar. Dates on the Information Sheet(s) and Consent Form(s) must be consistent.
3. Any amendments to the project must be approved by AUTEC prior to being implemented.
4. A progress report is due annually on the anniversary of the approval date.
5. A final report is due at the expiration of the approval period, or, upon completion of project.
6. Any serious or adverse events must be reported to AUTEC, this includes unforeseen issues that might affect continued ethical acceptability of the project.
7. AUTEC grants ethical approval only. You are responsible for obtaining management permission for access from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

The application number and title need to be referenced on all correspondence related to this project.

All forms are available online http://www.aut.ac.nz/research/researchethics

For any enquiries, please contact ethics@aut.ac.nz
(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: Liew_1031@hotmail.com; chloe.mckenzie@aut.ac.nz

Auckland University of Technology, D-88, Private Bag 92006, Auckland 1142, New Zealand.
T: +64 9 921 9999 ext. 8316: E: ethics@aut.ac.nz: www.aut.ac.nz/researchethics

Appendix 2: Participant Consent Form

AUT
TE WĀNANGA ARONUI
O TĀMAKI MAKAU RAU

Consent Form

For use when laboratory or field testing is involved.

Project title: Acute effects of eccentric cycling versus mobility drills on sprinting performance in recreational trained individuals.

Project Supervisor: Dr Matt Brughelli, Dr Chloe McKenzie

Researcher: Yit Liew

O I have read and understood the information provided about this research project in the Information Sheet dated 14/3/2024.

O I have had an opportunity to ask questions and to have them answered.

O I understand that participating in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged.

O I understand that if I withdraw from the study, I will be offered the choice between having any data identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removing my data may not be possible.

O I agree to take part in this research.

O I wish to receive a summary of my individual result (please tick one): YesO NoO

O I wish to receive a summary of the research findings (please tick one): YesO NoO

Participant's signature...

Participant's name: ....

Participant's Contact Details (if appropriate):

....

....

....

Date:

Approved by the Auckland University of Technology Ethics Committee on type the date on which the final approval was granted AUTEC Reference number type the AUTEC reference number

Note: The Participant should retain a copy of this

Appendix 3: Participant Information Sheet

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Participant Information Sheet

This Information Sheet is specifically designed for the Athletes.

Date Information Sheet Produced:

14/3/2024

Project Title

Acute effects of eccentric cycling versus mobility drills on sprinting performance in recreational trained individuals.

An Invitation

Hi, my name is Yit Liew, and I am a Master's student at AUT University. I would like to invite you to participate in our research project. The study aims to investigate the acute effects of eccentric cycling versus mobility drills on sprinting performance in recreational trained individuals.

It is solely your choice as to whether you participate in this study or not. If you decide you no longer want to participate, you can withdraw yourself or any information you have provided for this study at any time prior to the completion of data collection. However, once the findings have been produced, removing the data may not be possible. When you sign and date the consent form, you indicate your permission to participate in this study. Signing the consent form indicates that you have read and understood this information sheet, freely given your consent to participate, and that there has been no coercion or inducement to participate by the researchers from AUT.

What is the purpose of this research?

The purpose of this research study is to examine the acute benefits of eccentric cycling warm up on sprinting performance. Unlike traditional cycling, eccentric cycling involves resisting the backward movement of the pedals, powered by an electric motor. We're particularly interested in seeing if this kind of exercise can improve speed during sprints. By quantifying the force-velocity profile during sprinting before and after eccentric cycling training, the researchers seek to understand the potential potentiation acute effects of this exercise modality on sprinting performance in netball players.

Eccentric cycling is a relatively new exercise modality where the pedals are moved backwards by an electric motor, and the individual actively resists this backward force. It can be done by different positions to target arms, glutes, and hamstring. Eccentric cycling has been shown to less fatiguing than concentric cycling. However, there is a limited amount of research on the acute effects of eccentric cycling, particularly in the context of force-velocity profiling during sprinting, especially in netball players. Therefore, this study aims to address this gap in knowledge and explore the potential benefits of eccentric cycling on sprinting performance in recreational trained individuals.

The findings from this research could hold significant value for trainers, health professionals, and individuals, enables them to use eccentric cycling as a warm-up or pre-activation exercise before or actual training.

How was I identified and why am I being invited to participate in this research?

I was put in contact via my colleague, who has worked with you before. As this study is looking to examine the acute effects of eccentric cycling warm up on sprinting performance, you have been identified and invited to participate in this research. Your participation in this study would help to further our knowledge of this area. You are eligible to participate in this study if you are (1) between age 18-35 recreational active, (2) have no known medical conditions, (3) English-speaking, (4) able to complete questionnaires and give informed consent, (5) recreational active for the last two years.

How do I agree to participate in this research?

If you agree to participate in this research, email me at liew_1031@hotmail.com , to express your interest. You will be asked to report to the AUT-Millennium SPRINZ laboratory space, where you will be given written information about the testing procedure. Before signing the consent form, you will be given an opportunity to ask me any questions about the research study. Following this opportunity for questions or queries, you will be required to sign and date the consent form.

What will happen in this research?

Once you have decided to participate in the study, you will be asked to complete one familiarisation session at the AUT-Millennium SPRINZ laboratory space. A week following the familiarisation session, you will commence the testing phase of the study, which consists of two testing days. These testing days will be scheduled with a three-day interval between to ensure proper recovery and consistent data collection. All sessions, including the familiarisation and the testing procedures, will take place at the AUT-Millennium SPRINZ laboratory space. The demographic data that will be collected is your age and gender.

<u>The study testing procedures are as follows:</u>

Initially, you will complete the consent form provided to you if you wish to partake in the study. Following this, the researcher will verbally explain the testing procedures and equipment you will use. There will be two testing days for this research. You will undergo a standardised dynamic full-body warm-up to prepare for the assessments. The standard warm-up consists of a 10-minute duration of dynamic stretching exercises. The dynamic stretches include lunges, quad stretches, calf stretches, side bends, and 40m drills, including lifting knees up and kicking heels backwards. After the warm-up, you will proceed to a pre-test performance profiling test that uses force-velocity measurements for sprinting. Prior to testing the force-velocity profiling for sprinting, you will not be aware of whether you will undergo mobility drills or eccentric cycling. The allocation of intervention, either mobility drills or eccentric, will be randomly determined and concealed until the testing day at the venue. You will only discover which intervention you will undergo when you arrive at the testing facility.

1) Eccentric cycling on the arms

   Figure 1 demonstrates a specific position associated with two distinct cycling techniques: eccentric cycling on the arms. Eccentric cycling involves resisting the pedal in a counterclockwise motion while maintaining this posture. In other words, the participant actively pushes against the pedal's natural direction. You will need to perform this exercise for a duration of 2 minutes, followed by a 30-second rest period.

   Figure 1
   Eccentric cycling on the arms

2) Eccentric cycling on the glutes

   Figure 2 demonstrates a glute bridge position associated with two distinct cycling techniques: eccentric cycling on the glutes. Eccentric cycling involves resisting the pedal in a counterclockwise motion while maintaining the posture. In other words, the participant actively pushes against the pedal's natural direction. You will need to perform this exercise for 2 minutes, followed by a 30-second rest period.

Figure 2
Eccentric cycling on the glutes

3) Eccentric cycling on hamstring

Figure 3 demonstrates a hamstring bridge position associated with two distinct cycling techniques: eccentric cycling on the hamstring. Eccentric cycling involves resisting the pedal in a counterclockwise motion while maintaining the posture. In other words, the participant actively pushes against the pedal's natural direction. You will need to perform this exercise for 2 minutes, followed by a 30-second rest period.

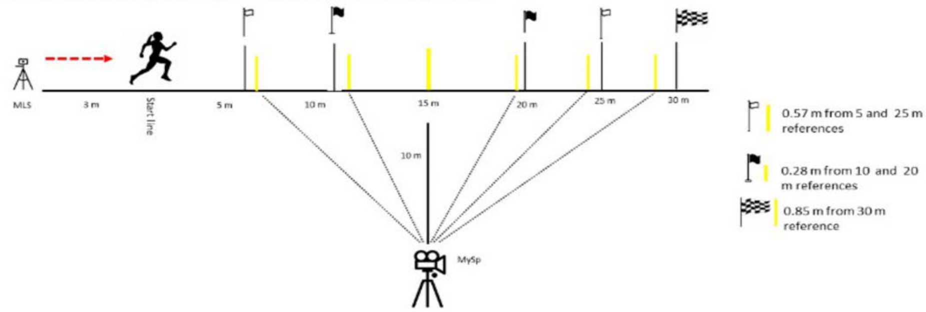
Figure 3
Eccentric cycling on the hamstring

4) Force-velocity profile for sprinting

You will be required to perform 2 sprints for the force-velocity profile, one is a pre-test, and the other one will be after the intervention. The post-intervention test will be conducted after 4 minutes after the respective interventions to capture the acute effects on the performance.

Figure 4

Force-velocity profile for sprinting (Ghigiarelli et al., 2022)



After the pre-testing, you will be asked to do a 6-minute training session targeting the arms, hamstrings, and glutes, with a specific focus on mobility drills or eccentric cycling. Proper instruction on technique and form will be provided to ensure optimal execution of the cycling exercises for both groups.

Following the interventions on each day, a post-intervention test will be conducted. You will need to undergo another performance profiling test using force-velocity measurements for sprinting. This test will be performed 4 minutes after the respective interventions to capture the acute effects on performance. You are then required to go through a similar process for the other type of interventions on the other day.

What are the discomforts and risks?

During the testing sessions, you will be asked to perform mobility drills and eccentric cycling. Therefore, you could potentially experience discomfort for a short period towards the last moments of each interval. You may experience some muscular fatigue after the session as well. During the next few days, slight muscle tenderness and soreness may be experienced for the next few days resulting from eccentric exercise.

How will these discomforts and risks be alleviated?

The two practice sessions aim to carefully progress your experience of eccentric cycling and mobility drills to reduce your potential for muscle soreness. Suppose you experience discomfort at any stage during the testing. In that case, you are encouraged to inform the researcher at the time so they can best address the problem. If you have any questions regarding the risk of discomfort you may experience, please feel free to address these concerns with the researcher so that you always feel comfortable throughout this research process.

What are the benefits?

You, as participants, will receive practical experience using an eccentric cycling ergometer which has the potential to help increase strength and improve mobility. Additionally, the study will include force-velocity testing during sprinting to assess your sprinting mechanics and power outputs. This testing will provide you with valuable insights on how your body responds to eccentric cycling and its potential impact on your sprinting performance. By understanding your force-velocity profile, you will gain a deeper understanding of your athletic capabilities and potential areas for improvement. Your participation in this study can contribute to advancing our knowledge of eccentric cycling and its potential benefits for enhancing athletic performance and overall fitness.

Health professionals and coaches throughout New Zealand, potentially internationally, can benefit from the research outcomes. The results may inform and enhance exercise prescription strategies, training protocols, and injury rehabilitation approaches, ultimately contributing to improved athletic performance and overall well-being in the sports and fitness community.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury because of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

Although the researchers collecting the data will be aware of the participants' identities due to the nature of the study, we will ensure participant privacy and confidentiality by employing coded identifiers throughout the research process. Immediately after data collection, all participants' names will be removed from the dataset to maintain their confidentiality. During the testing sessions, no individual data will be disclosed, thus safeguarding anonymity among the participants. The information of the participants will only be accessible to the researchers involved, and all results will be stored in a password-protected Excel spreadsheet. Any publications resulting from the study will not contain any identifiable details of the participants.

What are the costs of participating in this research?

Besides your time and effort, you will not have a financial cost to participate in this study. You must attend two 30-minute practice sessions before the testing session to become familiar with the movements. Additionally, there will be two testing sessions, each will take approximately 30 minutes to complete. The second testing session will occur approximately a week later at the same time of day. In total, the study requires a commitment of 2 hours: 1 hour for the practice sessions combined, and another hour for the two testing sessions. By joining, you agree to dedicate this amount of time to complete all aspects of the study.

What opportunity do I have to consider this invitation?

We would appreciate it if you could let us know within **two weeks** whether you would be available to participate in the study. After consideration, you may withdraw your participation at any time.

Will I receive feedback on the results of this research?

Yes, if requested, we can provide a comparison between each exercise protocol. This will include a force-velocity graph. The graph aims to provide insights into how each type of cycling impacts your sprinting performance. Whether you share this information with a health professional or others is your choice.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Matt Brughelli, matt.brughelli@aut.ac.nz, 09 921 9999 x7025 or 027 221 7777.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, ethics@aut.ac.nz, (+649) 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Yit Liew

Email: liew_1031@hotmail.com

Project Supervisor Contact Details:

Dr Matt Brughelli, Sports Performance Research Institute New Zealand (SPRINZ), School of Sport and Recreation, Faculty of Health and Environmental Sciences, AUT University, Private Bag 92006, Auckland 1020, matt.brughelli@aut.ac.nz, 09 921 9999 x7025 or 027 221 7777.

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.