THE EFFECT OF NEUROMUSCULAR WARM-UP ON BALANCE AND ANKLE MOBILITY AMONG PHYSICALLY ACTIVE FEMALES INVOLVED IN PIVOTING TEAM SPORTS

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By

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A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Health Sciences (Exercise and Sports Science)

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CERTIFICATE

Certified that the thesis entitled "THE EFFECT OF NEUROMUSCULAR WARM-UP ON BALANCE AND ANKLE MOBILITY AMONG PHYSICALLY ACTIVE FEMALES INVOLVED IN PIVOTING TEAM SPORTS" submitted by Puteri Nur Aisyah binti Mohd Zamri towards fulfilment for the Bachelor's Degree in Health Sciences (Exercise and Sports Science) is based on the investigation carried out under our guidance. The thesis part, therefore, has not submitted for the academic award of any other university or institution.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

………………………………
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Date: …23.6.2021………..

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KESAN PEMANASAN NEUROMUSKULAR PADA KESEIMBANGAN DAN PERGERAKAN PERGELANGAN KAKI DALAM KALANGAN WANITA YANG AKTIF SECARA FIZIKAL YANG TERLIBAT DALAM SUKAN PIVOT BERPASUKAN

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji keberkesanan pemanasan neuromuskular pada keseimbangan dan pergerakan pergelangan kaki. Sehingga kini, kajian yang menyelidiki kesan pemanasan neuromuskular pada kecederaan pergelangan kaki (diukur melalui keseimbangan dan mobiliti pergelangan kaki), terutama pada wanita, adalah sangat terhad. Oleh itu, kajian ini dijalankan. Dua puluh wanita yang aktif secara fizikal di Universiti Sains Malaysia mengambil bahagian dalam sukan berpasukan yang melibatkan pergerakan pivot; bola jaring, bola keranjang, frisbee, hoki padang, dan bola sepak telah direkrut. Mereka diedarkan secara rawak ke salah satu daripada dua kumpulan ini: kumpulan pemanasan neuromuskular, NWU (n = 10) atau kumpulan pemanasan umum, GWU (n = 10). Intervensi ini dilaksanakan selama 6 minggu di mana, para peserta dalam kumpulan NWU melakukan senaman dinamik yang merangkumi larian 20-meter, keseimbangan, plyometrik, dan penguatan. Sementara itu, para peserta dalam kumpulan GWU melakukan latihan regangan statik yang merangkumi regangan hamstring, regangan quadriceps, regangan gastrocnemius, regangan adductor (regangan rama-rama), dan regangan iliopsoas (regangan 'lunge'). Pengukuran ujian pra dan pasca dilakukan pada kedua-dua belah kaki, dengan bacaan purata dicatatkan untuk ujian 'Single Leg Balance' (SLB) untuk menilai keseimbangan badan dan 'Dorsiflexion Long Test' (DLT) untuk menilai pergerakan pergelangan kaki. ANOVA campuran telah digunakan untuk menganalisis data. Sebagai keputusannya, kesan antara kumpulan menunjukkan bahawa keseimbangan badan dan pergerakan pergelangan kaki

tiada perbezaan secara signifikan ($p>0.05$) antara kumpulan NWU dan GWU. Kesan dalam kumpulan menunjukkan bahawa GWU tidak mempunyai kesan yang signifikan ($p>0.05$) terhadap semua parameter yang diukur. Walau bagaimanapun, kumpulan NWU menunjukkan kenaikan yang signifikan dalam keseimbangan dan pergerakan pergelangan kaki dari ujian pra ke pasca. Maka, boleh disimpulkan bahawa program pemanasan neuromuskular selama 6 minggu adalah efektif dalam mengurangkan risiko kecederaan pergelangan kaki melalui peningkatan keseimbangan dan pergerakan pergelangan kaki para atlet yang terlibat dalam sukan pivot berpasukan.

THE EFFECT OF NEUROMUSCULAR WARM-UP ON BALANCE AND ANKLE MOBILITY AMONG PHYSICALLY ACTIVE FEMALES INVOLVED IN PIVOTING TEAM SPORTS

ABSTRACT

The purpose of this study is to investigate the effectiveness of neuromuscular warm-ups on balance and ankle mobility. To date, studies investigating the effects of neuromuscular warm-up on the risk of ankle injuries (measured through balance and ankle mobility), especially on females, are very limited. Thus, this study was carried out. Twenty physically active females in Universiti Sains Malaysia participated in pivoting team sports; netball, basketball, frisbee, field hockey, and soccer were recruited. They were distributed randomly to one of these two groups: neuromuscular warm-up group, NWU (n=10) or general warm-up group, GWU (n=10). The intervention was executed for 6 weeks where, participants in the NWU group performed dynamic exercise which include 20-meter running, balance, plyometrics, and strengthening. Meanwhile, participants in the GWU group performed static stretching which includes hamstring stretch, quadriceps stretch, gastrocnemius stretch, adductor stretching (butterfly stretch), and iliopsoas stretching (lunge stretch). The pre and post-test measurements were conducted on both legs, with average readings recorded for the Single Leg Balance (SLB) test for body balance assessment and Dorsiflexion Long Test (DLT) for ankle mobility assessment. Mixed ANOVA was used to analyse the data. As a result, between-group effects showed that balance and ankle mobility were not significantly different ($p>0.05$) between NWU and GWU groups. Within-group effects showed that GWU has no significant effects ($p>0.05$) on all the parameters measured. However, the NWU group showed a significant increase in balance and ankle mobility from pre to post-test. Thus, it can be concluded that 6 weeks of the neuromuscular warm-up program were

effective in reducing ankle injury risk through improving ankle balance and ankle mobility of the athletes involved in pivoting team sports.

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

Participation in sports is an important mechanism for promoting physical activity. Nevertheless, the injury will reduce the benefits of involvement during such practice, thus, injury prevention is important. Implementing evidence-informed safety policies and practices related to warm-up within community-based sports organizations is crucial to maximising the benefits of sport participation in public health and reducing barriers to sport participation (Andrew et al., 2013). Multiple factors including measurements of injury frequency (incidence), injury severity (time loss from sport, level and type of medical intervention), and overall injury burden (mortality and life-years adjusted for the disability) contribute to the significant impacts on participation and performance. Other factors include the availability of effective interventions, the probable economic gain associated with their implementation and the potential for significant impacts on participation and performance.

The aim of the neuromuscular training was to improve the effectiveness to generate a fast and optimal muscle firing pattern, to boost dynamic joint stability and to relearn the essential movement patterns and skills during daily living and sports activities (Risberg *et al.*, 2001). Only a few studies evaluated the influence of neuromuscular training, and most of them focused on either ACL-deficient knee subjects or the effect of training on injury prevention. Risberg and colleagues agreed that a lag in the reaction time of the neuromuscular can lead to dynamic joint instability with recurrent episodes of joint subluxation and deterioration. For long-term functional success, therefore, both mechanical stability and neuromuscular control are likely to be essential, and both factors must be addressed in the design of a neuromuscular warm-up program.

The relationship between poor balance control and heightened injury risk was identified in Risberg *et al.*, 2001 where balance ability was found to be strongly linked with the risk of ankle injury in both younger male and female basketball players. Similarly, a recent systematic review by Witchalls *et al.*, 2012 summarized the available evidence and suggested that lack of balance is an intrinsic factor associated with increased ankle injury risk. The ability to elevate the toes toward the shins is known as dorsiflexion and a good ankle mobility is when it is able to move the ankle joint through its full range of motion. When the ankle joint is restricted, it is referred to as an ankle joint restriction. Scar tissue in the joint or a tight joint capsule might cause this. A joint capsule is a fluid-filled connective tissue that acts as a natural hinge in the body.

The ankle joint is the most common site of an athlete injury. Ankle sprains represent 76.7% of injuries, followed by 16.3% of ankle fractures. Up to 80% of athletes with ankle sprain suffer from recurrent sprains, and up to 72% experience chronic instability (Padua, 2019). According to McGuine and Keene in 2017, several studies have found that a high percentage of ankle injuries are seen in activities that involve sudden stops and movements to cut, such as basketball and soccer, which categorized into a pivoting team sport. Besides, hamstring injuries, knee or ankle ligament injuries, hip/groin injuries and tendinopathies are especially common and mostly result in considerable loss of time from the sport.

A well-implemented warm-up comprising of stretching, strengthening, balance, agility and landing exercises may help in reducing lower limb injury incidence. Several elements of sensorimotor function, like strength, coordination, equilibrium and proprioception, are included in the neuromuscular warm-up exercises, however, emphasis can be, for instance, balance in one exercise and strength in another. The goal is to achieve equilibrium of loaded segments in static and dynamic conditions and to gain postural control in situations that mimic daily living conditions and more demanding activities. Attention is focused on the effectiveness and quality of each warm-up movement.

1.2 Problem Statement

Pasanen et al. (2008) has shown that several studies agreed neuromuscular warm-up program can reduce the risk of ankle and knee injury among athletes, while some other studies found no positive effects. These mixed findings may be attributed to the difficulty in interpreting these findings because of the methodological inconsistency such as protocols, number of participants and period of intervention. Thus, more studies are needed to confirm the validity and reliability of this neuromuscular warm-up program. A randomised control trial (RCT) will be used in this proposed study to study the effects of neuromuscular warm-up in preventing ankle injuries (by measuring balance status and ankle mobility) among physically active females involved in pivoting teams sports.

1.3 Study Objective

1.3.1 Main Objective

To examine the effectiveness of neuromuscular warm-up in balance and ankle mobility among physically active females involved in pivoting team sports.

1.3.2 Specific Objectives

i. To compare the balance between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports

ii. To compare the ankle mobility between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports

1.4 Study Hypotheses

H_{O1}: There is no significant difference in balance between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports.

H_{A1}: There is a significant difference in balance between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports.

H_{O2}: There is no significant difference in ankle mobility between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports.

H_{A2}: There is a significant difference in ankle mobility between the neuromuscular warm-up and general warm-up groups among physically active females involved in pivoting team sports.

1.5 Significance of the Study

It is hoped that this study will provide scientific evidence on the effectiveness of the neuromuscular warm-up in preventing ankle injuries. The test used to measure the effectiveness of the neuromuscular warm-up program on balance and ankle mobility; the possible intrinsic risk factors for ankle injuries. This finding may support the implementation of neuromuscular warm-up among athletes to improve their balance and ankle mobility, hence reduce the incidence of ankle injuries which eventually will improve sports performance.

1.6 Operational Definitions

- **Neuromuscular warm up (NWU)**

  A neuromuscular warm-up is a type of exercise that helps nerves and muscles react and communicate more effectively, comprising of stretching, strengthening, balance, agility, and landing exercises.

- **General warm-up (GWU)**

  A general warm-up usually includes a low-intensity aerobic component as well as dynamic or static stretching exercises.

- **Pivoting team sports**

  Sports with frequent pivoting motions (e.g. soccer, team handball, netball, basketball).

- **Single-Leg Balance test (SLB)**

  A screening tool to determine body balance.

- **Dorsiflexion Long Test (DLT)**

  A quantitative measurement used to estimate exclusively the ankle mobility.

CHAPTER 2
LITERATURE REVIEW

2.1 Ankle injury prevalence among the females

The lower extremity, especially the knee and ankle, is the most frequently injured body area among female athletes in community-based, school-based, and clinical studies. The National Athletic Trainers Association (NATA) study stated that the lower extremity was 63 per cent of the injuries. In 2005, Yang et al. reported 97.8 injuries per 100 000 athlete-exposures, A-E (95 per cent confidence interval (CI) 74.4 to 128.1) in the North Carolina High School Athletic Injury Study (NCHSAIS) for the lower female extremity incidence in general. In a national survey of high school athletes in 2005, the prevalence of lower extremity injury among girls ' sports was reported to be 1.14 per 1000 A-E and 72.6 per cent of the 664 lower extremity injuries suffered by girls were knee and ankle (Knowles, 2010).

Studies indicate that ankle injuries account for 13–50 per cent of women's injuries, depending on the sport (Knowles, 2010). The NCHSAIS reported the average rate of ankle injury among high school female athletes at 42.3 per 100 000 A-E (95% CI 30.2 to 59.3), with volleyball having the highest incidence of ankle injury (68.3 per 100 000 A-E, 95% CI 25.6 to 182.0). A study from the 2005–07 High School Reporting Injuries Online (RIO) program found that the incidence of female ankle injury was 5.4 per 10 000 A-E, comprising 32.5% of all female injuries. In competition, it is recorded that ankle injury rates are higher than in practice settings. It is theorized that, due to the production of greater body mass during maturation, adolescents are more likely to encounter an ankle injury than prepubescent athletes (LaBella *et al.*, 2011).

Based on Hunt et al. (2016), there is a significant incidence of foot and ankle injuries in female athletes compared to their male counterparts. Hunt and colleagues stated that female athletes suffered most prominently from ankle, lower leg, and midfoot injuries, as well as tendinopathies and bone stress injuries, which were more common in female athletes than in male athletes. There are significant differences between female and male athletes. Anatomical, hormonal, nutritional and functional differences may play a role and should be acknowledged in the treatment of female athletes and in the prevention of injury.

2.2 Intrinsic risk factor of ankle injury on females

2.2.1 Lower extremity strength

Knapik et al. (1991) reported no association between absolute strength and injury but considered particular strength imbalances to be a factor in the incidence of injury. Unfortunately, there is no research that directly measured the joint muscle strength of the ankle and its contribution to an ankle injury, which prevents comparison (Payne et al., 1997). Nevertheless, the recent study by Muehlbauer *et al.* (2015) shows that large-scale relations between balancing measures and lower-extremity muscle strength or power suggest that these neuromuscular components are interconnected and not independent of each other. As a result, success in one factor (e.g., balance) can (partially) lead to success in another (e.g., lower-extremity muscle strength). In addition, training-induced increases in lower extremity muscle strength (e.g., the maximum strength of plantar flexors) can have an effect on balance efficiency (e.g., postural sway) or vice versa.

Numerous studies have shown a transition of training-related benefits from one aspect to the other and vice versa. For example, Gruber et al. (2007) looked at improvements in balance and strength efficiency following 4 weeks of balance or resistance training in healthy young adults. The authors reported substantial changes in the rate of strength development (RFD) after balance training and posture swing after ballistic strength training (Muehlbauer *et al.*, 2015).

2.2.2 Extremity dominance

In Beynnon, Murphy & Alosa's study (2002), limb dominance was unrelated to the possibility of an ankle injury to male and female athletes competing in soccer and lacrosse and female athletes competing in field hockey. Likewise, Surve et al (1994). found that soccer athletes recorded no difference in the incidence of ankle injuries between dominant and non-dominant ankles. Ekstrand and Gillquist in 1982 on the other hand, noticed that the dominant leg had substantially more ankle injuries in male soccer players, with 92 per cent of ankle injuries affecting the dominant leg. Such opposing results may have been the influence of a variety of study designs or methods used for data analysis.

Another reason is that there was a lack of clarity on the concept and determinants of lower-limb dominance. The most widely used approaches were kicking and hopping tests on a single leg. In 1998, Hoffman et al. carried out a series of functional experiments, which they called the "functional determination of the dominant limb" and determined that the dominant limb was the one that conducted the action with greater precision and ability. They claimed that the dominant leg was the one used to kick a ball. While research by Alonso et al., 2011, shows the dominant limb may be defined on the basis of muscle strength, practical usage and personal preference, and these parameters may interfere with balance. Limb dominance should be defined by which leg the person prefers and relies on a variety of functional tasks, including the maintaining of balance.

Moreover, there was little difference between the dominant and the non-dominant limbs at both levels of instability, although, at the point of greater instability of the equipment, the range of motion was greater due to the need for additional posture changes in order to maintain equilibrium. Nevertheless, these results are close to those of Alonso et al. (2009), who discovered that there was no disparity between the limbs in groups of sedentary individuals and recreational football players. Due to little research previously done on relations of limb dominance and ankle injury, it can be concluded that limb dominance had no significant impact on the intrinsic risk factor of ankle injuries either on females or males.

2.3 Effect of warm-up on an ankle injury

2.3.1 Effect of neuromuscular warm up on female athletes

Neuromuscular training focuses on activities that allow the nerves and muscles to respond and interact with one another. Neuromuscular training programs are designed both to increase the strength of the knee joint and to raise awareness of the correct balance and technique for the individual. The programs achieve this goal by using a number of different techniques to prepare the individual's body as well as its conscious mind. Neuromuscular Training Program (NMT) is used to improve unconscious motor responses by stimulating both afferent signals and central mechanisms in charge of dynamic joint control (Benis *et al.*, 2016).

Ankle injuries are effectively prevented by neuromuscular exercise, either on a balancing board or on a balancing mat, in soccer and other sports (Engebretsen *et al.*, 2010). A recent systematic study comparing balance work (using balance boards) and neuromuscular exercises (without balance boards) showed a 36 per cent and 50 per cent reduction in ankle sprains, respectively (Herman et al., 2012). Furthermore, the sensitivity analysis conducted in this review suggested that the introduction of equipment, especially balancing boards, to programs for warming up, can be effective in reducing ankle injuries. It shows that neuromuscular approaches can reduce ankle injuries (Herman *et al.*, 2012). In addition, balance training also contributes to the improvement of motor skills, leading to an increase in the rate of development of strength and therefore improved athletic performance (Padua *et al.*, 2019).

Previously, Neuromuscular Training Warm-up programs have been consistent in demonstrating the protective effect of reducing the risk of lower extremity injuries (LEIs) in multiple athletic populations involving youth and adults (Owoeye *et al.*, 2018). Thus, it is believed that vigorous sprinting and bounding warm-up exercises enhance the activity of the core mechanisms of neuromuscular function and muscle activation to a greater degree than jogging or slow running.

2.3.2 Effect of general warm-up on female athletes

Warm-up refers to muscle actions performed before a higher muscle demand, typically before recreational or high-intensity competitive events occur, involving general and specific warm-up routines. General warm-up normally involves an aerobic element of relatively low intensity (e.g., sub-maximal running) and stretching exercises. Warm-ups, which increase blood flow into the muscles involved and boost muscle temperature, are performed for 5 to 15 mins before the main exercise is performed. Warm-ups can reduce the risk of damage to the muscles and tendons as well as reduce heavy cardiac loads, which can occur when workouts of high intensity are suddenly started (Park *et al.*, 2018). In other words, increased muscle temperature provides greater flexibility, which prepares the athlete for the activity needs of the sport, and an increase in heart rate and blood flow provides oxygen and other essential nutrients to the muscles to be used during exercise.

Padua et al. (2019) stated that athletes who did not execute general stretching as part of their warm-up protocol were 2.6 times more possible to have ankle injuries than athletes who stretched. Stretching exercise in general warm-up can be either static or dynamic. To stimulate connective tissue plastic elongation, static stretching is defined as a steady, deliberate, consistent lengthening of the muscle by positioning the muscle on tension to a point of a stretching sensation, maintaining the position for a period of time and repeated. Dynamic stretching, on the other hand, involves shifting the limb from its neutral position to the endpoint, where the muscles are at their full length, and then bringing the limb back to its original state. Throughout the stretch, the muscles are actively tightened, and the joints are moved through their complete range of motion. Such dynamic action shall be carried out in a smooth, regulated manner and shall be repeated for a specified time frame. These functional and sport-specific movements help to loosen up the muscles and reduce stiffness.

Though it was generally agreed that athletes should conduct warm-up exercises and stretching procedures before and after taking part in a physically demanding sport. However, various clinical reports have varying insights on the efficacy of general warm-up and stretching procedures in minimizing injuries. Although some studies have indicated that there has been no ‘reduction in risk’ of injury or overall injury, other studies have indicated positive effects and a decline in musculotendinous injuries from warm-up and stretching intervention programs.

On the whole, warm-up is interpreted as a preparatory exercise by athletes to enhance neuromuscular performance and minimize sports injuries. In fact, warm-up increases performance by reducing muscle viscous resistance (i.e., smoother contraction) and increasing the speed of nerve transmission (Andrade *et al.*, 2015).

CHAPTER 3
METHODOLOGY

3.1 Study Design

In this study, a randomised controlled trial (RCT) was used as the study design. The RCT is a study in which participants are distributed randomly to one of two groups: one (the experimental group) undergoing the intervention being tested, and the other (the contrast group or control) receiving alternative (conventional) treatment (Kendall, 2003). The two groups are then monitored to see if there are any variations in outcome between them. The results and subsequent review was used to determine the efficacy of the intervention, which is to what degree of treatment, procedure, or service does better than harm to participants (Kendall, 2003). In the present study, the participants were selected by using a computer-generated randomization list, which randomly assigned to either a neuromuscular warm-up group (NWU) or general warm-up group (GWU). This study obtained ethical approval from the Jawatankuasa Etika Penyelidikan Manusia Universiti Sains Malaysia (JEPeM-USM) (Appendix A; JEPeM code: USM/JEPeM/20040217).

3.2 Sampling Technique, Population and Location of the Study

In this study, the snowball sampling technique was used to recruit the participants among the students of Universiti Sains Malaysia (USM). All the data was collected at the fields and courts in USM.

3.3 Selection Criteria

3.3.1 Inclusion Criteria

The selection of participants was based on the following criteria:

- Female
- Age 18-25 years old
- Physically active - involved in pivoting team sports (basketball, handball, netball, etc.) at least 3 days per week with approximately 60 minutes per session.
- Healthy – assessed through a health questionnaire (Appendix B)

3.3.2 Exclusion Criteria

The exclusion criteria for this study are:

- Had recent history of lower limb injuries for at least 6 months.
- Had any other illness that could compromise their training.

3.4 Sample Size Calculation

The sample size was calculated by using PS Power and Sample Size Calculation version 3.1.2 by Creative Commons Attribution-Non-Commercial-No Derivs 3.0 United States License. The power of the study was set at 80% with a 95% confidence interval. By using the results of distance achieved during the Dorsiflexion Long Test (DLT) in a previous study (Padua et al., 2019), the standard deviation (SD) of 1.0 cm and difference in population mean of 1.5 cm were used for the calculation. The calculated sample size was 8 participants per group. Considering 25% of drop-out rate, another 2 participants per group were recruited. Hence, a total of 20 participants (N=20) were recruited with 10 participants per group (n=10).

3.5 Study Instruments

3.5.1 Single-Leg Balance (SLB) Test

The Single-Leg Balance (SLB) test was used to determine balance because it is a screening tool that is available at a low cost and able to predict ankle sprains inexpensively compared to other tests. A study by Trojian & McKeag (2006) showed a positive result for the association between the SLB test and future ankle sprains. Thus, the SLB test is a valid and reliable tool for predicting ankle sprains. To perform this test, participants were required to stand on one foot without shoes with the contralateral knee bent and not touching the weight-bearing leg; the hips were level to the ground; the eyes open and fixed on a spot marked on the wall, and then the eyes were closed for 10 seconds (Figure 3.1).

During this test, based on Trojian and McKeag, (2006) the participants were given a -1 score if they pass the test. The participants were considered as having a positive test (+1 score; high risk for ankle injuries) if their legs touched each other, the feet moved on the floor, the foot touched down, or the arms moved from their start position. If the first trial is positive, a second trial was carried out, and the results of the second trial were counted for analysis. The SLB test was carried out for both legs. An SLB test was considered positive if the athlete was unable to carry out the test on either or both legs.

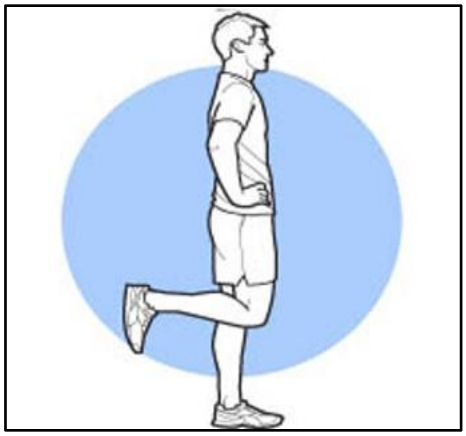


Figure 3.1: Single leg balance test

3.5.2 Dorsiflexion Long Test (DLT)

The Dorsiflexion Long Test (DLT) represents a quantitative measurement used to estimate exclusively the ankle mobility. This test was chosen to determine ankle mobility because it provided acceptable agreement findings and evidence supporting the validity of the test by Powden *et al.*, (2015). Besides, this test uses a standardized protocol, which can be easily replicated in clinical or research environment settings.

The test was performed barefooted. Participants were asked to place the heel centre of the tested foot perpendicular to the wall (Figure 3.2). The first toe was located in a marked line on the ground by a piece of guide tape. Then, the participants were asked to flex their knees until it touches the wall, reaching the maximum ankle dorsiflexion. The maximum distance from the wall to the toe without lifting the examined heel was measured. Three measurements were taken for each leg and the mean was calculated and used for data analysis. According to Xixirry, Riberto & Manoel (2019), participants with a limited range of dorsiflexion showed an increased risk of injury, meaning that distance shorter than 9 to 10 centimetres is considered as dorsiflexion restriction.

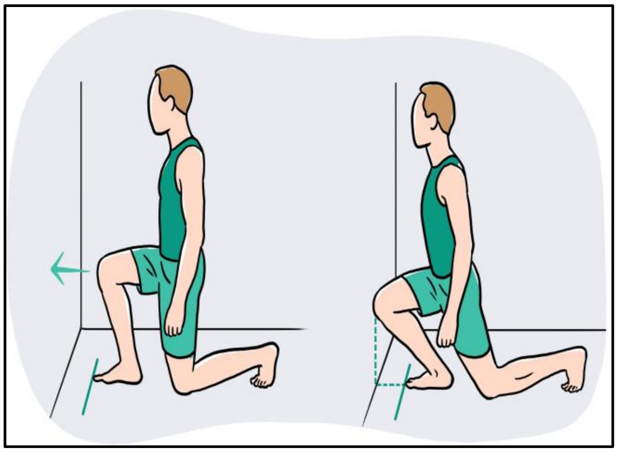


Figure 3.2: Dorsiflexion long test

3.6 Study Procedures

Physically active females involved in pivoting team sports in USM were randomly approached. During the first meeting, the participants were briefly informed about the study and if they agreed to participate in the study, the consent form will be given to them for signing (Appendix C). After obtaining informed consent, participants underwent the pre-test which includes anthropometry measurement using Tanita body composition analyser (body height, weight, and fat percentage), Single Leg Balance (SLB) test and Dorsiflexion Long Test (DLT). All the data obtained was recorded in the Data collection Form (Appendix D). Then, they were randomly categorised into the following two groups: neuromuscular warm-up group (NWU) or general warm-up group (GWU).

During the 6 weeks of the intervention period, a participant in the GWU group underwent a standard general warm-up routine which was static stretching, which lasted for 10 min, 3 times per week for 6 weeks. Static stretching exercises that were carried out are hamstring stretch, quadriceps stretch, gastrocnemius stretch, adductor stretching (butterfly stretch), and iliopsoas stretching (lunge stretch) as detailed in Table 3.1.

On the other hand, participants in the NWU group underwent a neuromuscular warm-up routine (10 min) as detailed in Table 3.2. All the warm-up sessions were instructed by the researcher, and it was conducted at the fields in USM prior to their game session (pivoting team sports). After completing the warm-up session, participants in both groups had their actual training session according to their sports with the respective coach for approximately 60 minutes.

The duration of 6 weeks for the intervention period was chosen because previous studies showed that at least 6 weeks is needed for the adaptations to occur (Brown *et al.*, 2017). After 6 weeks of the intervention period, a post-test was carried out. This includes the SLB test and DLT. The participants' information was kept confidential by the researchers and will not be made available to the public until legislation demands release. All information is stored on a computer and processed. Only members of the research team were given access to the participant's information.

Table 3.1: General warm-up procedures (3 times per week for 6 weeks)

1. Hamstring Stretching (2 minutes)
-Participants have to sit vertically. One leg is extended and the other leg is in contact with the inner thigh of the extended leg. -Participants have to bend forward with both hands touches the toes of the extended leg. -Hold the position for 30 seconds, relax, repeat 3 times. -The same procedure will be repeated with the opposite leg.
2. Quadriceps Stretching (2 minutes)
-Participants have to sit on the floor while bending one leg to their side. -Next, participants have to slowly lie back to stretch out the quadriceps. -Hold the position for 30 seconds, relax, repeat 3 times. -The same procedure will be repeated with the opposite leg.
3. Gastrocnemius Stretching (2 minutes)
-Participants have to put one foot in front (on the floor) and bend one knee; the other leg straight behind. -Slowly, participants have to shift the hips forward until they feel their straight leg stretched on the gastrocnemius. -Hold the position for 30 seconds, relax, repeat 3 times. -The same procedure will be repeated with the opposite leg.
4. Adductor Stretching - Butterfly stretch (2 minutes)
-Participants have to position the soles of the feet together in a sitting posture. -Participants have to push themselves forward, with their hands around the feet. -Hold the position for 30 seconds, relax, repeat 3 times.
5. Iliopsoas Stretching - Lunge stretch (2 minutes)
-Participants have to sit on both knees, push one leg forward until the forward leg's knee is directly over the ankle. -While doing that, participants have to fix the position of the knees on the ground and the forward foot. -Hold the position for 30 seconds, relax, repeat 3 times. -The same procedure will be repeated with the opposite leg.

Adapted from: Andrade et al., 2015.

Table 3.2: Neuromuscular warm-up procedures (3 times per week for 6 weeks)

1. 20-meter running exercises (3 minutes)
• 2 minutes of eight running technique exercises listed below (2 x 20 m) - Carioca running - Sideways gallop - Zigzag running forward - Zigzag running backwards - Skipping - Walking lunges × 4-8 steps and slow forward running - Slow alternate bounding - Combination hops (right-right-left-left-right-right) • A speed run (2 x 20 m)
2. Balance and body control exercises (2 minutes)
• The squat technique (Week 1-3) ○ Double leg: 2 × 10 repetitions ○ Single leg: 2 × 10 repetitions for each leg • Balance board exercise (Week 4-6) ○ Double leg: 2 × 30 seconds ○ Single leg: 2 × 30 seconds for each leg
3. Plyometrics (3 minutes)
• Forward jumps (Week 1 & 2) ○ Double leg jumps: 2 × 3 repetitions ○ Single leg hops: 2 × 3 repetitions for each leg • Jumps in place (Week 3 & 4) ○ Split squat jumps: 2 × 8 repetitions • Jumps over markers (Week 5 & 6) ○ Double leg: three-dimensional jumps: 2 × 8 repetitions ○ Single leg: three-dimensional hops: 2 × 4 repetitions for each leg
4. Strengthening exercises (2 minutes)
• Double leg squat with a pair of dumbbell : 3 × 8 repetitions (Week 1 & 2) • Isometric side and front bridge: 2 × 20 seconds for each right and left side (Week 3 & 4) • Cross curl-up: 2 × 10 repetitions for each right and left side (Week 5 & 6)

Adapted from: Pasanen *et al.*, 2008

3.7 Data Analysis & Statistics

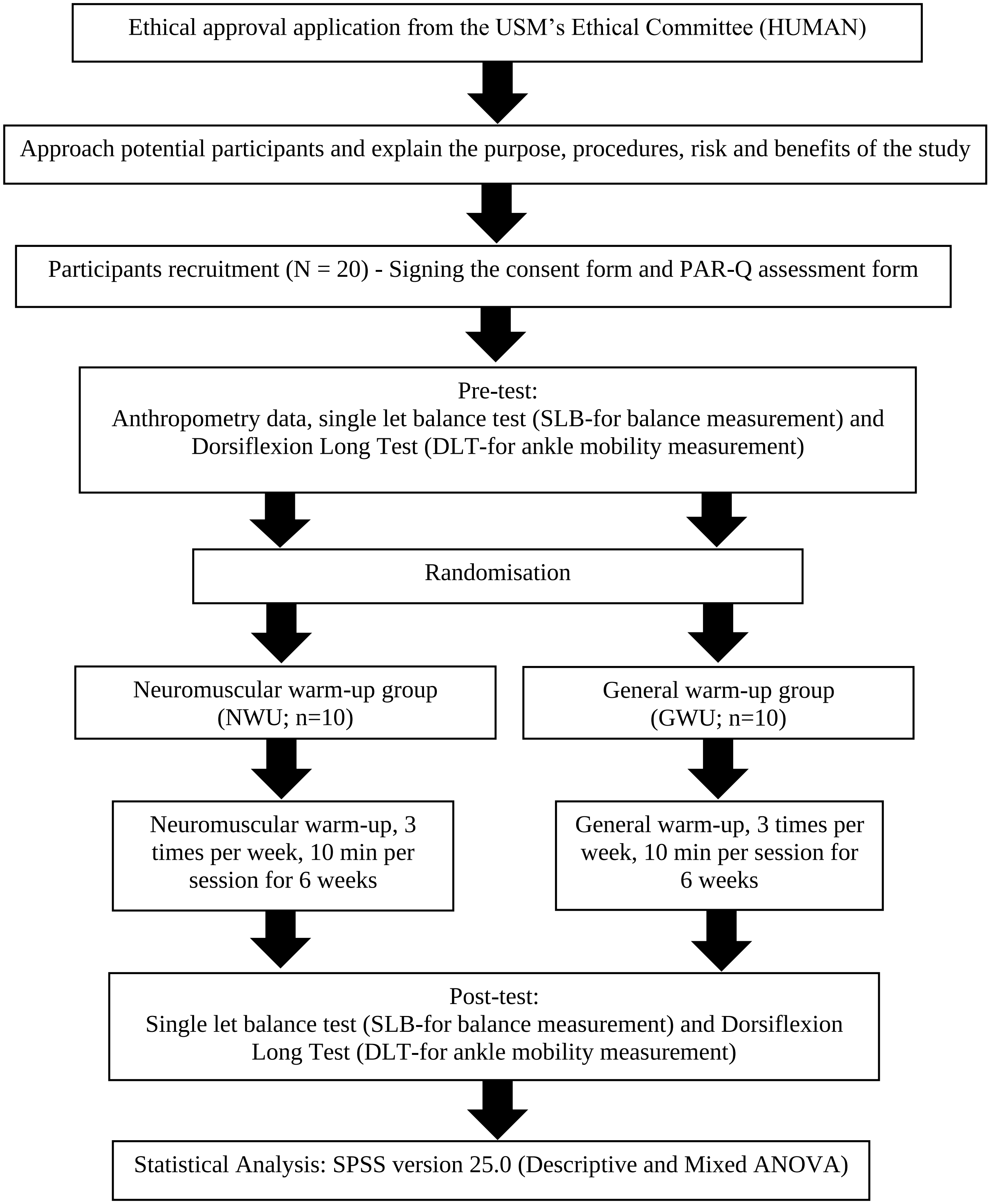
All statistical analyses were conducted using the statistical software IBM SPSS version 25.0 Armonk, NY: IBM Corp. Descriptive and mixed Analysis of Variance (ANOVA) was used. Data were presented as mean ± standard deviation (SD). The significance level for all statistical tests was set at $p \leq 0.05$.

3.8 Ethical Clearance

For ethical consideration, permission to conduct the research study was sought from the Human Research Ethics Committee (HREC), University Sains Malaysia (USM). Informed consent was obtained from every participant after they provided sufficient information regarding the nature and responsibility of the study, as well as the significance of their involvement in the study before data collection. The participants were notified of the risks, their right to participate voluntary, and the right to make the decision in whether to take part or reject the research study without any constraint or inducement and the right to discontinue the study at any time, without incurring a penalty.

There was no potential risk that might happen to participants. If the participants feel unwell before or during the tests and intervention, they were allowed to rest or postponed it to another day. The possible benefits that participants might get from this study include receiving a token of appreciation and getting an opportunity to contribute to the development of this area of study. However, all participants who were involved in this study were not covered by insurance.

3.9 Study Flowchart



CHAPTER 4
RESULTS

4.1 Physical Characteristics of The Participants

A total of 20 participants were recruited and completed the study with 10 participants in the general warm-up group (GWU) and another 10 participants in the neuromuscular warm-up (NWU) group. The mean age, body height, body weight, body mass index (BMI) and body fat percentage of participants according to the group are shown in Table 4.1. The Independent-Samples t Test was used to verify that all variables were normally distributed. There were no significant differences ($p > 0.05$) in physical and physiological characteristics of the participants between groups.

Table 4.1: Physical and physiological characteristics of the participants

Variables	NWU (n=10)	GWU (n=10)	p-value
	Mean ± SD		
Age (years)	22.0 ± 0.3	23.0 ± 1.4	0.395
Body height (cm)	159.0 ± 4.1	157.2 ± 6.6	0.475
Body weight (kg)	54.0 ± 8.5	54.9 ± 6.9	0.817
Body mass index (BMI) (kg/m^2)	21.3 ± 2.7	22.1 ± 1.9	0.431
Body Fat Percentage (%)	25.6 ± 5.2	27.0 ± 2.8	0.486

Values are expressed as means ± standard deviations (SD). P values correspond to comparison between groups
Abbreviation : NWU = Neuromuscular warm-up; GWU = General warm-up

4.2 Adherence to The Warm-up Training Programme

The total training days during the 6 weeks of intervention was 18 days. The average attendance of the participants during training sessions was good at 95%.