COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING AMONG FEMALE RECREATIONAL PLAYERS WITH AND WITHOUT HISTORY OF ANKLE SPRAIN

NUR NEESA ADRYANA BINTI SABRI

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COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING AMONG FEMALE RECREATIONAL PLAYERS WITH AND WITHOUT HISTORY OF ANKLE SPRAIN

by

NUR NEESA ADRYANA BINTI SABRI

Thesis submitted in fulfilment of the requirements

for the degree of

Bachelor of Health Science (Exercise and Sport Science)

June 2021

CERTIFICATE

This is to certify that the dissertation entitled COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING AMONG FEMALE RECREATIONAL PLAYERS WITH AND WITHOUT HISTORY OF ANKLE SPRAIN is the bona fide record of research work done by Mr/Ms NUR NEESA ADRYANA BINTI SABRI during the period from March 2020 to June 2021 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Health Science (Honours) (Exercise and Sport Science).

Main supervisor,

Dr. Shazlin Shaharudin

Lecturer,

Exercise and Sports Science Programme, School of Health Sciences

Universiti Sains Malaysia, Health Campus,

16150 Kubang Kerian, Kelantan, Malaysia

Date: 23 JUNE 2021

DECLARATION

I hereby declare that this dissertation is the result of my own investigation, 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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NUR NEESA ADRYANA BINTI SABRI

Date: 21 June 2021

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACL	Anterior Cruciate Ligament
ASIS	Anterior Superior Iliac Spine
BMI	Body Mass Index
DKV	Dynamic Knee Valgus
IC	Initial Contact
GRF	Ground Reaction Force
QTM	Qualisys Track Manager
SD	Standard Deviation
SLL	Single Leg Landing
SPSS	Statistical Package for the Social Sciences
JEPeM	Jawatankuasa Etika Penyelidikan Manusia
USM	Universiti Sains Malaysia
WHO	World Health Organisation

LIST OF APPENDICES

PERBANDINGAN BIOMECHANIK KAKI SEMASA PENDARATAN KAKI TUNGGAL DALAM KALANGAN ATLET REKREASI WANITA YANG MEMPUNYAI SEJARAH ATAU TIDAK MEMPUNYAI SEJARAH BUKU LALI TERSELIUH.

ABSTRAK

Tujuan kajian ini adalah untuk membandingkan pemboleh ubah kinetik anggota bawah (iaitu sendi lutut, buku lali dan pinggul) (iaitu momen) dan kinematik (iaitu sudut) antara dua kumpulan (iaitu, n=15 dengan sejarah pergelangan kaki dan n=15 tanpa sejarah pergelangan kaki) di kalangan atlet rekreasi wanita dalam sukan bola tampar, bola jaring dan bola keranjang dari Universiti Sains Malaysia, Kampus Kesihatan. Pemboleh ubah kinetik dan kinematik atlet diukur dan dikenal pasti pada dua fasa pendaratan (iaitu, Kontak Awal dan daya tindak balas tanah menegak maksimum) dengan menggunakan Qualisys Track Manager (v2.16) yang terdiri daripada enam kamera tangkapan gerakan dan satu platform kekuatan Bertec. Kemudian pengiraan dinamik songsang bagi menghasilkan model kerangka otot dilakukan dengan menggunakan perisian V3D Pro (v5). Atlet diarahkan untuk melakukan pendaratan satu kaki selama tiga kali percubaan pada plat pengukur daya. Ujian-t bebas digunakan untuk menilai sama ada terdapat perbezaan yang signifikan di antara kumpulan. Berdasarkan ujian, terdapat perbezaan yang signifikan untuk sudut pinggul pada kontak awal yang mana kumpulan dengan sejarah menunjukkan peningkatan pinggul yang lebih besar (p= 0,01) dibandingkan dengan kumpulan tanpa sejarah pada kinematik satah hadapan. Untuk kinetik satah hadapan, terdapat perbezaan yang berbeza (iaitu, momen pinggul (p = 0.04) dan momen lutut (p = 0.03) pada vGRF maksimum xi dan

momen pergelangan kaki ($p = 0.01$) pada kontak awal) antara kumpulan. Dari hasil kajian, ia menunjukkan bahawa, atlet universiti wanita yang mempunyai sejarah kecederaan pergelangan kaki mendarat dengan valgus lutut dinamik (DKV) yang mana hasilnya menunjukkan *adducted* pinggul, *abducted* lutut dan *everted* pergelangan kaki yang lebih tinggi berbanding dengan yang tidak mempunyai sejarah kecederaan pergelangan kaki. Oleh itu, jurulatih dan pemain disarankan untuk memasukkan lebih banyak sesi latihan yang akan menumpukan pada latihan kekuatan untuk otot pinggul, sendi lutut dan pergelangan kaki terutamanya untuk atlet wanita dengan sejarah pergelangan kaki.

COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING AMONG FEMALE RECREATIONAL PLAYERS WITH AND WIHOUT HISTORY OF ANKLE SPRAIN

ABSTRACT

The purpose of this study was to compare the lower extremities' (i.e., Ankle, Hip and Knee joint) kinetics (i.e., moments) and kinematics (i.e., angles) variables between two groups (i.e., n=15 with history and n=15 without history of ankle sprain) among recreational volleyball, netball and basketball athletes from Universiti Sains Malaysia, Health Campus. Kinetic and kinematic variables of the athletes were measured and identified at two phases of landing (i.e., Initial Contact and Maximum vGRF) using Qualisys Track Manager (v2.16) which consists of six motion capture camera and one Bertec force platform. Then inverse dynamic calculation for musculoskeletal model was conducted using V3D Pro software (v5). Athletes were instructed to do Single Leg Landing (SLL) for a total of three trials on the force plate. Independent T-test was used to evaluate if there was any significant differences across groups. Based on the test, there were significant different for hip angle at initial contact which group with history showed greater hip adduction (p=0.01) compare to group without history on frontal plane kinematics. For frontal plane kinetics, there were significances different (i.e., hip moment (p=0.04) and knee moment (p=0.03) at maximum vGRF and ankle moment (p=0.01) at initial contact) between groups. From the results, it showed that, female university athletes with history of ankle sprain landed with dynamic knee valgus (DKV) which the results shown hip adducted, knee abducted and ankle everted compared to those without history of ankle sprain. Therefore, coaches and players are suggested to

include more training sessions that will focus on strength exercises for hip muscles, knee and ankle joint particularly among female athletes with history of ankle sprain.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Ankle sprain is one of the most common injuries in sports, and reinjury rates as high as 73% have been reported (Yeung et.al., 1994). Sprains were also very common in sports, especially court games and team sports. Ankle-injury incidences were highest in court games and team sports, such as rugby, soccer, volleyball, handball and basketball (Fong et al., 2007). It often occurs during a jump landing or lateral (i.e., side-to-side) motion, particularly when participants are fatigued (Webster et al., 2016). When a substantial lateral ankle sprain occurs, a common outcome is the repeated giving way of the ankle during activities which is known as ankle instability. Chronic ankle instability (CAI) is characterised by residual lateral instability categorised as mechanical instability related to anatomical changes in tissues surrounding the ankle (Hertel, 2000). It is also a functional or perceived instability related to neuromuscular changes, or recurrent sprains in which a patient experiences repeated inversion injury with activity (Hertel, 2000).

The ankle, one of the most important lower extremity joints helps maintain centre of mass (COM) and body posture stability (Lee and Lin, 2007). Ankle sprains account for as many as 15%-25% of the injuries treated in medical practice and 10%-30% of all injuries in sports (Lötscher and Hintermann, 2014). In a systematic large-scale review, Fong et al, (2007) showed 49.3% of ankle sprains were caused by participation in sports, with basketball (41.1%), football (9.3%), and soccer (7.9%) accounting for over half of all ankle sprains sustained during athletic activity (Fong et al., 2007; McCriskin et al., 2015; Waterman et al., 2010). About half of all athletes who sprain their ankles do not seek medical assistance after the incident, and this may have a profound adverse impact on their future in sports (Jian-Zhi et al., 2019). Reluctance to receive rehabilitation and treatment after an ankle sprain causes symptoms such as long-term ankle instability and pain (Macleod et al., 2014) as well as increased likelihood of recurrent injuries (Delahunt et al., 2010; Sierra-Guzman et al., 2017). Mechanical ankle instability and functional ankle instability likely exist on a continuum, are not easy to separate, and may occur in both amateur athletes and elite athletes. The relapse rate for ankle sprains can reach as high as 40% and often lead to CAI (Wikstrom and Brown, 2013; Yeung et al., 1994).

Basketball, netball and volleyball are sports that require frequent jumps and landings, cutting manoeuvres and contact with other players. For this study, the target players are female recreational athletes who involved regularly in training of these sports. Due to the training and competitive games, athletes are more prone to get ankle sprain injuries. For example, in netball, it involves jumping and landing almost all the time during the game which can lead to injury if not landing correctly. Besides, volleyball players sometimes also land with single leg landing after spiking and for basketball, some athletes use single-leg landing(SLL) after jumping to block opponent or to score a point. All the landing in this sport usually involve SLL technique and based on personal experience, many of my teammates in my netball teams had a history of ankle sprain when playing netball. So, this is the purpose why I wanted to research about SLL among female athletes because I want to know the events or processes that may lead to ankle sprains in athletes.

Findings of the meta-analysis of cumulative incidence rate and prevalence period by sex elucidated a higher risk of ankle sprain in females compared with males (Doherty et al., 2013). Of the 94 studies that did report exposure figures for sex, 42 reported ankle sprain per 1,000 athlete exposures and 44 reported ankle sprain per 1,000 h, giving a cumulative incidence rate of 13.6 sprains per 1,000 exposures in women versus 6.94 per 1,000 exposures in men (Doherty et al., 2013). This is probably due to high joint flexibility but less muscular strength among women compared to men (Jacobson, 2006). Moreover, excessive dynamic knee valgus, which is an altered kinetic chain of lower limb observed during dynamic tasks such as landing, is more common in females (Hewett et al., 2005). Besides, due to menstrual cycle which is oestrogen is known to affect pain perception, thus a sportswoman might be more likely to report injuries during low-oestrogen states, such as around the time of her menses (Jacobson, 2006).Therefore, in the current study, data collection was conducted during any phases of menstrual cycle except during menstruation.

Despite the high prevalence of CAI among female athletes in these sports, to the best of our knowledge, studies on SLL from maximum jump were limited. Moreover, studies that compared lower limb biomechanics during SLL among those with and without history of ankle sprain are scarce. Therefore, the purpose of this study is to compare the lower limb biomechanics during SLL among female recreational players with and without history of ankle sprain. This is crucial to understand and attenuate the progression of ankle sprain to CAI. Ankle sprains and subsequent CAI may lead to significant time loss from participation in sports, delayed return to play, and persistent disability in individuals who participate in sporting events.

1.2 Objectives

1.2.1 General objective

To compare the lower limb biomechanics during single leg landing among female recreational players with and without history of ankle sprain

1.2.2 Specific objectives

1. To compare the lower limb kinematics during single leg landing among female recreational players with and without history of ankle sprain
2. To compare the lower limb kinetics during single leg landing among female recreational players with and without history of ankle sprain

1.3 Research Hypothesis

1. H_o : There are no significant differences of lower limb kinematics during single leg landing among female recreational players with and without history of ankle sprain

   H_1 : There are significant differences of lower limb kinematics during single leg landing among female recreational players with and without history of ankle sprain

2. H_o : There are no significant differences effect of lower limb kinetics during single leg landing among female recreational players with and without history of ankle sprain

   H_1 : There are significant differences of lower limb kinetics during single leg landing among female recreational players with and without history of ankle sprain

1.4 Problem statement

Ankle sprain is the most common type of ankle injuries. Proper landing techniques are imperative for stabilising the ankle during a jump landing. Awkward landings could permit the foot to invert excessively and, consequently, causes ankle ligament sprains (Ross et al., 2002). Sports such as netball, volleyball and basketball involved intense single leg landing particularly during competitive game situation. Female players are prone to get ankle injuries compared to male players during a jump landing due to excessive dynamic knee valgus motions in female players. However, studies that compare lower limb biomechanics during single leg landing among female recreational players with and without history of ankle sprain are scarce. This aspect is crucial to understand the biomechanical differences of lower limb across those with and without history of ankle sprain, so that preventive measures can be taken to attenuate the progression of ankle sprain to CAI.

1.5 Significance of the study

Findings of the present study may assist clinician, coaches and athletes in prescribing prevention program or non-operative treatment to prevent ankle sprain and CAI among female athletes. Specifically, our results may assist the athletes to practice safer landing techniques during training and competitions. This may reduce the number of ankle sprain injuries and CAI that often occurs during non-contact movement in females.

1.6 Operational Definition

Table 1.1 Operational Definition

	Operational definition
Female Recreational Players	College student that participates in specific sport (volleyball, netball and basketball) and has played casually or competitively in the minimum of three months before the recruitment period.
Single-leg landing from maximum jump height	A vertical distance from bottom to top that require participant to jump off from a platform based on their maximum jump height and land with a single leg.
History of ankle sprain	Those who was diagnosed with grade 1 ankle sprain for at least six months prior to data collection (Lamb, et al., 2005)

CHAPTER 2

LITERATURE REVIEW

2.1 Biomechanics of Landing

Biomechanics of landing is important to be investigated because landing is a common manoeuvre in many sports such as netball, basketball and volleyball. It has been postulated, for example, that if an athlete is not properly aligned or if an unusual foot placement at landing occurs, he or she may be at increased risk for injury (Steel & Milburn, 1987). Muscle activity and joint motion are important in decreasing the impact forces associated with landing which must be attenuated in the lower extremity joints (Tamura, et al., 2017). Therefore, there is a risk of injury during landing activities, and the kinematics and forces involved in different landing strategies may be closely related to the occurrence of trauma (Self & Paine, 2001). Additionally, excessive knee valgus or hip adduction during jumping, squatting, and lunging movements are often considered as a mechanism associated with lower extremity injuries (Herrington, 2011).

Most landing studies focused on several common biomechanical variables to characterise the role of different factors in injury (Ball et al., 1999: Colby et al., 2000). These variables include the joint kinematics and peak vertical ground reaction force (vGRF). Peak vGRF may elaborate internal loads that may cause injury if not sufficiently distributed or attenuated by the musculoskeletal system (Salci et al., 2004). Additionally, some studies have investigated the biomechanical factors that can minimise the impact force and knee loading during landing. For instance, Devita & Skelly (1992) reported that subjects had reduced GRF when landing with increased knee flexion angle. While Chappell (2005) found that male athletes decreased their knee flexion angle at initial contact during stop-jump landing when fatigued. These results appeared to indicate that increasing knee flexion angle at initial contact with the ground may decrease impact forces and knee loading in landing tasks. Moreover, the landing height has been reported to affect joint kinematics, kinetics and energetics. A previous study showed that ankle and hip extensor moments significantly increased with landing height 0.32–1.28 m (Yeow et al., 2009). Zhang, et al., (2000) further demonstrated that moments, powers and eccentric work at lower extremity joints can be generally elevated with an increment in landing height. Based on these biomechanical studies, safer landing techniques have been identified and practised worldwide.

There are two types of jump-landing which are single legged and double legged landings. Both types of landings involve three motions, which are ankle dorsiflexion, knee flexion, and hip flexion (Taylor et al., 2016). Single-leg landings (SLL) result in significantly decreased knee flexion at the floor contact (i.e., stiff landing), increased knee valgus, and increased rectus femoris activity as compared to double-legged landings (Devita & Skelly, 1992). Previous investigators have suggested that a single-leg landing is more likely to cause ACL injuries because of the decreased knee and hip flexion angles and less-efficient energy dissipation strategies during a single-leg landing compared with a double-leg landing (Wang, 2011; Yeow, Lee, & Goh, 2010, 2011). Therefore, it is valuable to evaluate lower extremity biomechanics during single-leg landings.

Basketball is a very popular team sport throughout the world, characterised by short and explosive efforts, agility, rapid changes of direction, as well as jumping and landing movements. Regardless of the specific motor skills, the jumping and landing abilities of these athletes are one of the key elements in successful basketball performance. Jumping is the skill that attribute for defensive and offensive plays in basketball. Competitive basketball games require up to 70 jumps per player and include jump shots, blockshots, rebounds and lay-ups (BenAbdelkrim, et al., 2007; McClay et al., 1994; McInnes et al., 1995). In basketball, rapid and repetitive jumps are often required for rebound and block actions (Wissel, 2012). These jumps can lead to strenuous loads on the lower limb during landing and can be regarded as the common risk factor for ankle ligament, anterior cruciate ligament (ACL), and fifth metatarsal stress fracture injuries (Cumps et.al., 2007; McKay et al., 2001; Siegmund et al., 2008).

Volleyball has unique biomechanical demands on athletes, including the completion of repetitive jump-landing manoeuvres during training or competition. It has been observed that female volleyball athletes perform up to 73 jump-landings over the course of a two games period (Tillman et al., 2004). Landings after a block jump could be single- or double-leg landings depending on prior placement or action. SLL frequently occur when players move from the middle of the court as middle blockers (Lobietti et al., 2010) or after spiking during games (Tillman et al., 2004).

Landing from a jump is a task that is important in netball. It is a skill that is intrinsic to successful performance. The forces associated with landings in netball have been shown to be considerable. For instance, Steele &Milburn (1989) noted vertical ground reaction forces (VGRFs) up to 6.8 times of body weights during landings. In netball, how the players land may affect their agility when changing direction. Additionally, the current rules in netball whereby the players have to step at landing from a jump restrict the player to take only one step after landing. Therefore, rapid deceleration of the body must occur, hence VGRFs on landing are typically high among netballers (Hopper et al., 1999).

2.2 Injuries associated with landing

Ankle sprains are one of the most common injuries associated with athletics (Hootman et al., 2007). Furthermore, up to 73% of athletes who sustain ankle sprains experience recurrent ankle sprains and 59% show functional loss and residual symptoms that have impaired athletic performance. (Yeung et al., 1994). Residual symptoms resulting from ankle sprains are often associated with a condition known as chronic ankle instability (CAI). Based on Hertel (2002), CAI may be associated with several mechanical impairments in ankle function, including a deficit in ankle-joint dorsiflexion range of motion (ROM). In the biomechanics of tasks involving landing, dorsiflexion ROM plays a prominent role during landing whereby greater passive open chain dorsiflexion ROM has been associated with greater hip and knee flexion and lower ground reaction forces (GRFs) during a jump-landing task in healthy individuals (Fong et al., 2011). Those with greater dorsiflexion ROM land with a less erect posture by using greater sagittal-plane displacement, which allows the body to attenuate forces more efficiently (Fong et al., 2011). Therefore, the available amount of dorsiflexion ROM may influence function not only at the ankle but also at more proximal structures in the lower extremity.

People with chronic ankle instability (CAI) exhibit less weight-bearing dorsiflexion ROM and less knee flexion during landing than people with stable ankles. Examining the relationship between dorsiflexion ROM and landing biomechanics may identify a modifiable factor associated with altered kinematics and kinetics during landing tasks. During a SLL, persons with CAI demonstrated moderate to strong relationships between dorsiflexion ROM and sagittal-plane kinematics at the knee and hip and vGRF (Hadzic et al, 2009 ; Aerts et al, 2013). Persons with less dorsiflexion ROM exhibited a less flexed landing (i.e., stiff landing) strategy that attenuated GRF less efficiently. Persons who have CAI and less dorsiflexion ROM may also exhibit more erect landing postures and greater GRF, which may have implications for sustaining future lower extremity injuries or episodes of giving way (Hadzic et al, 2009 ; Aerts et al, 2013).

Numerous studies have observed differences in lower extremity biomechanics between male and female athletes during landing and cutting activities. The injury mechanisms at the knee joint are multifactorial and are complicated due to the requirements of specific movement activities performed in dynamic environments (i.e., athletics venues). Both contact and non-contact activities play critical roles in determining how the knee joint responds to the given loading conditions. The type of training, task, fatigue level of the individual, and anatomical structure contributes to the potential injury of the knee joint. In particular, when landing from a certain height, the knee biomechanics are modified to absorb energy to reduce the impact of the contact forces upon the lower extremities. Females are reported to have greater dynamic knee valgus which is a potential sign of knee injury at landing compared to males, and thus a greater potential for knee injury (Olson, 2019). Proposed mechanisms to achieve this include neuromuscular training on correct foot landing, shoe design such as higher ankle support, and myo electric anti-sprain stimulation (Fong, Chu, & Chan, 2012).

Females tend to land in a more upright posture with less hip and knee flexion, greater internal hip rotation, tibial rotation, and knee valgus. However, the presence of adult gender differences in landing mechanics may depend on the landing types (e.g., single leg, double leg) and landing tasks (e.g., drop jump, vertical jump, strides jump). The biomechanical explanation often given for this injury is a more extended knee position at ground contact, which results in higher external GRF, as well as a greater resultant force vector between the patellar tendon and the tibia coupled with a large eccentric quadriceps contraction (Hughes et al., 2008). These biomechanical factors culminate in increased anterior translation of the tibia relative to the femur, which can mechanically strain the ACL. These performance mechanics are also supported by functional electromyographic (EMG) studies that have shown females employ a neuromuscular strategy, defined by significantly greater quadriceps activation and significantly less hamstring activation, during landing (Hughes et al., 2008)

2.3 Dynamic Knee Valgus

Dynamic knee valgus (DKV), described as a combination of hip adduction, hip internal rotation, and knee abduction is recognised as a common lower extremity alignment seen in non-contact injury situations (Tamura, et al., 2017). It is an abnormal movement pattern visually characterised by excessive medial movement of the lower extremity during weight bearing (Figure 2.1). An increased knee valgus angle during landings is one of the main causative factors for non-contact injuries, including ankle sprain and ACL tear. Prospective studies have reported that increased knee valgus angle and knee abduction moment during landings were predictive of non-contact injuries in female athletes. These studies suggested the importance of injury prevention for athletes who land with DKV (Tamura et al., 2017).

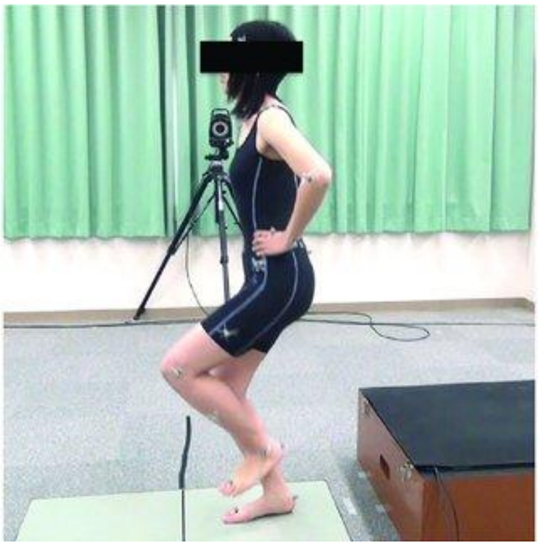

Figure 2.1 Subject landing with single leg after jumping

(adapted from https://www.researchgate.net/profile/Kiyokazu_Akasaka/publication/317712962/figure/fig1/AS:508181235367936@1498171256892/The-landing-phase-of-a-single-leg-drop-vertical-jump-A-single-leg-drop-vertical-jump-on_Q320.jpg)

The risk of injury in sport may be related to deviations in lower-limb alignment. DKV that occurs across three planes of movement and consists of internal rotation and adduction of the femur and concomitant contralateral pelvic drop, is an example of biomechanical deviation. Differences in hip and knee kinematic components of DKV may explain the emergence of different pain problems in people who exhibit the same observed movement impairment (Schmidt et al., 2019). DKV is regarded not only as frontal plane motion (hip adduction, knee abduction, and ankle eversion), but also as horizontal plane motion (femoral internal rotation and tibial internal or external rotation). There is no consensus about the direction of tibial rotation during dynamic knee valgus. Tibial rotation should be significantly affected by ankle and foot kinematics. Ankle eversion causes tibial internal rotation, and foot internal and external rotations also theoretically causes tibial internal and external rotations through the ankle joint (Ishida et al., 2014). During one leg landing, the knee rotates internally immediately after initial contact, and females demonstrated greater internal rotation than males (Kiriyama et al., 2009; Nagano et al.,2007). They speculated that greater internal rotation immediately after landing is a risk factor for ACL injury (Nagano et al., 2007).

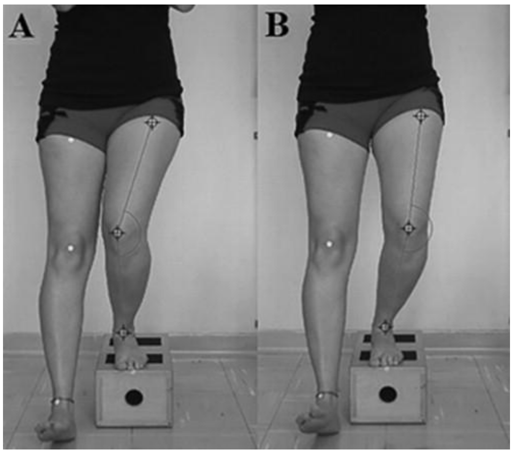

Figure 2.2 Dynamic knee valgus in figure A and normal motion in figure B

(adapted from https://www.bodyworkmovementtherapies.com)

The mechanism of DKV is commonly described with proximal (top-down) and distal (bottom-up) kinetic chain. Most studies focused on top-down kinetic chain for example effects of hip strengthening training on DKV (Azhar et al., 2019; Mail et al., 2019). At the moment, studies on bottom-up kinetic chain (i.e., effects of foot arch, foot position, ankle strength, ankle ROM on DKV) are scarce. Hence, by studying landing biomechanics among those with and without history of ankle sprain, indirectly it may shed lights on the bottom-up kinetic chain of DKV.

CHAPTER 3

METHODOLOGY

3.1 Study Design

This was a cross-sectional study. Thirty (30) female recreational players were recruited in this study which consists of 15 athletes with history of ankle sprain and 15 athletes without the history of ankle sprain. The target population was the students in Universiti Sains Malaysia who are playing sports that involve jumping and landing such as volleyball, netball and basketball. The participants were selected based on inclusion and exclusion criteria. Each participant went a session of SLL test which took about 30 minutes per session. The study was conducted at Exercise and Sports Science laboratory of School of Health Sciences, Universiti Sains Malaysia, Kota Bharu, Kelantan. The protocol of this study was approved by Human Research Ethics Committee, Universiti Sains Malaysia (USM/JEPeM/20050214)

3.2 Sample Size Calculation

The sample size calculation was done by using the G*Power Software which is a free-to-use software used to calculate statistical power. This software was available in University Dusseldorf official website. A prior sample size of independent t-test shows that 15 participants were sufficient to yield 0.8 power of study with effect size 0.9. Effect size was based on Cohen (1998). Cohen suggested that d=0.9 be considered a 'large' effect size. From this calculation, 16 participants were needed to be able to reject null hypothesis. By inclusion of 20% drop out, a total of 18 participants per group were recruited. Purposive sampling method was also applied.

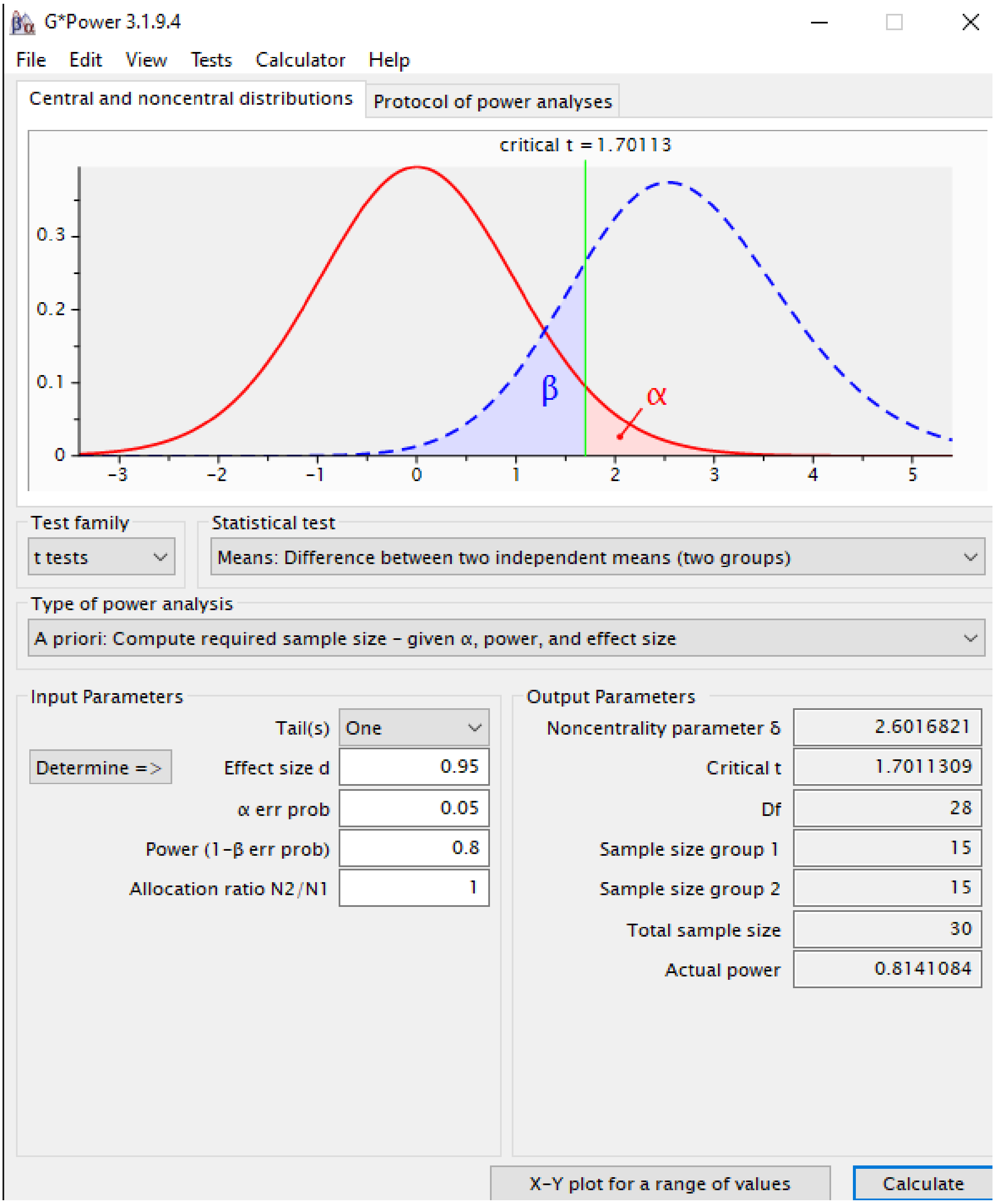

Figure 3.1 Sample Size Calculation

3.3 Study Participants

These were the inclusion and exclusion criteria for those without ankle sprain.

3.3.1 Without Injury Group

Inclusion Criteria:

- Have normal Body Mass Index (Table 3.1)
- Age between 19 to 25 years
- Recreational player involved in jumping sport in either netball, volleyball or basketball
- Have no history of ankle sprain

Exclusion Criteria:

- Have history of ankle sprain

3.3.2 With Injury Group

Inclusion Criteria:

- Was diagnosed with grade 1 ankle sprain after six months and prior to data collection (Lamb, et al., 2005)
- Have normal Body Mass Index (Table 3.1)
- Age between 19 to 25 years
- Recreational player that play jumping sport in either netball, volleyball or basketball

Exclusion criteria

- Had an injury of ankle sprain and/or other back and lower limb injuries less than six months prior to data collection
- Actively playing

Table 3.1 The Classification of BMI from The International Classification of adult underweight, overweight and obesity according to BMI (adapted from World Health Organization, 2004)

Classification	**Body Mass Index (BMI)**(kg/m²)
Underweight	< 18.5
Normal	18.50 – 24.99
Overweight	≥ 25.00
Obesity	≥ 30.00

3.3.3 Recruitment of Participants

All participants were recruited voluntarily through advertisement and word of mouth. The details of the study methodology were provided and explained prior to their agreement. Participation of the study was opened to basketball, netball, and volleyball players. This study only involved students of Universiti Sains Malaysia, Health Campus. Participants were encouraged to decide their involvement in the study without other outside influence such as their friends, teammates and coaches. They filled an informed consent form upon agreement to participate.

3.4 Study Protocol

The purpose of this study was to compare the lower limb biomechanics during single leg landing between athletes with and without history of ankle sprain.

Recruitment of participants

Female athletes with history of ankle sprain

n=18

Female athletes without ankle sprain

n=18

Single Leg Landing Test

- Warming up session (5 minutes)
- The participants need to cycle on Cycle Ergometer at 60 RPM with 50 Watts of work rate with additional of 5 times squat jumps
- The participants will perform 3 times maximal double leg jumping of dominant leg without specific heights (based on its maximum height) and then execute single leg landing of the same leg on force platform
- The participant will be given 5 minutes rest interval between trials.
- After all trials was completed then the participants will perform cooling down (5 minutes) cycle on an unloaded cycle ergometer (60 RPM).

Analysis of data

Figure 3.2 Study flowchart

3.4.1 Physical Characteristics of Participants

Firstly, when the participants agreed to join this study, they were given an inform consent form. In the form, they were asked to provide honest information about their medical history and medications. After through explanation regarding the study details, their signed consent form was obtained.

Then, they went a physical check up, which include measurement of height, body fat percentage, and the length of leg segments. Body weight (kg) and height (cm) were measured with a digital medical scale (Seca 769, Hamburg, Germany) while body fat percentage were evaluated using Electronic Body Fat Percentage Analyzer (Omron HBF-360, Kyoto, Japan). The length of the leg segments were measured using a measuring tape. Leg length was quantified as the distance (cm) from the anterior superior iliac spine (ASIS) to the centre of the ipsilateral medial malleolus with the participant in standing and supine positions. Next, single leg test were conducted by the participants.

3.4.2 Test Protocol

The test was conducted at Exercise and Sports Science Lab, Universiti Sains Malaysia. The participants were required to wear fit clothes for ease of movement and accuracy of data collection.

3.4.2.1 Single Leg Landing test (SLL)

Upon arriving the lab, participants were instructed to do a warming up session for 5 minutes on a Cycle Ergometer (Cybex Inc., Ronkonkoma, NY, USA). The cycle ergometer was set at 50 Watts of resistance and the participants were required to cycle at constant velocity of 60 RPM throughout the warming up session. Then, the warming up session was continued with 5 times of ballistic jumps. These warming up session was important in order to prevent injury by preparing the muscles, tendons, joints and bones for the activity.

Figure 3.3 Cycle Ergometer

(adapted from https://pimage.sport-thieme.de/detail-fillscale/ergo-fit-cycle-4000-ergometer/225-2302)

Then, participants were required to change their clothes into a fit wear. After that, a number of 35 retroreflective markers were placed on their lower body based on the Plug-in-Gait Marker Set, specifically on the sacrum, bilaterally on anterior superior iliac spine, medial and lateral thigh, medial and lateral femoral epicondyle, lateral shin, calcaneus, medial and lateral malleolus and second metatarsal for static measurements. Following static pose captured, six markers from the medial parts of the lower limb were removed for the dynamic measurement or actual testing. Accurate markers placement on selected anatomical landmarks is important to create bone model of the participants. They were asked to jump with two legs as high as they can which is based on their maximum height of jumping and then land with a single leg on the force platform (Kistler, Switzerland). The jumping and landing trials were conducted for three times with dominant leg (injured vs non injured) as the land leg. Participants performed single leg landing (SLL) task with barefoot, to remove the influence of shoes' impact absorption ability and also the bias of wearing different types of shoes across participants. After all the test trials have completed, the participants cycled on unloaded cycle ergometer at 60 RPM for 5 minutes and conducted leg stretching as part of the cooling down session.

The trajectories of the reflective markers during SLL were identified using Qualisys Track Manager Software (Qualisys, version 2.6.673, Gothenburg, Sweden). There were six cameras captured which are three at the front and three at the back. Then, inverse dynamics calculation was applied to build a musculoskeletal model using visual 3D (V3D) analysis software by C-Motion (V3D software, version 6.03.06, Germantown USA). Further analysis using the software were carried on to identify the lower limbs kinematics and kinetic variables in frontal plane.

Figure 3.4 Retroreflective markers

(adapted from https://cdn-content.qualisys.com/2014/12/super-spherical-markers-3634-314x314.jpg)

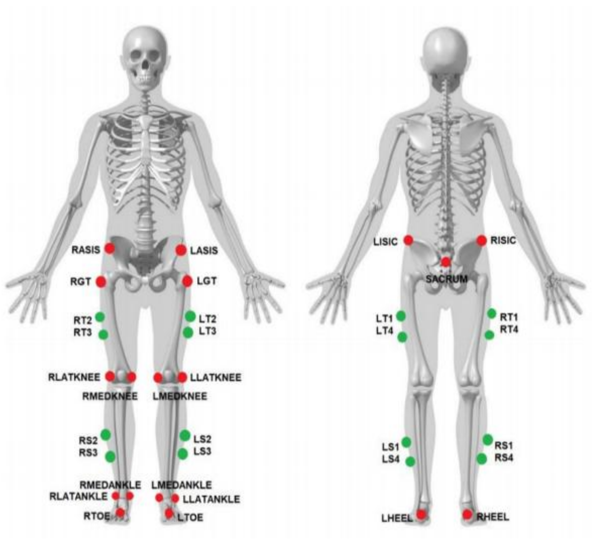

Figure 3.5 Gait module sample and marker's placement for lower limb

(Image from https://www.qualisys.com/software/analysis-modules/)

Figure 3.6 Single Leg Landing test

(adapted from

researchgate.net/profile/Boyi_Dai/publication/283682650/figure/fig4/AS:61430954985

0626@1523474218041/figure-fig4_Q320.jpg)

3.5 Statistical Analysis

In this research of study, Statistical Package for the Social Sciences (SPSS) version 25.0 was used to perform statistical analysis. The distribution of data was tested using Shapiro-Wilk Test since it is more precise for smaller sample size ($n<50$). Independent t-test was used to compare the lower limb biomechanics of female university athletes with and without history of ankle sprain. Kinematics and kinetics of hip, knee and ankle joint were compared during landing at two distinct phases of landing (e.g., initial contact and maximum vGRF).

3.6 Community sensitivities and benefits

The study was conducted in a close room; this was due to community sensitivity and to protect participants' privacy. Opposite gender was not allowed to be around the testing area. The researcher's team from the same gender conducted the test in an enclosed lab setting. There were minimal potential risks toward the participants. Researcher in charged had made sure the participants followed the correct testing procedure toward the end of the session in order to prevent any harm from occurring. Any effort or precautions such as warming up, demonstrations, familiarisation and cooling down were done in order to reduce health and fitness related risks. First aid kit and professional staff were ready if any unexpected situation may occur. If participants have any injuries caused by participation in the study, participants were referred to Hospital Universiti Sains Malaysia, for an extensive medical examination.

Following participation in the study, the athletes learned about the biomechanical factors during landing that were inefficient and dangerous to them. Besides, coaches also benefit from the study in term of planning for injury prevention intervention which not only can contribute to the participated athletes but to the whole