# A BIOMECHANICAL COMPARISON OF DOMINANT VERSUS NON-DOMINANT LEG DURING SINGLE LEG LANDING AMONG FEMALE VOLLEYBALL RECREATIONAL PLAYERS

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**A BIOMECHANICAL COMPARISON OF DOMINANT VERSUS NON-DOMINANT LEG DURING SINGLE LEG LANDING AMONG FEMALE VOLLEYBALL RECREATIONAL PLAYERS**

**By**

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Dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Health Science (Honours) (Exercise & Sports Science)

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## CERTIFICATE

This is to certify that the dissertation entitled "A BIOMECHANICAL COMPARISON OF DOMINANT VERSUS NON-DOMINANT LEG DURING SINGLE LEG LANDING AMONG FEMALE VOLLEYBALL RECREATIONAL PLAYERS" is the bona fide record of research work done by Ms "NADHIRAH BINTI MANSOR" during the period from March 2020 until 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 fulfillment for the degree of Bachelor of Exercise and Sports Science.

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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.

Date: 23 JUNE 2021

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Signature,

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## LIST OF ABBREVIATIONS

2D= Two Dimensional

3D= Three Dimensional

ACL = Anterior Cruciate Ligament

ASIS = Anterior Superior Iliac Spine

BMI= Body Mass Index

DKV = Dynamic Knee Valgus

IC = Initial Contact

MVGRF = Maximum Vertical Ground Force

SD = Standard Deviation

SLL = Single Leg Landing

SPPS= Statistical Package for Social Sciences

WHO= World Health Organization

PERBANDINGAN BIOMEKANIKAL KAKI DOMINAN DENGAN KAKI BUKAN DOMINAN SEMASA PENDARATAN KAKI TUNGGAL DALAM KALANGAN PEMAIN REKREASI BOLA TAMPAR WANITA

## ABSTRAK

Bola tampar telah menjadi salah satu sukan yang paling banyak mengambil bahagian di dunia. Penyertaan memerlukan pengetahuan tentang banyak kemahiran fizikal, dan prestasi biasanya bergantung kepada keupayaan individu untuk melompat dan mendarat. Kecederaan ACL adalah koyak atau terseliuh ligamen anterior cruciate (ACL). Kebanyakan kecederaan ACL untuk sukan yang tidak bersentuhan berlaku semasa pendaratan dan mungkin disebabkan oleh keabnormalan biomekanikal anggota kaki atau ketidakseimbangan dalam anggota badan yang dominan dan tidak dominan. Tujuan kajian ini adalah untuk membandingkan biomekanikal kaki dominan dan bukan dominan semasa pendaratan kaki tunggal dalam kalangan pemain rekreasi bola tampar wanita. Lima belas pemain bola tampar rekreasi universiti wanita telah menyertai kajian ini. Empat belas daripada peserta mempunyai kaki kanan sebagai kaki dominan. Mereka melakukan tiga kali ujian tiga-dimensi (3D) "Single Leg Landing" (SLL) pada kedua-dua kaki dominan dan bukan dominan. Sendi ekstremiti yang lebih rendah iaitu pergelangan kaki, pinggul dan lutut kinematik serta kinetik telah dinilai menggunakan "Qualisys Motion Capture System". Ketiga-tiga sendi itu dibandingkan antara dua fasa iaitu kontak awal dan maksimum "vertical ground reaction force" (mVGRF) menggunakan ujian-t berpasangan. Ujian-t yang berpasangan digunakan untuk mengetahui sama ada terdapat sebarang perbezaan penting antara kaki dominan dan bukan dominan semasa pendaratan kaki tunggal. Sebagai keputusannya, terdapat perbezaan yang tinggi hasil penting perbandingan antara kinematik satah hadapan (sudut) dan kinetik (momen) sendi ekstremis yang lebih rendah (contohnya, pergelangan kaki, pinggul dan lutut). Berdasarkan peraturan tangan kanan, "hip adduction" yang lebih besar ditemui apabila wanita mendarat dengan kaki bukan dominan pada fasa vGRF maksimum untuk kedua-dua kinematik dan kinetik. Dalam kinematik, kaki bukan dominan menunjukkan adduksi lutut yang lebih besar (1.48o, p = 0.27) semasa kontak awal manakala semasa maksimum "vertical ground reaction force" (mVGRF) kaki bukan dominan menunjukkan adduksi pergelangan kaki yang lebih besar (1.01o, p = 0.24). Manakala dalam kinetik, kaki bukan dominan menunjukkan momen pergelangan kaki yang lebih besar (0.30 Nm/kg, p < 0.05) dan momen pinggul (0.28 Nm/kg, p = 0.15) berbanding kaki dominan semasa kontak awal. Semasa maksimum vGRF, kaki bukan dominan menunjukkan momen pinggul yang lebih besar (3.06 Nm/kg, p < 0.05) dan momen lutut (1.84 Nm/kg, p < 0.05). Oleh itu, valgus lutut yang lebih besar semasa mendarat ditemui di kaki yang tidak dominan dan mungkin menunjukkan bahawa mendarat dengan kaki tidak dominan berkemungkinan akan meningkatkan risiko kecederaan tidak bersentuhan dikalangan pemain bola tampar rekreasi wanita. Oleh itu, jurulatih dan pemain disarankan untuk memasukkan latihan yang lebih khusus yang memberi tumpuan kepada kekuatan otot pinggul dan paha pada kaki bukan dominan. Mereka juga harus memberi tumpuan kepada kedua-dua kaki semasa latihan dan pertandingan agar mereka mendarat dengan selamat, kerana mereka terdedah kepada kecederaan tanpa kontak

A BIOMECHANICAL COMPARISON OF DOMINANT VERSUS NON-DOMINANT LEG DURING SINGLE LEG LANDING AMONG FEMALE VOLLEYBALL RECREATIONAL PLAYERS


## ABSTRACT

Volleyball has become one of the most participated sports in the world. Participation requires knowledge of many physical skills, and performance and usually depends on the individual's ability to jump and land. An ACL injury is a tear or sprain of the anterior cruciate ligaments (ACL). Most sports-related non-contact ACL injuries occur during landing and may be caused by lower limb biomechanical abnormalities or imbalances in the dominant and non-dominant limbs. Abnormal loading of a particular limb may cause unnatural forces to be absorbed at the joints of the loaded and/or unloaded limb. The purpose of this study is to compare the biomechanical of dominant and non-dominant leg during single leg landing among female volleyball recreational players. Fifteen female university recreational volleyball players (22years old) were recruited in this study. Fourteen from the participants were having the right leg as their dominant leg. They performed three times three-dimensional (3D) Single Leg Landing (SLL) test on both dominant and non-dominant legs. The lower extremity joint which is the ankle, hip and knee kinematics and kinetics was evaluated using the Qualisys Motion Capture System. All the three joints were compared among the two phases which are the initial contact and maximum vertical ground reaction force (mVGRF) using paired t-test. The paired t-test was used to know if there were any significant differences between the dominant and non-dominant legs during SLL. As a result, there were high variability of significant result for comparison between the dominant and non-dominant legs on frontal plane kinematics (angle) and kinetics (moments) of lower extremity joints (ankle, hip and knee). According to right-hand rule, a larger hip

adduction is found when women land with non-dominant legs in the maximum vGRF phase for both kinematic and kinetic. In kinematics, non-dominant leg showed greater knee adduction ($1.48^o$, $p = 0.27$) during initial contact meanwhile during maximum vGRF non- dominant leg showed greater ankle adduction ($1.01^o$, $p = 0.24$). Meanwhile in kinetics, non-dominant leg showed greater ankle moment (0.30 Nm/kg, $p < 0.05$) and hip moment (0.28 Nm/kg, $p = 0.15$) compared than dominant leg during initial contact. Meanwhile, during maximum vGRF, non-dominant leg showed greater hip moment (3.06 Nm/kg, $p < 0.05$) and knee moment (1.84 Nm/kg, $p < 0.05$). However, greater knee valgus during landing was found in the non-dominant limb and may indicate that landing with non-dominant leg may increase the risk of non-contact injury among female recreational volleyball players. Therefore, coaches and players are suggested to include more specific training focusing on the developing hip and thigh muscle strength on non-dominant leg. Also, they should focus on both legs strengthening during training and competitions to make them land safely, because they are vulnerable to non-contact injuries.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

Volleyball is a sport that require movements that involve landing from a jump. These types of movement frequently produce large amounts of force that must be absorbed by the joints of lower extremities. When landing from any type of jump, vertical ground reaction forces (GRFs) are absorbed through external flexor moments of the ankle, knee, and hip. Excessive vertical GRFs can increase the risk of injury sustained by these joints (Spencer, 2015). Several kinematic and kinetic risk factors have been linked to lower extremity injuries during landing, including large GRFs, small joint flexion angles, large hip adduction, knee abduction, and hip and knee internal rotation angles. Furthermore, large internal knee extension, adduction, and external rotation joints moments have all been associated with heightened injury risk (Hovey et al., 2019).

Volleyball players use step close technique to jump and land with one leg. Players develop a preferred lead leg, which is stressed more than the trail leg (Stephens et al., 2007). Moreover, lower extremity asymmetry is an important factor because it can lead to overloading of one limb and contributes to the development of unilateral lower limb injuries such as anterior cruciate ligament (ACL) injury (McPherson et al., 2016). Both the dominant and non-dominant limbs are at risk for injury: the dominant limb because of the greater dependence and increased loading, while the non-dominant limb because of its inability to maintain performance under normal loads (Edwards et al., 2012). Over 70% of all sport-related non-contact ACL injuries occur when landing from a jump (Southard et al. 2012). Patellar tendinosis or jumper’s knee is an anterior knee pain pathology most frequently found in volleyball players with an incidence of 9% to 64% (Crumps et al., 2008).

ACL ruptures frequently occur in non-contact athletic manoeuvres during significant and rapid decelerations of the body's centre of mass such as those that occur with cutting or landing from jump (Laughlin et al., 2011). Greater knee valgus during landing was found in the dominant limb and may indicate that the dominant limb of both males and females are more prone to ACL injury (Spencer, 2015).

Biomechanical imbalances between the dominant and non-dominant limb and the effect on non-contact injuries have not been thoroughly researched (Brophy et al., 2010). Therefore, the purpose of the present study was to examine if there are differences in lower extremity joint biomechanics during the landing phase of a jump between the dominant and non-dominant leg. Volleyball as the focus of the research because there were few studies conducted in this sport. Female university athletes were chosen in this study because university have female volleyball teams that have great experienced in their sport and most of them aged 19-25 years old. Thus, this is a great opportunity to conduct a study about them.

## 1.2 Problem statement

It is common practice to study jump landing mechanics by having subjects step off a box set at a certain height instead of landing from a jump. However, very few have studied landings from a maximum effort of countermovement jump from the ground which replicate the real-life situation in sports. Furthermore, there has not been much research conducted on the effect of limb dominance on other lower extremity joints among female volleyball players. Increased knee valgus may have been caused in the dominant limb as compensation for a weaker non- dominant limb. Due to the limb of preference, people may be more comfortable performing an unfamiliar task with that preferred limb. The preferential limb may then become over worked and develop abnormal biomechanics as a result. Previous study by Ford, Myer & Hewett (2003) showed that female athletes would demonstrate greater valgus knee motion (ligament dominance) and greater side to side (leg dominance) differences in valgus knee angle at landing from a 31 cm height. Therefore, it is the aim of this study to determine biomechanical imbalances that might exist between the dominant and non-dominant limb joint during the landing phase of a jump and determine if these imbalances are correlated to increased risk of joint injury. However, these differences were not yet studied in single landing at maximum jumping height.

## 1.3 Research Question

i. What are the biomechanical differences between the dominant and non-dominant legs during single leg landing task among female volleyball players?

## 1.4 Objectives

### 1.4.1 General Objective

To compare the biomechanics of dominant vs non-dominant leg during single leg landing among female volleyball players.

### 1.4.2 Specific Objectives

I. To compare the kinematics (angle) of ankle, hip and knee joints of dominant vs non-dominant leg during single leg landing among female volleyball players.

II. To compare the kinetics (moments) of ankle, hip and knee joints dominant vs non-dominant leg during single leg landing among female volleyball players.

## 1.5 Hypotheses of the Study

Null Hypothesis ($H_O$): There is no significant difference between kinematics of dominant vs non-dominant leg during single leg landing among female volleyball players.

Alternative Hypothesis ($H_A$): There is significant difference between kinematics of dominant vs non-dominant leg during single leg landing among female volleyball players.

Null Hypothesis ($H_O$): There is no significant difference between kinetics of dominant vs non-dominant leg during single leg landing among female volleyball players.

Alternative Hypothesis ($H_A$): There is significant difference between kinetics of dominant vs non-dominant leg during single leg landing among female volleyball players.

## 1.6 Significance of the Study

A better understanding of the interaction between structures of the lower limb, kinetics and kinematic pattern that contributes to traumatic lower extremity injuries may enhance preventative interventions and post injury rehabilitation (Spencer, 2015). This study will help the female volleyball players, coaches and team managers in prevention of future serious injuries associated with landing. They will be aware of how their strength may influence their landing biomechanics hence specific training programme can be prescribed.

## 1.7 Operational definition

| | |
|---|---|
| **SLL** | Single leg landing is defined as landing with one leg after performing a single leg countermovement jump with maximum height jumping. |
| **Dominant leg** | Limb dominance was defined as the preferred limb to kick a ball (Avedesian, Judge, Wang, & Dickin, 2018). The leg used in order to manipulate an object or to lead out in movement (van Melick et al., 2017). |
| **Non-dominant leg** | The leg which performs the stabilizing or supporting role. |
| **Female volleyball players** | Women volleyball players that aged between 19 to 25 years old. They must have represented university for volleyball tournament at least once and involve in regular training at least 3 times a week. |
| **Kinematic** | Branch of classical mechanics that describes the motions of points, bodies and system of bodies without considering the mass of each or the forces that caused the motion. In this study, we focused on the angle during SLL. |
| **Kinetic** | Analysis of forces and torques that cause motion. In this study, we focused on vertical ground reaction forces. |

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Biomechanics of Landing

### 2.1.1 Landing in Volleyball

The sport of volleyball places 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 are usually performed as single- or double-leg landings. Single-leg landings frequently occur when players move from the middle of the court as middle blockers (Lobietti et al., 2010). The players usually use “go” landings in situations when they are late moving from the middle to the outside position of the court against an opponent’s spike. The “reverse” landing is used when players are not late moving against an opponent’s spike, but usually must react in a reverse direction to the game situation (e.g. a softly hit ball that falls just over the block). Due to the single-leg landing, the players land in a more stiffed knee position, that is, with less knee flexion. On the other hand, a double-leg landing appears more compliant (i.e. less stiff) in that the knee is more flexed. Zahradnik et al. (2016) showed that the “go” and “reverse” landings have an increased risk of potential anterior cruciate ligament (ACL) injury due to the combined effects of a single-leg landing, lower knee flexion and a higher ground reaction force (GRF) resulting in a stiff landing.

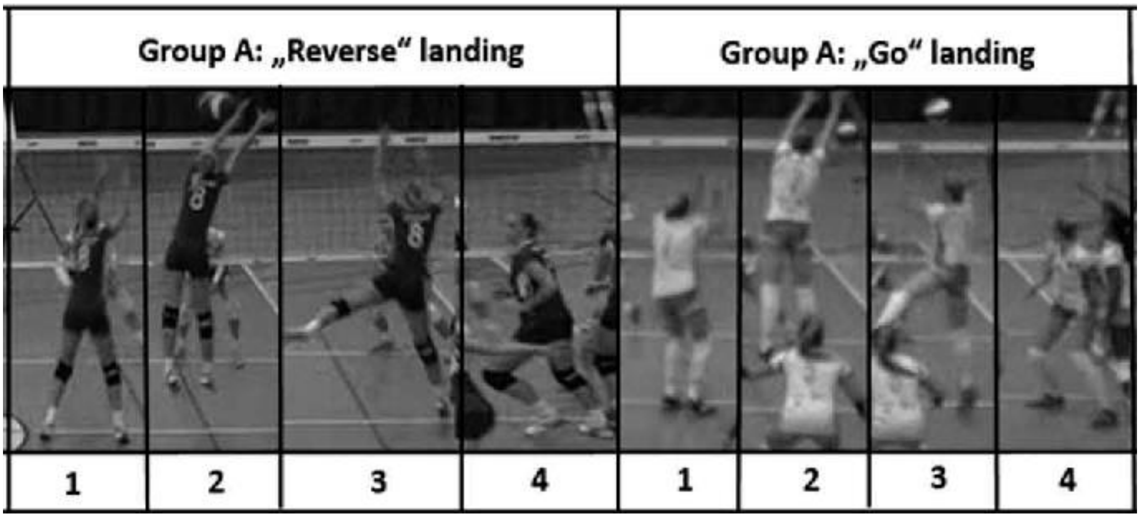


*Figure 2.1: Go and reverse landings in volleyball- single-leg landing with subsequent movement in a lateral direction (adopted from Zahradnik et al., 2017).*

Soft and stiff landings had relatively large and small amounts of knee flexion, respectively, during the floor contact phase. The action of landing from a vertical fall applied forces and moments to the lower extremities that accelerated hip and knee flexion and ankle dorsiflexion, thus causing the extremities to collapse. The goal of a successful landing was to resist this collapse by applying counter extensor moments at these joints in such a way that the body's negative velocity was reduced to zero without injury. These extensor moments primarily worked eccentrically to absorb kinetic energy from the skeletal system and stop the person's fall (Devita et al., 1992). The stiff landing was characterized by a more erect final position and, therefore, had a smaller range of motion at each joint compared with the soft landing (Devita et al., 1992). Thus, soft landings are effective in reducing the impact applied to lower extremity joints by the ground.

In volleyball, a higher risk of ACL injury was exhibited in the right leg during two landing techniques, including a bilateral stick landing and a right step back from the net. A study by Gabbard et al., (1996) concluded that most people are right leg dominant and left leg non-dominant. To prevent injury, restoring the strength and performance of the affected side is suggested to improve the symmetry of the lower extremities (Sinsurin et al., 2017).

### 2.1.2 Landing technique across gender and leg dominance

Biomechanical differences between males and females during jump landing may contribute to the greater injury risk in females. Specifically, females displayed smaller hip and knee flexion angle at initial ground contact, greater anterior tibial shear force, greater knee extension moments, and greater vertical GRF compared to males (Dewig, 2016).

Research by Weinhandl et al., (2015) indicate that females exhibit decreased initial contact (IC) hip abduction, along with increased peak knee extensor and plantar flexor moments when landing from a height equal to their maximum jumping ability. Additionally, while both females and males utilise the knee as the primary energy absorber, females selected a landing strategy which emphasises greater energy absorption from the ankle plantar flexor musculature than their male counterparts Weinhandl et al. (2015).

A female volleyball athlete may be at a higher risk for knee injury in the non-dominant limb due to altered trunk mechanics when completing an offensive jump-landing manoeuvre (Avedesian et al., 2018). This is because, the athlete needed to laterally bend the trunk in order to complete the non-dominant jump-landing, displacing the centre of mass over the landing limb (Powers, 2010). As the trunk shifts towards the non-dominant limb, the external landing force moves lateral to the knee joint centre, increasing the amount of knee abduction and strain on the ACL (Powers, 2010). This is in contrast to a dominant limb landing, in which the centre of mass visually shifted away from the landing limb. Further analysis of sagittal plane mechanics revealed that athlete landed on the dominant and non-dominant limbs with 8–12° of initial contact knee flexion, approximately 10° less knee flexion compared to female athletes who sustained an ACL injury in live competition (Koga et al., 2010).

**2.2 Dynamic knee valgus**

Dynamic knee valgus (DKV) described as a combination of hip adduction, hip internal rotation, and knee abduction is recognized as a common lower extremity alignment seen in non-contact ACL injury situations (Tamura et al., 2017). Dynamic knee valgus is an abnormal movement pattern visually characterized by excessive medial movement of the lower extremity during weight bearing. 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). Additionally, ACL injuries happened because of direct contact, indirect contact and non-contact which by doing a wrong movement especially in sport activities associated with pivoting, decelerating and jumping. Dynamic knee valgus during landing usually associated with an increased risk of non-contact ACL injury (Schmidt et al., 2019).

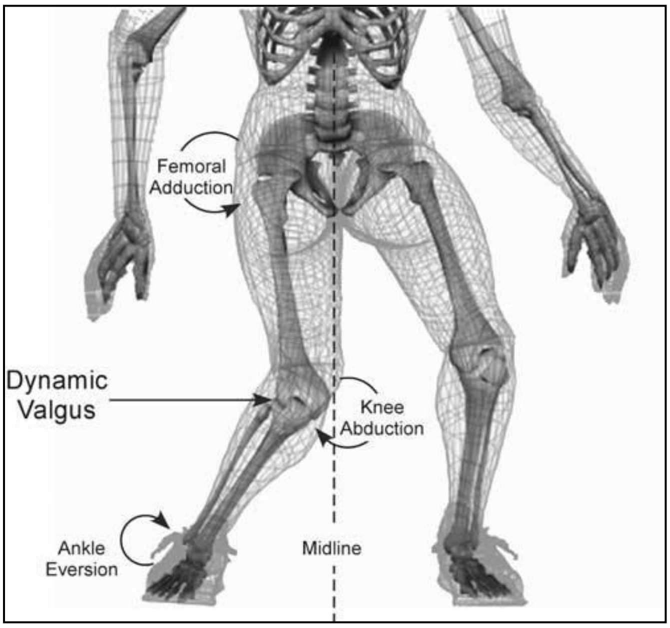


*Figure 2.2: Dynamic valgus was defined as the position or motion, measured in 3 dimensions, of the distal femur toward and distal tibia away from the midline of the body. Dynamic valgus may have included the indicated motions and moments (adopted from Hewett et al., 2005).*

Several studies have reported, through video analysis, female athletes land with the knee nearly extended, the hip adducted and internally rotated, the tibia externally rotated and the foot in an over-pronated position (Neamatallah, 2018). Based on Herrington & Munro (2010), for drop jump landing task, knee angle should be symmetrical and in the range of 7-13$^{o}$ for females and 3-8$^{o}$ for males to be described as average for the population studied. Likewise, for a unilateral step landing task, knee valgus angle should be symmetrical and in the range of 5-12$^{o}$ for females and 1-9$^{o}$ for males (Herrington et al., 2010). Decreased knee flexion and increased knee valgus, tibial rotation, hip adduction and internal rotation during landing and cutting manoeuvres are commonly seen during ACL injury episodes and can increase strain placed on the ACL (Munro et al., 2012).

In a study by Shin et al. (2009), physiologic levels of valgus moments from an *in vivo* study of single-leg landing were applied to a three-dimensional dynamic knee model, previously developed and tested for ACL strain measurement during simulated landing. The ACL strain, knee valgus angle, tibial rotation, and medial collateral ligament (MCL) strain was calculated and analysed. They found that increasing the peak valgus moment during single leg landing increases the peak ACL strain non-linearly. Moreover, increased knee valgus, in combination with knee internal rotation, appears to place the greatest load on the ACL and lead to injury (Avedesian et al., 2018). Therefore, performance during unilateral landing tasks (e.g., single leg landing) should be prospectively evaluated as an injury risk prediction tool as it may be more sensitive than bilateral landing tasks previously suggested. Injury prevention programs should include unilateral jumping, landing and decelerating techniques and consider the mechanisms of injury in each sport (Munro et al., 2012).

# CHAPTER 3

# METHODOLOGY

## 3.1 Study Design

This was a cross sectional study. Fifteen female Universiti Sains Malaysia (USM) recreational players who participated in volleyball_took part in the study. Every participant required to perform three trials of single leg landing (SLL) on dominant and non-dominant leg. The test was conducted at Exercise & Sports Science Laboratory of School of Health Sciences, USM, Kota Bharu, Kelantan. The study was completed in three months.

## 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. A prior sample size of paired t-test show that 15 participants are sufficient to yield 0.8 power of study with effect size 0.8. Effect size is based on Cohen (1988). Cohen suggested that d=0.8 is considered as a 'large' effect size. From this calculation, 15 participants are needed to be able to reject null hypothesis.

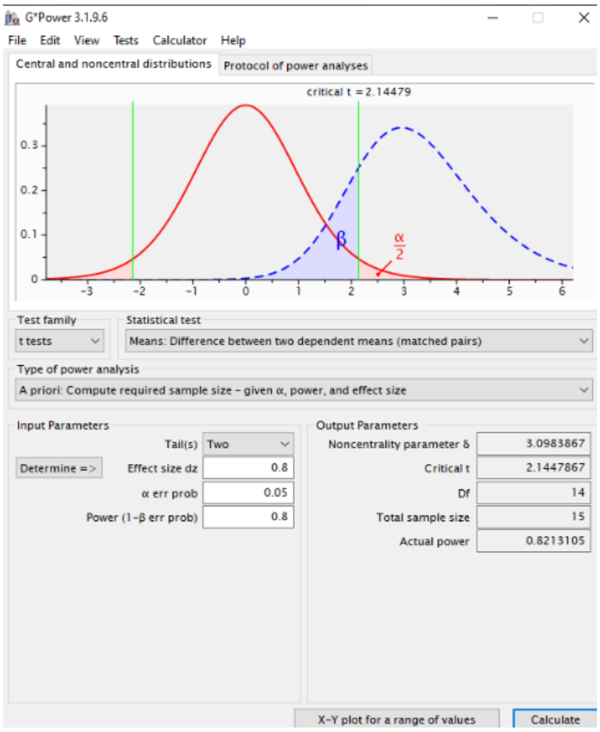

*Figure 3.1: Sample size calculation*

## 3.3 Study Participants

### 3.3.1 Inclusion criteria

The selection of the participants were based on the following criteria:

- Normal Body Mass Index (BMI) ranging from 18.5 to 24.9 kg.m$^{-2}$ (WHO, 2004)
- Aged between 19-25 years old
- Recreational volleyball players
- Involve in regular training (3 times per week)
- Female
- Healthy

### 3.3.2 Exclusion criteria

Participants were excluded if they:

- has lower extremity pain or injury affecting landing performance
- has history of knee ligament injury or any lower limb and/or back surgery

### 3.3.3 Recruitment of participants

Purposive sampling method was applied. Participants were recruited through snowball technique (mouth to mouth) and poster regarding the study. The details of the study were provided and explained prior to their participation. Their sign consent was collected when they agreed to join the study.

## 3.4 Study Protocol

The purpose of this study was to compare the biomechanics of dominant versus non-dominant leg during single leg landing (SLL) among USM female volleyball recreational players. The participants were required to perform SLL on both legs (Figure 3.2).

All participants were required to do a pre-test measurement which include measuring body height, weight, body fat percentage and the length of leg segments. Body weight (kg) and height (m) were measured using digital medical scale (Seca 769, Hamburg, Germany) meanwhile body fat percentage was evaluated using Electronic Body Fat Percentage Analyzer (Omron HBF-360, Kyoto, Japan). The length of leg segments was measured with a measuring tape. Leg length was quantified from the anterior superior iliac spine (ASIS) to the centre of ipsilateral medial malleolus with participant in standing and supine positions. In addition, they were asked to provide information about their medical history and medications. After that, the participants underwent the SLL test session.

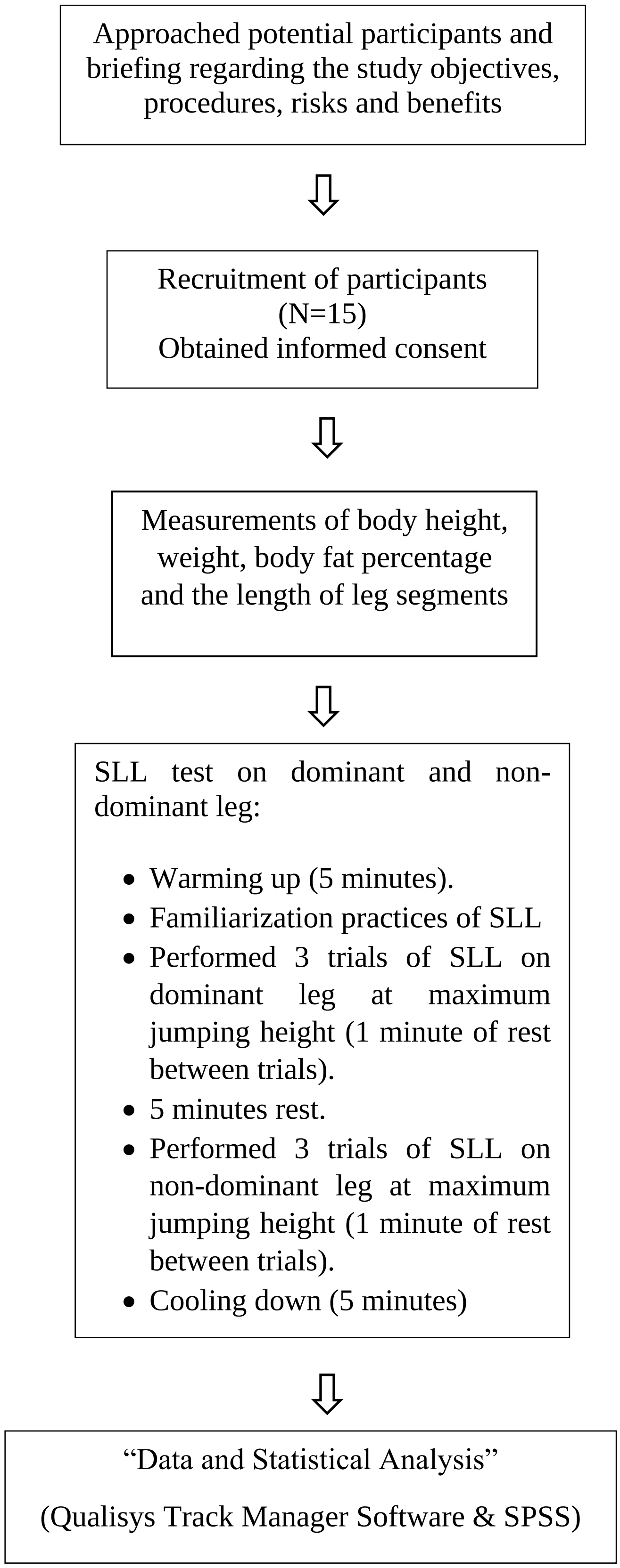


*Figure 3.2: Flowchart of the study protocol*

### 3.4.2 Tests protocol - Single Leg Landing Test

Participants performed the SLL with 3D motion capture and analysis. The test was conducted at Exercise and Sports Science Laboratory, USM. The participants was required to wear fit attire for ease and accuracy of markers placement and data collection.

The risks of participation in this study are minimal. Participants may experience muscle soreness during single leg landing. However, this situation can be reduced by familiarization, warming up and stretching prior to and following the sessions. Researcher are trained in providing cardiopulmonary resuscitation (CPR). If participants have any injuries caused by participation in the study, participant was referred to Hospital Universiti Sains Malaysia, for an extensive medical examination. Participants must not had menstruation during the test because it can decrease jump performance during the test (Lebrun et al. 1995). They also were advised to have enough sleep the night prior, at least six hours and they should consume meal and avoid caffeine at least two hours before the session.

#### 3.4.2.1 Single Leg Landing (SLL) test with maximum jumping height

Before the test began, participants were required to do a warm session about 5 minutes to avoid any injury during the test. Participants were required to cycle on ergometer (Cybex Inc., Ronkonkoma, NY, USA) at 60 RPM with resistance set at 50 watts. After that, the test was demonstrated to the participants by the researcher. Then, the participants practiced the landing task for three times with supervision by the researcher.

*Figure3.3: Countermovement jump (CMJ). Participant are required to jump with both leg on force plate with their own maximum jumping height. (adopted from Macgregor, (2016).*

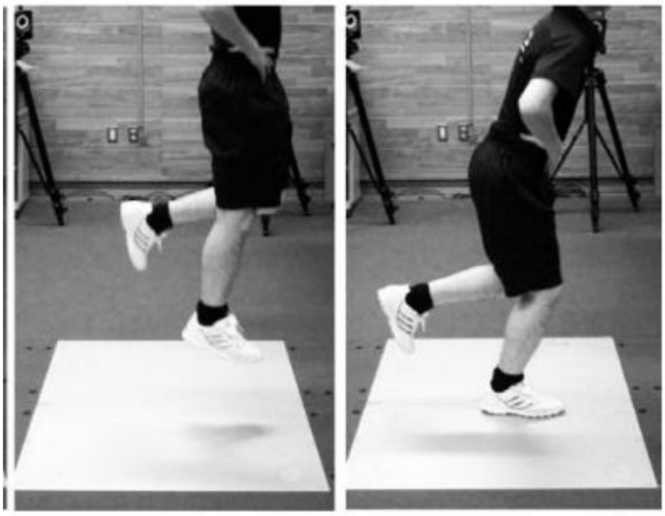

*Figure 3.4: Participant are required to land with single leg. Start with dominant leg first. After 3 trials, followed with non-dominant leg. (adopted from Kobayashi (2013).*

In this test, there was no fixed height because the participants were jumped at their own maximum jumping height. Participants were instructed to execute countermovement jump (CMJ) on full effort or as high as they can. Then landed with single leg. They started with dominant leg first then followed with non-dominant leg after three trials. Limb dominance was defined as the preferred limb to kick a ball (Avedesian, Judge, Wang, & Dickin, 2018). The SLL was taken as landing of the leg with the foot contacting the force-plate (Kristler, USA). After three trials, they were proceeded with non-dominant leg. Rest between the trials was 1 minute while rest between dominant and non-dominant leg session was 5 minutes. Participants were required to hold the landing position for at least two seconds before stepping off the force plate. It was suggested for the participants to implement natural landing style with forefoot contact the ground first and bend their knee slightly to reduce the risk of injury.

Throughout the experiment, participants were barefooted to prevent any data variability due to different shoe types. Fifteen retroreflective markers were attached to their lower body based on the Plug-in-Gait Marker Set, specifically on the sacrum and bilaterally on the ASIS, lateral thigh, lateral femoral epicondyle, lateral shin, calcaneus, lateral malleolus and second metatarsal. Placement of accurate markers on selected anatomical landmarks was important to create bone model. Qualisys Track Manager Software (2.6.673, Gothenburg, Sweden) was used to identify the trajectories of the reflective markers during SLL. Then, inverse dynamics calculation was applied to build a musculoskeletal model using V3D software (version 5, Gothenburg, Sweden).

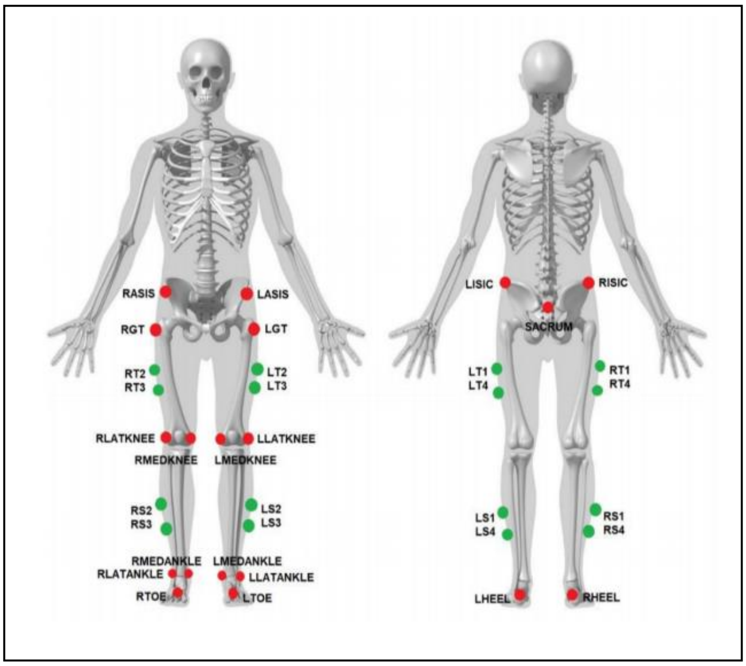


*Figure 3.5: Gait module sample and marker's placement for lower limb. Image from https://www.qualisys.com/software/analysis-module*

*Figure 3.6: Reflective markers & Qualisys Motion Capture System cameras (Oqus 311)*

The study focused on the landing phase of the SLL. Variables of interest included the joint kinematics (angles) and joint kinetics (moments) of hip, knee and ankle joints at initial contact and maximum vertical ground reaction force (vGRF) landing phases. These variables were compared across dominant and non-dominant legs of the same group of participants.

### 3.5 Equipment

1. Force platform (Bertec, USA) was used in the SLL test to measure the ground reaction forces generated by a body standing on or moving across them.
2. Qualisys Track Manager Software (version 2.6.673, Gothenburg, Sweden) captured the trajectory of reflective markers.
3. 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).

### 3.6 Measurements

Anthropometric data included weight, height, BMI, body fat percentage, and length of leg segments. Data collection sheet was used to collect all the information and test results. Body Mass Index (BMI) was calculated by body mass in kilogram divided by the square of the body height in metres. The classification of BMI followed the norms from the International Classification (WHO, 2004) (Table 3.1)

*Table 3.1: The Classification of BMI norms from the International Classification (WHO, 2004)*

| Body Mass Index (BMI) | Nutritional Status |
|---|---|
| **<18.5** | Underweight |
| **18.5-24.9** | Normal |
| **25.0-29.9** | Pre-obesity |
| **30.0-34.9** | Obesity class I |
| **35.0-39.9** | Obesity class II |
| **>40.0** | Obesity class III |

### 3.7 Statistical Analysis

In this study, the distribution of data was tested using Shapiro Wilk Test since it was more precise for smaller sample size ($n<50$). Paired T-test was applied to analyse the comparison of joint angle and moments of dominant and non-dominant lower limbs. Statistical Package for the Social Sciences (SPSS) version 24.0 (IBM, US) was used to perform every single statistical analysis. The statistical significance was set at $p<0.05$ and the data were presented in means and standard deviation (SD).

### 3.8 Community sensitivities

Due to community sensitivity and protection of participant's privacy, data collection was conducted in an enclosed lab area because it is understandable that participants felt uneasy to wear tight fitting clothes during assessment. Men was not allowed to be near with the participants during the test. For accuracy of marker placement, researchers have to palpate the bony landmark. Permission was asked and only the same gender researcher palpated the participant.

# CHAPTER 4

# RESULTS

This chapter presents the findings on biomechanical comparison of dominant vs non-dominant leg during single leg landing among female volleyball recreational players. Fifteen female Universiti Sains Malaysia (USM) recreational players who participated in volleyball with ranged aged between 19-25 years old volunteered to take part in this study. They are physically active at least 3 times a week. All of them successfully completed the experimental tests. The study was conducted at Exercise & Sports Science Laboratory of School of Health Sciences, USM, Kota Bharu, Kelantan. The duration of data collection was 1 hour per participant.

## 4.1 Dominant vs Non-Dominant Leg Screening Test

Leg dominance was determined by asking participants which leg they used to kick a ball (Ford et al., 2003). There are 14 participants who are right-leg dominant meanwhile only 1 of the participants who is left-leg dominant. Legs' length was measured from the anterior superior iliac spine (ASIS) to the centre of ipsilateral medial malleolus in standing position. Results indicated that, dominant leg length was 82.20 ± 4.26 cm while the non-dominant leg was 82.53 ± 4.50 cm.

## 4.2 Physical Characteristics

Table 4.1 shows the physical characteristics of participants. All participants are within the normal range of Body Mass Index (BMI) and body fat percentage for female aged 19-25 years old (22 ± 1.38 years old).

*Table 4.1 Physical characteristics of participants (N=15)*

| Physical Characteristics | Mean | (SD) |
|---|---|---|
| Body Weight (kg) | 50.81 | (5.63) |
| Height (m) | 1.57 | (0.05) |
| Body Mass Index (BMI) (kg/m²) | 20.70 | (2.06) |
| Body Fat Percentage (%) | 20.49 | (3.28) |
| Length of the Dominant Leg (cm) | 82.20 | (4.26) |
| Length of the Non-Dominant Leg (cm) | 82.53 | (4.50) |

**4.3 Lower limb frontal plane kinematics of dominant vs non-dominant leg during single leg landing.**

The kinematics of ankle, hip and knee joints for dominant and non-dominant legs were compared across two different landing phases. Namely ankle, knee and hip joint frontal plane kinematics across dominant and non-dominant legs at initial contact among female recreational volleyballers (Table 4.2) and ankle, knee and hip joint frontal plane kinematics across dominant and non-dominant leg at maximum vertical Ground Reaction Force (vGRF) among female recreational volleyballers (Table 4.3).

Due to right hand rule, the frontal plane of the leg will have opposite direction than the other leg. Meaning that, for the right leg, positive values mean adduction which is the same for the negative values of the left leg.

Initial contact phase was defined as the point in the trial when the vertical GRF exceeded 10 N through the lowest point of center of gravity during stance (Jamaludin et al., 2020). Maximum vertical Ground Reaction Force (vGRF) is the maximum value of vGRF during landing phase. The motions in frontal plane are abduction or adduction.