COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING BETWEEN MALE AND FEMALE VOLLEYBALL RECREATIONAL ATHLETES

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SCHOOL OF HEALTH SCIENCES
UNIVERSITI SAINS MALAYSIA

2021

COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING BETWEEN MALE AND FEMALE VOLLEYBALL RECREATIONAL ATHLETES

by

AMIR ARIFUDEEN BIN MOHD FADZIR

**Thesis submitted in fulfilment of the requirements
for the degree of
Bachelor of Health Science (Honours) (Exercise and Sports Science)**

June 2021

CERTIFICATE

This is to certify that the dissertation entitled COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING BETWEEN MALE AND FEMALE VOLLEYBALL RECREATIONAL ATHLETES is the bona fide record of research work done by Mr AMIR ARIFUDEEN BIN MOHD FADZIR during the period from August 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 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: 23rd June 2021

ACKNOWLEDGEMENT

We would like to express our gratitude to Allah SWT for giving us opportunity and help us endlessly in finishing this thesis Comparison of Lower Limb Biomechanics during Single Leg Landing between Male and Female Volleyball Recreational Athletes with Dr Shazlin Shaharudin. This study was hoped can provide some beneficial information for volleyball athletes in USM specifically and the entire sports science community in general. Our thanks goes out to all in the team – The top management of Universiti Sains Malaysia, Health Campus, School of Health Science, Exercise and Sports Science Programme, Final Year Project Coordinator; Dr Nur Syamsina Ahmad, Exercise and Sports Science Laboratory Staffs; Mr Hafezi Mat Zain and Ms. Azilawati Azizan for commitment and patience in helping us overcoming numerous obstacles in finishing the task. Moreover, in completing this thesis, we had to take help and guidance from our respected seniors and alumni who deserved our gratitude; Ms. Nazatul Izzati, Ms. Farhah Nadhirah and Ms, Veenothini Pentaya for helping us in using the Qualisys Track Manager. A very special gratitude was given to both my parents Mr Mohd Fadzir Mansor and Ms. Jamaiah Yeet, for tremendous support and confidence given for me in completing this study. Thank you also to Ms. Neesa Adryana Sabri, Ms Nadhirah Mansor and all my exercise and sports science coursemates for your aid during the whole data collection process. Last but not least, very special thanks to Dr Shazlin Shaharudin, for the tremendous effort in providing us insight and support in completing this thesis. Your guidance and sacrifices in terms of time, funding, and energy given will not be able for us to repay in any way.

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LIST OF ABBREVIATIONS

ACL	Anterior Cruciate Ligament
ASIS	Anterior Superior Iliac Spine
BMI	Body Mass Index
CMJ	Counter Movement Jump
DKV	Dynamic Knee Valgus
DLL	Double Leg Landing
DLSJ	Double Leg Stop Jump
EMG	Electromyography
FPPA	Frontal Plane Projection Angle
GRF	Ground Reaction Force
IAD	Inter-Anterior superior iliac spine Distance
IC	Initial Contact
JEPeM	Jawatankuasa Etika Penyelidikan Manusia
MKF	Maximum Knee Flexion
MvGRF	Maximum vertical Ground Reaction Force
NCAA	National Collegiate Athletic Association
PFJ	Patellofemoral Joint
PFPS	Patellofemoral Pain Syndrome
PPSG	Pusat Pengajian Sains Pergigian
PPSK	Pusat Pengajian Sains Kesihatan
PPSP	Pusat Pengajian Sains Perubatan
QTM	Qualisys Track Manager
RPM	Rotation Per Minute
SD	Standard Deviation
SLL	Single Leg Landing
SLSJ	Single Leg Stop Jump
SPSS	Statistical Package for the Social Sciences

SUKAD	Sukan Antara Desasiswa
USM	Universiti Sains Malaysia
WHO	World Health Organization

LIST OF APPENDICES

PERBANDINGAN BIOMEKANIK KETIKA PENDARATAN SATU KAKI ANTARA ATLET BOLA TAMPAR REKREASI LELAKI DAN PEREMPUAN

ABSTRAK

Kajian lampau telah menunjukkan bahawa kinematik sendi pada satah hadapan (penambahan atau pengurangan sudut) adalah lebih ketara pada perempuan berbanding lelaki. Kajian ini bertujuan untuk membandingkan pemboleh ubah bahagian kaki (Buku Lali, Pinggul dan sendi Lutut) iaitu kinetik (momen) dan kinematik (sudut) antara pemain bola tampar rekreasi lelaki (n=12) dan wanita (n=15) dari Universiti Sains Malaysia, Kampus Kesihatan. Pemboleh ubah kinetik dan kinematik telah diukur dan dikenal pasti pada dua fasa mendarat (sentuhan awal dan daya tindak balas tanah menegak maksimum) dengan menggunakan Qualisys Track Manager (v2.16) yang terdiri daripada enam buah kamera tangkapan pergerakan dan satu plat daya Bertec. Kemudian pengiraan dinamik berbalik dilakukan bagi menghasilkan model kerangka otot dengan menggunakan perisian V3D Pro (v5). Kesemua percubaan ujian telah dijalankan di makmal Sains Senaman dan Sukan, Pusat Pengajian Sains Kesihatan, USM. Para atlet telah diarahkan untuk melakukan Pendaratan Satu Kaki dari Lompatan Berpantul sebanyak tiga kali di atas plat daya. Keputusan kajian ini menunjukkan, tiada perbezaan signifikan pada semua pemboleh ubah kinematik pada kedua-dua fasa iaitu Sentuhan Awal (p = 0.481, 0.635, 0.394) dan Daya Tindak balas Tanah Menegak Maksimum (p = 0.679, 0.978, 0.964). Keputusan ke atas pemboleh ubah kinetik pada fasa Sentuhan Awal (p = 0.710, 0.774, 0.871) dan Daya Tindak balas Tanah Menegak Maksimum (p = 0.609, 0.662, 0.387) antara pemain lelaki dan perempuan juga turut menunjukkan tiada perbezaan signifikan walaupun kedua-duanya menunjukkan perbezaan ketara bagi nilai purata Daya Tindak balas Tanah Menegak (p 0.032, 0.000). Kesimpulan dari hasil kajian mendapati, kedua-dua kumpulan jantina memiliki valgus lutut dinamik (DKV) yang normal dan mereka mempamerkan postur badan yang ergonomik semasa mendarat yang membantu mereka untuk mengurangkan risiko kecederaan di bahagian kaki. Keputusan kajian ini turut berpotensi membantu para atlet dan jurulatih kami dalam merancang senaman dan program latihan yang memfokuskan pergerakan medial-lateral bahagian kaki dalam keadaan yang selamat dan berkesan.

Kata Kunci: Bahagian Bawah Kaki, Daya Tindak balas Tanah Menegak Maksimum, Jantina, Kinetik, Kinematik, Kontak Awal, Lompatan Pergerakan Balas, Momen, Satah Hadapan, Sudut, Qualisys.

COMPARISON OF LOWER LIMB BIOMECHANICS DURING SINGLE LEG LANDING BETWEEN MALE AND FEMALE VOLLEYBALL RECREATIONAL ATHLETES

ABSTRACT

Previous study has shown that frontal plane knee joint kinematic (i.e., abduction or adduction) were significantly higher in female than male. 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 male (n=12) and female (n=15) recreational volleyball 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 consisted of six motion capture camera and one Bertec force platform. Then inverse dynamic calculation for musculoskeletal model was conducted using V3D Pro software (v5). All the test trials were conducted at Exercise and Sports Science Laboratory, School of Health Science, USM. Athletes were instructed to do Single Leg Landing (SLL) from Counter Movement Jump (CMJ) for a total of three trials on the force plate. Result of this study showed, there were no significant differences on all kinematics variables at both phases of Initial Contact ($p = 0.481, 0.635, 0.394$) and MvGRF ($p = 0.679, 0.978, 0.964$). Similar no significant result was also shown on kinetic variables at both Initial Contact ($p = 0.710, 0.774, 0.871$) and MvGRF ($p = 0.609, 0.662, 0.387$) between male and female athletes although the vGRF ($p = 0.032, 0.000$) was proven to be significantly different. Inference of this research revealed that both gender groups shown to have normal DKV, and they implement an ergonomic posture during landing which can help to reduce risk of lower limb injuries. Result of this study can potentially help our athletes and their coaches in planning exercise and training program that focus on medial-lateral motion of lower limb in safe and effective conditions.

Keyword: Angle, Counter Movement Jump, Frontal Plane, Gender, Initial Contact, Kinematic, Kinetic, Maximum vGRF, Moment, Qualisys.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Jumping and landing are very common skills in sports such as basketball, netball, football and also volleyball. The landing phase which is the moment of feet contacting with the ground is an important move during execution of skills. Improper or awkward landing steps can lead to injuries. For example, a lot of repetitive jump-land movements were involved during running . These jump-land movement are executed at a success rate of 1500 times per mile (930 times per km) (Dufek & Bates, 1991). Furthermore, it was also shown that subsequent movement after a landing was executed lead to increased risk of injuries (Zahradnik *et al.*, 2018). Poor landing is associated with increased risk of injuries of lower extremities. For instance, anterior cruciate ligament (ACL) injuries are reported to have prevalence of 85 over 100.000 people per year which contribute as one of the most common injuries in sport (Ardern *et al.*, 2016). During jumping and landing movements which are fundamental parts of blocking and spiking in volleyball, around 63 percent of musculoskeletal injuries were observed compared to other injuries (Gerberich *et al.*, 1987).

Biomechanically, landing from a jump consists of a few phases that can be measured including initial contact (IC), maximum vertical ground reaction force (vGRF) and dynamic knee flexion (DKF) angle. Initial contact (IC) is the phase where the feet fully touch the ground either to absorb the impacts from jumping or to load up the force to the ground for next jumps or leaps. For maximum vGRF, increment of knee flexion angle during landing will lead to reduced vGRF which is significant for injury risk reduction (DeVita and Skelly, 1992). Knee flexion angle during single leg landing (SLL) was increased significantly ($p = 0.041$) among healthy young athletes compared to adult athletes (Mueske *et al.*, 2019).

Volleyball is a sport with combination of aerobic and anaerobic intensity and involves a lot of jumping and landing motion throughout one full set of 25 points. This jump-land motion in volleyball involves the spiking approaches, servings, blocking and setting the ball. More additional movement after landing from a block was observed in male volleyball players compared to female although the number of landing was lower (Zahradnik *et al.*, 2018). Single leg landing has shown to cause higher number of lower limb injuries compared to double leg landing (DLL) (Wang, 2011). A study by Sinsurin et al., (2017), showed that volleyball athletes used different strategies with their dominant or non-dominant limbs depending on the demand of the extremities during SLL. They observed that during SLL, significantly higher GRF ($p < .001$), larger flexion moment ($p < .001$) and lesser knee extensor ($p = .002$) were observed compared to DLL. These biomechanics are related to increase risks of injuries in volleyball players.

Male athletes often show significant higher and stronger force production compared to their female counter parts due to their physical builds and natural hormones aids (Miller *et al.*, 1993). GRF data suggested greater power in males while EMG data showed that males and females both utilised different strategies of muscle activity during speed approach and planting angle on dominant leg in volleyball spike jump (Fuchs *et al.*, 2019). Females soccer athletes also showed higher leg stiffness which attributed by higher vGRF and decreased in centre of mass (COM) displacement compared to male soccer athletes during landing (Lyle *et al.*, 2014). They also showed that female athletes are two to four times higher to get non-contact ACL injuries compared to male athletes (Lyle *et al.*, 2014) . By landing with higher knee flexion angle, it increases the ability of hamstring muscles to prevent anterior tibial translation which are the common cause of ACL injuries in women (Fagenbaum & Darling, 2003). Wave as a result from initial contact are also contributing factor of injuries on lower extremities where these wave can lead to joint laxity and injury such as stress fracture, tendon inflammation and also joint degenerative disease in female volleyball players (Rostami *et al.*, 2020). Another instance, female volleyball players with low back pain (LBP) showed significantly higher lordosis angle in upright standing posture and increased lumbar extension at IC and maximum vGRF compared to male counterparts (Movahed *et al.*, 2019).

Dynamic knee valgus (DKV) is a condition of body position where the knee collapse medially from internal-external rotation or excessive valgus or from both conditions (Krosshaug *et al.*, 2007).While knee valgus excursion is defined as movement of the knee from peak knee varus condition to peak knee valgus or abduction (Jenkins *et al.*, 2017). There is significantly greater DKV angle on unilateral loading task either from asymptomatic control or limb on patients with patellofemoral pain syndrome (PFPS) (Herrington, 2014). Increased of knee valgus angle during SLL after overhead strokes with back steps may increase the risk of ACL injuries (Kimura et al., 2010). In a volleyball game, there will be several circumstances that a player needs to execute SLL especially after blocking and spiking motion. These SLL motions are needed as the players need to get ready quickly for next attack or defence due to the fast pace of the game played. Reduction of knee flexion angle during landing after volleyball spikes among women players was caused by the quadricep's high compensatory torque that excessively accelerate the tibia and caused knee valgus may potentially incurred ACL injury (Ball *et al.*, 1999).

Previous studies on SLL applied instrumentation of drop jump box placed 10 cm away from the force plate with the fixed height set at 40 cm for female participants (Movahed *et al.*, 2019). The participants were required to drop onto the force platform by alleviating their legs and not jumping from the box which indicated a controlled SLL (Movahed *et al.*, 2019). Another study involved SLL from drop box jump with a fixed height of 60 cm among male participants (Salci *et al.*, 2004). However, this type of landing is not the real representations during sports activities. Therefore, the purpose of the current study is to provide the comparison of maximum effort counter movement jump (CMJ) on SLL between genders. Through this study, we also evaluated the style of landing that can cause higher risk of non-contact injuries (e.g., ACL injury, ankle sprain) particularly in women which eventually provide significant data to prepare precaution plan or preventive exercises programme. The nature of this study protocols that use natural jump height or maximal effort CMJ will be able to provide a more realistic movement that mimic the condition in game situation. Most of the previous studies are using vertical drop jump in order to measure participants' SLL (Lyle *et al.,* 2014; Nyman and Armstrong, 2015; Tamura *et al.*, 2017; Peng *et al.*, 2019; Seymore *et al.*, 2019).

1.2 Problem Statement

During drop landing motion in volleyball, it was observed that there is increment of GRF about two to five times of body weight. These elevation of force can cause strain to surrounding muscle tissue on lower limb and also cause the leg to push into valgus position (Seymore *et al.*, 2019). On gender basis, female volleyball athletes have shown that they produced higher peak knee extensor and ankle plantar flexion angle moment compared to their male counterpart with equal maximum jumping abilities (Weinhandl et al., 2015). Previous studies on SLL using drop jump box at specific heights are not representing the athletes actual jumping-landing ability. Furthermore, by using these specific heights, it can increase possibilities either the athletes are exerting lower or higher force of effort than their capability. Peng *et al.*, (2019) showed that when athletes performed a drop jump from a height exceeding their 100 percent CMJ height, there will be negative works at the knee and ankle joints. Negative works here means that the joint recruit muscles for contraction, but the stress exerted was greater than the muscles can bear. Moreover, studies that investigated the lower limb biomechanics during SLL from maximum effort counter movement jump in male and female athletes are scarce. The current study aims to investigate the biomechanics of SLL technique used by recreational male and female volleyball athletes that may predispose them to non-contact lower limb injuries.

1.3 Research Objective

1.3.1 General Objectives

To compare the lower limb biomechanics during single leg landing between male and female volleyball recreational players.

1.3.2 Specific Objectives

1) To compare the lower limb kinematics during single leg landing between male and female volleyball recreational players.

2) To compare the lower limb kinetics during single leg landing between male and female volleyball recreational players.

1.4 Research Hypotheses

1) Null Hypothesis (H_o): There are no significant differences of the lower limb kinematics (joint angle at MvGRF and Initial Contact) during single leg landing between male and female volleyball recreational players.

Alternatives Hypothesis (H_A): There are significant differences of the lower limb kinematics (joint angle at MvGRF and Initial Contact) during single leg landing between male and female volleyball recreational players.

2) Null Hypothesis (H_o): There are no significant differences of the lower limb kinetics (joint moment at MvGRF and Initial Contact) during single leg landing between male and female volleyball recreational players.

Alternatives Hypothesis (HA): There are significant differences of the lower limb kinetics (joint moment at MvGRF and Initial Contact) during single leg landing between male and female volleyball recreational players.

1.5 Significance of the Study

In volleyball, jump-land motion is considered as major skills because it is executed most of the time during spiking and blocking and it may determine the likelihood to obtain a point in a match. For a more advance player, these jump-land skills are applied and can be seen in almost every fundamental aspect in volleyball from serving, overhead passing, setting, spiking and blocking. By studying the biomechanics of SLL between male and female volleyball players, a greater understanding of their unique strategy and landing technique that prevent injuries on lower limb can be achieved. Through this study, the athletes may learn the biomechanical factors of their movement during landing that are inefficient and dangerous to them. Coaches and players may get benefits from the data in terms of injury prevention strategies which not only can contribute to the recreational athletes but to the elite and collegiate volleyball population as well. The injury prevention interventions planned based on the causes of injury in lower limb due to landing may reduce the associated cost of injury to majority collegiate athletes in general.

1.6 Operational Definition

Table 1.1: Operational Definitions

Abbreviations	Operational definition
Dynamic Knee Valgus	The combination of hip adduction, hip internal rotation, knee flexion, knee external rotation, knee abduction, ankle inversion and ankle dorsiflexion during dynamic motions.
Recreational Athletes	College student that participates in specific sport (volleyball) who are playing casually or competitively in the minimum of three months before the recruitment period.
Frontal Plane Kinematics	Branch of classical mechanics that describes the motions of points, bodies, and system of bodies without considering the mass of each or other forces that caused the motion. In this study, joint angles during landing phases were focused on.
Frontal Plane Kinetics	Analysis of forces and torques that cause motion. For this study, the joint moments and maximum vGRF were our focus.
Maximal Effort Countermovement Jump (CMJ)	Participants make an upright standing position first and then makes a preliminary downward movement by flexing at the knees and hips, then immediately extends the knees and hips again to jump vertically up off the ground by executing the highest height that individual able to.

Table 1.1, Continued

Single Leg Landing (SLL)	Landing with dominant leg on the specified area after execution of maximal effort CMJ. Able to hold landing position or gain stable landing posture for at least five seconds without any external aids.
Maximum vertical Ground Reaction Force (MvGRF)	The highest value of positive z-axis forces produces which is exerted by the ground on a body in contact with it during landing. Ground Reaction force are also commonly recognised as Normal force.
Initial Contact	Defined as the point where vGRF exceeded 10 N in the landing trials (Hoch et al., 2015)

CHAPTER 2

LITERATURE REVIEW

2.1 Biomechanics of landing

Landing is an important gross motor skill that brings the body from a certain height to the land. Execution of landing from jumps can be found in various sports such as rugby, basketball, netball and volleyball. Landing from a jump involve lower extremities muscles mainly the gluteus, quadriceps, hamstring, gastrocnemius, soleus and also many other small muscles in the leg. During landing, maintaining a good body posture is important because an ergonomically landing posture is more energy efficient and can prevent from injuries (Olson, 2020). For instance, comparison between a person that land with their leg straighten (i.e., stiff landing) and person that bend their leg (i.e., soft landing) showed that the individuals with stiff landing are more prone to injury due to the high stress given on the ankle, knee and its hip (DeVita and Skelly, 1992). There was low shock dissipation from the lower limb muscle and joints (hip and knee) when the leg is straightened but more shock is absorbed by the ankle (Yeow, Lee and Goh, 2011). The soft landing involves knee flexion angle of more than 63^{o} when the landing is executed. Another type of landing is the stiff landing where the angle of the knee flexion is less than $63^{o.}$ (Devita, and Skelly, 1992). Landing tension and vertical Ground Reaction Force (vGRF) is also associated with the height of landing. The higher the landing, the higher the force exerted on the feet due to the increased of potential energy, hence increased GRF at the point of contact (Yeow, Lee and Goh, 2011).

Single leg landing (SLL) is an act of coming from flight or jump by deposited one leg on the ground (Figure 2.1), whereas DLL is performed similarly as SLL but using both legs (Figure 2.2). People normally land from a jump on their both feet. In certain sports, due to multidirectional and high velocity gameplay, athletes are often performed landing on one of their legs. For instance, during a typical volleyball games, SLL can be observed when players blocking a ball, whether it results in successful block or unsuccessful block. Players usually perform successful block with stick landing and unsuccessful block with step-back landing, however step-back landing would expose the player’s limb to a risk of ACL injury (Zahradnik *et al.*, 2015). During SLL with stepping afterwards, the leg is more likely to deviate towards varus side (Sinsurin et al., 2017). Overall, blocking contributes five to 13 percent of point scored in Volleyball Division 1 of National Collegiate Athletic Association (NCAA) 2016 games.

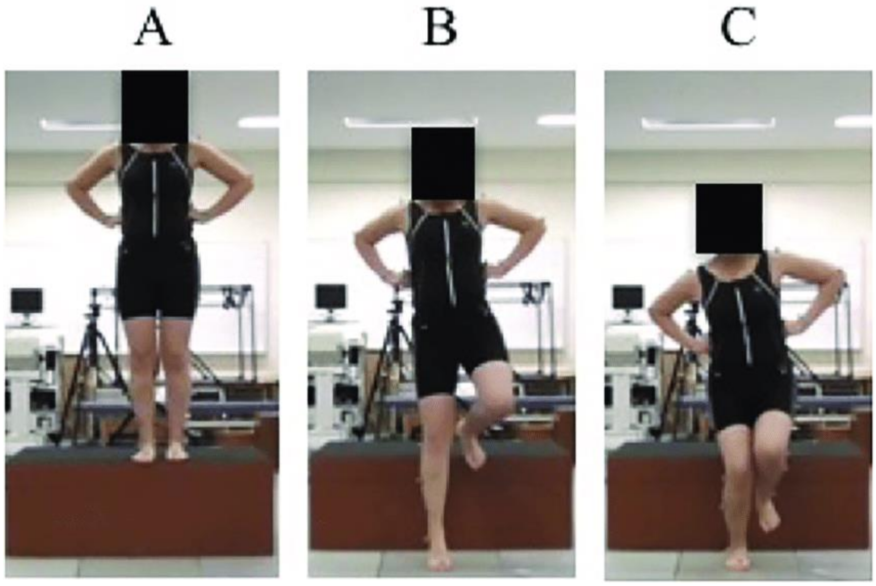

Figure 2.1: Single Leg Landing (SLL) from Drop Jump Box
(Uebayashi et al., 2019)

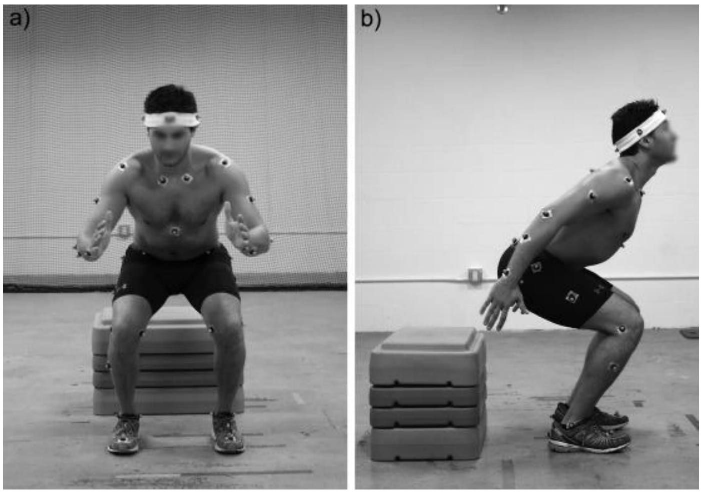

Figure 2.2: Double Leg Landing (DLL) from Drop Jump Box
(McPherson et al., 2016)

The knees are more likely to be abducted in DLL (Jenkins et al., 2017). There is a higher risk of ACL injury in execution of SLL compared to DLL because during SLL more body weight is loaded on the standing leg which then also increase forces exerted on the ground (Wang, 2011). It is also shown that maximum knee and hip flexion angle which related to soft type of landing are greater during DLL compared to SLL due to increase in strength and balance demands on the participants (Donohue *et al.*, 2015). Instance of landing with single leg are commonly seen after blocking in volleyball because in certain game actions, players need to quickly get ready to perform other actions of skills. This may cause the players to land with one of their leg and ready to take a step backward for attacking or a sidestep for further blocking.

2.1.1 Biomechanics of landing in volleyball

Volleyball is a game of six people in a court that consist combination of aerobic and anaerobic movements. Landing after a blocking is one of the complex techniques in volleyball. After landing from a block, the athletes will usually execute either stick landing or step back landing. In step back landing the athletes will exert high GRF on the dominant leg (Rostami et al., 2020).

A study involving ten male national university volleyball players who performed double leg stop jump (DLSJ) task it was observed that the athletes showed significantly small hip and knee angle and lower knee angular velocity at initial foot contact with the ground ($p < 0.05$). For Single leg stop jump (SLSJ), smaller maximum hip and knee flexion on landing were observed than DLSJ. Greater peak posterior GRF and peak vGRF was also produced during SLSJ ($p < 0.05$). The volleyball players executed SLSJ also exerted greater peak knee extension moment, peak knee valgus moment during landing, exhibited greater peak knee proximal tibia anterior and lateral sheer forces during landing compare to DLSJ (Wang, 2011). These stop jumps and landing movements, especially during blocking are really important in order to execute a blocking with accurate timing.

In addition, landing is associated with jumping sports. Based on a study by Horita *et al.*, (2002) it is identified that female athletes who involved in jumping, cutting and pivoting sports have higher rate of ACL injury incidences compared to male athletes playing similar sports. Women have more tendency to get injuries due to their own body weight and weaker muscle surrounding joints that associates with instability. Compared to men, women badminton players are also more vulnerable to the ACL injuries due to SLL after an overhead stroke due to the same reason (Kimura *et al.*, 2010).

Zhao and Gu (2019) found that there was no difference in initial contact moment between male and female badminton players. They also found that female players have significantly smaller peak posterior GRF moment, ankle dorsiflexion angle, knee and hip flexion angle compared to male players. Female athletes often exhibit greater knee varus and valgus excursion resulting of higher knee valgus and varus velocity compared to male athletes (Jenkins *et al.*, 2017). There is approximately 5^{o} greater overall frontal plane movement at the toe-off of those female athletes compared to males. Male athletes often rely on their larger hips musculature to absorb impact energy, whereas female athletes are commonly absorb energy on the knees and ankles (Weinhandl et al., 2015). Although athletes in general utilise their knee as primary energy absorber, female are more prone to absorb higher energy through ankle plantar flexion musculature compared to their male counterparts (Weinhandl et al., 2015). However, most previous studies focused on DLL or landing from a drop jump box. Landing from a drop jump does not represent real game situations and actual ability of the players. This can further result to over or lower than the actual maximal effort.

2.2 Dynamic Knee Valgus

Dynamic knee valgus (DKV) is a combination of hip adduction, hip internal rotation, and knee abduction identified as common lower extremity alignment in non-contact ACL injury (Hewett et al., 2005).

Figure 2.3: Dynamic Knee Valgus
(Schmidt, Harris-Hayes & Salsich, 2019)

Dynamic knee valgus (DKV) is related to kinetic chain motion, where medial motion of the knee joint, tibia abduction, and foot pronation can occur due to excessive frontal and transverse motion of the hip. The influence of proximal joint such as hip and trunk on knee motions is called top-down causes of excessive DKV. Tibiofemoral alignment can be assessed for DKV during static and dynamic position by using 3D motion capture system and force platform. Tibiofemoral alignment may reflect varus or valgus static alignment (Sharma *et al.*, 2010). The changes in lower limb posture may increase hip internal rotation and increase knee valgus loads, which may increase load upon patellofemoral joint (PFJ) with lower in knee flexion angle can cause development of patellofemoral pain syndrome (PFPS) (Cashman, 2012). Furthermore, people with weak hip abductors and external rotators may show increase in knee valgus, which lead to higher risk of injury of the lower extremities (Cashman, 2012).

On the other hand, DKV may be caused by bottom-up kinetic chain, which is related to positioning of the foot, types of foot arch, ankle range of motion and ankle strength. Toe direction may also affect the knee rotation (Ishida *et al.*, 2014). For example, ankle eversion causes tibia internal rotation in natural standing position in four different modes which are feet flat on floor, wedges angle at 10^o, 15^o and 20^o for 20 seconds to induce hyper pronation (Khamis and Yizhar, 2007). In a study by Jamaludin *et al.*, (2020), male athletes with greater strength of plantarflexor or dorsiflexor may land with greater knee varus angle. Significant relationship between ankle strength and knee FPPA at specific landing phases were observed in male (maximum vGRF phase) and female (MKF, IC and maximum vGRF phase) athletes with normal DKV (Jamaludin *et al.*, 2020)

Landing with knee valgus alignment may lead to poor dynamic lower extremity alignment such as increased in knee abduction moment (Hewett et al., 2005). Tamura et al., (2017) observed that individuals with DKV experienced higher knee angular impulse compared to those with varus knee. Tamura et al., (2017) also stated that landing with DKV may increase impact on the knee joints during deceleration phase of landing. DKV can be a factor that reduce an individual capacity to take the impact imposed on the knee joint during landing. Additionally, difference in hip and knee components observed on people with movement impairment were caused by a few different pain problems (Schmidt et al., 2019).

Dynamic Knee Valgus during landing are often related with non-contact injuries such as ACL tear, PFPS and ankle sprain. Female volleyball players are shown to suffer significantly greater non-contact ACL injuries than male volleyball players (Hewett *et al.*, 2005). Although rate of ACL injury in volleyball is not as common as Patella Tendinopathy, prevalence of this injury was shown to be more serious. ACL injury is usually observed during landing from awkward jump or a cutting maneuver (Eerkes, 2012). Hootman, Dick & Agel (2007) reported the rate of ACL injury at 0.09 per 1000 exposure for female volleyball athletes. DKV is also more significant in women and young athletes compared to male or adult athletes because of their biomechanical risk factors and anthropometrics which lead to higher risk of ACL injury (Mueske *et al.*, 2019). Therefore, in the current study, DKV will be observed during SLL among male and female volleyball players.

CHAPTER 3

METHODOLOGY

3.1 Study Design

This is a cross sectional study. The purpose of this research is to compare biomechanics of lower limb (e.g., hip, knee, ankle) between men and women during single leg landing (SLL). Fifteen male and female recreational volleyball players in USM Health Campus were involved in the study. This study's protocol was approved by the Human Research Ethics Committee, Universiti Sains Malaysia (USM/JEPeM/20040204) and completed within four months. The data collection procedure was conducted at Sports Science Lab PPSK, USM Health Campus, Kubang Kerian for about one hour per participant.

3.2 Sample size calculation

The sample size calculation was done by using the G*Power Software (v.3.1.9.2, Universität Düsseldorf, Germany) which is a free-to-use software to calculate a statistical power. The margin α-error was fixed to 5% with confidence interval at 95%. Priori calculation has shown that, 10 participants per sample group (males and female) were sufficient to get an effect size, d of 1.8 with alpha, α error probability of 0.05 and power of 95%. The statistical analysis test used was independent t-test. By inclusion of estimated 33 percent drop out, 15 participants for each group were recruited. Purposive sampling method was applied in recruiting the participants.

3.3 Study Participants

3.3.1 Inclusion Criteria

This study involved 30 volleyball players who had participated recreationally and actively involved in the sport for at least three months. They consisted of 15 male and 15 female athletes who had broad playing experience in volleyball games. The participants were thoroughly briefed beforehand regarding the study procedure. Participants were asked to be honest when signing the consent form for medical treatment section and inform the researcher immediately if there is any occurrence of health-related problems during the period of study.

Inclusion Criteria

- Age between 18-25 years old.
- No history of any lower limb, back injuries or undergoes medical surgery for the past six months before the data collection.
- Playing actively in volleyball at least in the previous three months.

3.3.2 Exclusion criteria

Exclusion Criteria

- Any severe lower limb and/or back injury for the past six months that requires surgery.
- Physician exclusion from any form of physical activities.
- Non-college residents or staying outside campus.

3.3.3 Recruitment of participants

Volleyball players were selected in the present study because of significant number of players from various level of participation. These recent years there was increments of players going for the team selection in recent Sukan Antara Desasiswa (SUKAD) academic session 2018/2019, USM Health Campus had sent two teams for both men and women volleyball event which constitute a total of 40 players. Participants were recruited using advertisement posters. Also, researcher collaborated with the college volleyball coaches to reach the participants. The information about the study were thoroughly explained to potential participation prior to their consent. Through this study the team and coaches gained insight on relevant data that can be use in their training sessions. The participants decision to participate in the study was not influenced by their coaches and other players.

3.4 Study Protocol

The flowchart of the study was shown in the figure below.

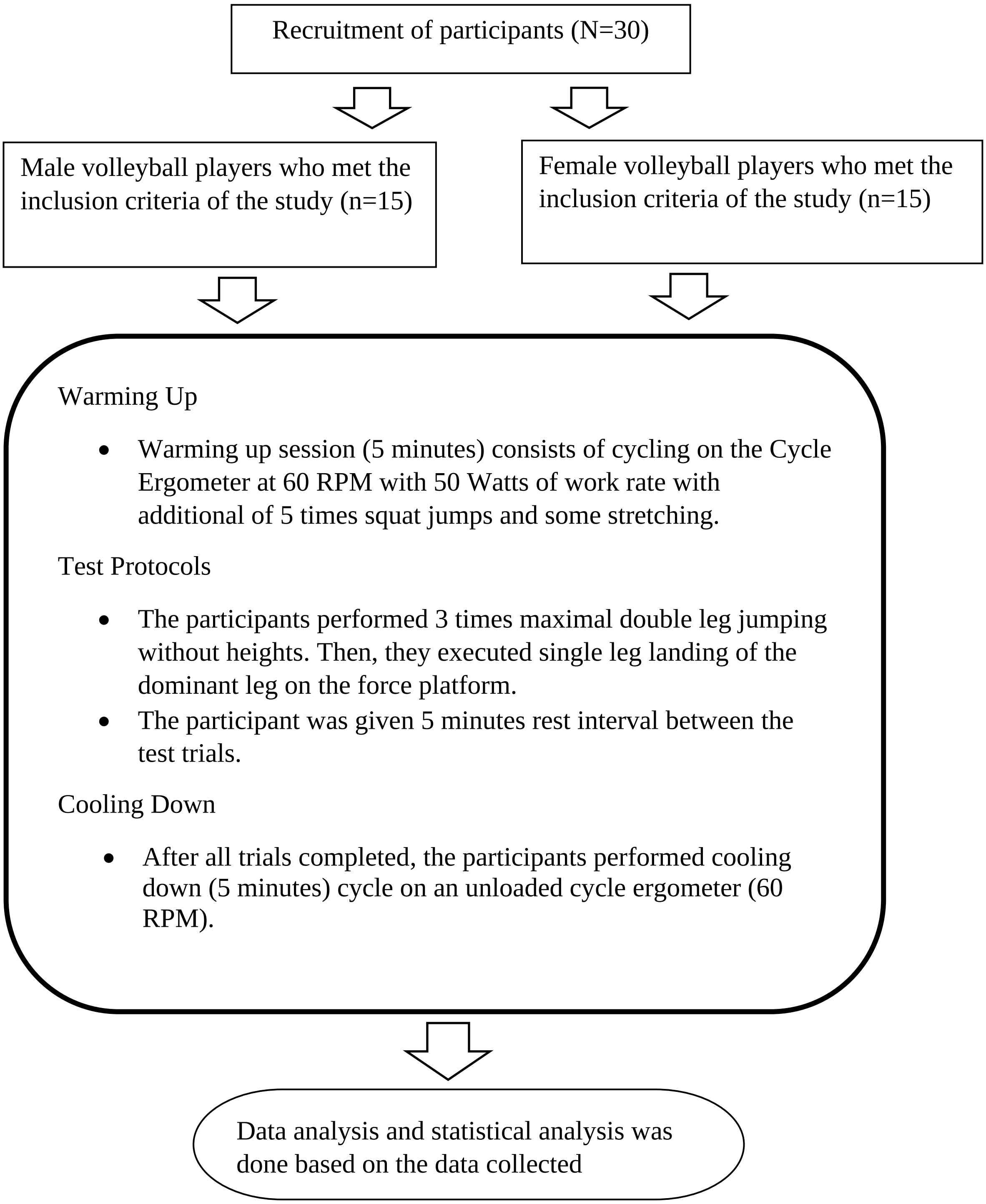

Figure 3.1: Study flowchart

3.4.1 Physical Characteristics of Participants

Participants underwent physical check-ups such as measurement of body height, weight, body fat percentage and length of dominant leg segments. Dominant leg was determined by asking the participants their favourable leg to shoot a ball as far as possible (Ford, Myer & Hewett, 2003). Body weight (kg) and height (m) were measured using digital medical scale (Seca 769, Hamburg, Germany). Body fat percentage was evaluated with an Electronic Body Fat Percentage Analyzer (Omron HBF-375, Kyoto, Japan) and length of dominant leg segments were measured by using measuring tape. Length of leg segments were quantified as the distance (cm) between Anterior Superior Iliac Spine (ASIS) and ipsilateral medial malleolus. The leg length was measured in both during standing and supine position. Then the tests were carried out.

Figure 3.2: Omron HBF-375 Electronic Body Fat Percentage Analyzer
Image from https://www.omronhealthcare-ap.com/my/product/102-hbf-375/1

3.4.2 Single Leg Landing Test

Before commencing the test, the participants were instructed to do a warming up session for 5 minutes on Cycle Ergometer (Cybex Inc., Ronkonkoma, NY, USA). The resistance was set up at 50 Watts 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 ballistic jumps. These warming up session is important in order to prevent injury by preparing the muscles, tendons, joints and bones for the activity and will likely to increase performance compared to do testing without warming up first.

Figure 3.3: Cybex Fitron Cycle-Ergometer Physical Therapy Stationary Hydraulic Exercise Bicycle for warming up and cooling down session.
Image from https://www.k-bid.com/auction/17285/item/48

For the testing exercises, the researcher demonstrated first for further understanding of what the participants need to do. Then only the researcher allowed the participants to do a practice session. If the participants find there was no difficulty to execute the exercises, then the researcher proceed with the actual testing of 3D test. For this purpose, a number of 35 retroreflective markers (25-mm diameter) were placed on the participants lower leg based on 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.

Figure 3.4: Reflective Markers
Image from https://simplifaster.com/articles/3d-motion-capture-sport/