COMPARISON OF KNEE KINEMATICS DURING SINGLE LEG SQUAT AMONG PHYSICALLY ACTIVE FEMALES WITH AND WITHOUT DYNAMIC KNEE VALGUS

VEENOTHINI PENTAYA

SCHOOL OF HEALTH SCIENCES

UNIVERSITI SAINS MALAYSIA

2020

CERTIFICATE

This is to certify that the dissertation entitled Comparison of knee kinematics during single leg squat among physically active females with and without dynamic knee valgus_is the bona fide record of research work done by Ms Veenothini Pentaya during the period from June to December 2019 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 Bachelor of Health Science (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: …….

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.

……

Veenothini Pentaya
Student, Exercise and Sports Science Programme,
School of Health Sciences
Universiti Sains Malaysia
Health Campus
16150 Kubang Kerian
Kelantan, Malaysia
Date: ……..

ACKNOWLEDGEMENT

First of all, I would like to thank God for providing me the strength, courage and patience to complete this biomechanics study successfully. I am very thankful to the Research Ethic Committee of USM for approving my research ethics prior to my study.

I would like to express my deepest appreciation to my Supervisor, Dr. Shazlin Shaharudin for her utmost dedication and whose work demonstrated to me the concerns of biomechanical studies in the provided time by ethics committee with so much of patience, guidance and encouragement towards me. Not forgetting all my supportive lecturers of Exercise and Sport Science who have been encouraging me throughout the process of this study.

In addition, I would like to also thank Mr. Mohd Hafezi Mat Zain and Mrs. Azilawati Azizan for their assistance in providing me to use the laboratory during data collection and analysis.

I am also grateful and would like to thank from the bottom of my heart to my two seniors, Nazatul Izzati Jamaludin and Farhah Nadhirah Aiman Sahabuddin, who have been also patiently teaching and guiding me throughout this study since I was new to this field.

Not to forget my dearest participants who voluntarily and immediately agreed to join this study. Their willingness and contribution to spare their time, not only during the weekdays but also during the weekends.

Last but not least, I am very grateful to have my parents as my pillar of strength in my life. My father, Pentaya Appanan and my mother, Salammal Subramniam have always been giving the love, care, concern and support not only during this research and the span of study in University Sains Malaysia, Kubang Kerian, Kelantan but also throughout my life. My thanks would not be enough to fill through whatever they have done for me.

Signature,

…….

(VEENOTHINI PENTAYA)

Final Year Student,

Exercise and Sports Science,

Universiti Sains Malaysia,

Kubang Kerian, Kelantan

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF ABBEVIATIONS

2D = Two-Dimensional

3D = Three-Dimensional

ACL = Anterior Cruciate Ligament

ASIS = Anterior Superior Iliac Spine

BMI = Body Mass Index

DKV = Dynamic Knee Valgus

DVJ = Drop Vertical Jump

FPPA = Frontal Plane Projection Angle

PFPS = Patellofemoral Pain Syndrome

PI = Physical Instructor

SD = Standard Deviation

SLS = Single Leg Squat

SPSS = Statistical Package for Social Sciences

V3D = Visual Three-Dimensional

WHO = World Health Organisation

ABSTRACT

Single Leg Squat (SLS) is a commonly used clinical assessment of lower limb function and a common motion in sports (i.e., running, landing from jumps, stepping) and daily activity (i.e., gait). SLS is used to evaluate Dynamic Knee Valgus (DKV) which can be applied to identify a potential risk factor for injury, a predictor for recovery and an outcome measure of rehabilitation. Moreover, females showed greater risks of knee injury compared to males due to DKV. Many clinical biomechanical tests such as drop-jump, star excursion balance, functional movement screen (FMS) and SLS tests were proposed to assess the risk of lower limb injuries. Hence, by studying the differences of knee mechanics during SLS among physically active females with and without excessive DKV, we may identify important biomechanical factors which could be trained to reduce risks of lower limb injury. This current study evaluated the knee kinematics during SLS at squat depth of 45˚and 60˚among physically active females (i.e., runner, volleyball and netball) with or without DKV. Thirty participants went through the Drop Vertical Jump (DVJ) screening test to confirm their eligibility to participate in the study. The two-dimensional (2D) frontal plane projection angle (FPPA) of the knee joint of dominant leg was evaluated from this screening test. This was done to observe the presence of excessive DVJ. The normal value of FPPA for females during DVJ test is from the range of 7˚- 13˚. From the screening test, 12 participants were within the normal range of knee FPPA (i.e., Group non-DKV) and 12 participants had exceeded the normal range of knee FPPA during DVJ screening test (i.e., Group DKV). Six participants were excluded from this study due to not meeting the inclusion criteria of having knee FPPA value within 7˚- 13˚. The knee FPPA for

these six participants were lesser than 7° (i.e., varus knee). Hence the total number of study participants are N=24. The two groups were compared and analysed using Independent T-Test. Independent T-Test was used to know if there were any significant differences across the depths of the squat and groups. Based on the test, there were no significant differences in the knee frontal plane angle during single leg squat at 45˚and 60˚knee flexion for dominant and non-dominant legs among physically active females with and without excessive DKV. By performing these tests, two-dimensional (2D) kinematic analysis of knee FFPA may help coaches and other professionals to detect asymmetries between dominant and non-dominant limbs, and to develop training programs with the goal of reducing overall lower extremity injury risk.

ABSTRAK

“Single Leg Squat” (SLS) adalah penilaian klinikal yang biasa digunakan untuk fungsi anggota bahagian bawah dan gerakan umum dalam sukan (iaitu, berlari, mendarat, melangkah) dan aktiviti harian (iaitu, berjalan). SLS digunakan untuk menilai “Dynamic Knee Valgus" (DKV) yang boleh digunakan untuk mengenal pasti faktor risiko yang berpotensi untuk kecederaan, prediktor untuk pemulihan dan langkah pemulihan. Selain itu, wanita menunjukkan risiko kecederaan lutut yang lebih besar berbanding lelaki kerana DKV. Banyak ujian biomekanik klinikal seperti “drop-jump”, “star excursion balance”, “functional movement screen” (FMS) dan ujian SLS dicadangkan untuk menilai risiko kecederaan anggota bahagian bawah. Oleh itu, dengan mengkaji perbezaan mekanik lutut semasa SLS di kalangan wanita yang aktif secara fizikal dengan dan tanpa DKV yang berlebihan, kita boleh mengenal pasti faktor-faktor biomekanik yang penting yang boleh dilatih untuk mengurangkan risiko kecederaan anggota badan yang lebih rendah. Kajian terkini ini telah menilai kinematik lutut semasa SLS pada kedalaman setinggan 45˚ dan 60˚ di kalangan wanita yang aktif secara fizikal (iaitu, pelari, pemain bola tampar dan pemain bola jaring) dengan atau tanpa DKV. Tiga puluh peserta menjalani ujian skrining Drop Vertical Jump (DVJ) untuk mengesahkan kelayakan mereka untuk mengambil bahagian dalam kajian ini. Dua dimensi (2D) :Frontal Plane Projection Angle” (FPPA) dari sendi lutut kaki dominan telah dinilai dari ujian skrining ini. Ujian ini telah dilakukan untuk memerhatikan kehadiran DVJ yang berlebihan. Nilai normal FPPA untuk perempuan semasa ujian DVJ adalah dari julat 7˚- 13˚. Dari ujian skrining, 12 peserta berada dalam lingkungan normal lutut FPPA (iaitu, Kumpulan bukan DKV) dan 12 peserta telah melebihi jangkauan normal lutut FPPA semasa ujian skrining DVJ (iaitu, Kumpulan DKV). Enam

peserta dikecualikan daripada kajian ini kerana tidak memenuhi kriteria inklusi - FPPA lutut untuk enam peserta ini kurang daripada 7 ° (iaitu, lutut varus). Oleh itu jumlah peserta kajian adalah N = 24. Kedua-dua kumpulan itu telah dibandingkan dan dianalisis menggunakan “Independent T-Test”. “Independent T-Test” digunakan untuk mengetahui sama ada terdapat perbezaan yang ketara di sebalik kedalaman cangkung dan kumpulan. Berdasarkan ujian itu, terdapat bahawa tiada perbezaan signifikan dalam sudut satah lutut pada kaki persendian kaki pada 45˚ dan 60˚yang dominan dan tidak dominan di kalangan perempuan yang aktif secara fizikal dengan dan tanpa DKV yang berlebihan. Dengan melakukan ujian-ujian ini, analisis kinematic dua dimensi (2D) FFPA lutut, ujian ini boleh membantu jurulatih dan profesional lain untuk mengesan asimetri antara anggota yang dominan dan tidak dominan serta untuk membangunkan program latihan dengan matlamat untuk mengurangkan risiko kecederaan anggota badan bahagian bawah secara keseluruhannya.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Dynamic knee valgus (DKV) is an abnormal movement pattern visually characterised by excessive medial collapse of the lower extremity during weight bearing (Schmidt et al, 2017). Excessive DKV or inward movement of the knee due to the altered kinematics of hip and ankle joints (Munro, et al, 2012) is an important aspect being observed during Single-Leg Squat (SLS) test (Kianifar et al, 2017). Furthermore, excessive DKV was consistently reported to cause non-contact lower limb injuries such as Anterior Cruciate Ligament (ACL) tear and Patellofemoral Pain Syndrome (PFPS) (Herrington, 2014; Kristianslund et al, 2014; McLean et al, 2005; Hewett et al., 2005; McLean et al., 2005; Malinzak et al, 2001). Non-contact injuries usually occur during cutting, pivoting, landing, and sudden deceleration prior to direction changes in sports (Powers, 2010). Therefore, DKV is a crucial biomechanical factor to be assessed during screening tests. The normal average two-dimensional (2D) knee FPPA during landing from Drop Vertical Jump (DVJ) is 7°-13° for females (Munro et al., 2012) indicating the normal values for DKV and exceeding it will be considered excessive DKV. DVJ is the screening test that we conducted to identify our participants as those with normal or excessive DKV.

Many clinical biomechanical tests such as drop-jump (Hewett et al., 2005), star excursion balance (Hegedus et al., 2016), functional movement screen (FMS)

(Everard et al, 2017) (Smith et al, 2017) and SLS (Munro et al., 2012; Schurr et al., 2017) tests were proposed to assess the risk of lower limb injuries. The SLS is a functional test commonly used to evaluate abnormal movement patterns of the lower limbs in terms of kinetic chain or co-ordinating muscle activity (Gianola, et al, 2017). This scale accounts for the assessment of five dimensions: overall impression, trunk posture, pelvis alignment, hip joint motion and knee join (Gianola et al., 2017). This test is favoured by clinicians as it has relevance as a surrogate for higher functional activities such as running and jumping. The SLS is potentially promising as a functional test since it involves both daily activity and athletic task and showed good validity and reliability (Gianola et al., 2017).

Females showed higher prevalence of ACL injury than males, and they exhibit excessive hip adduction, hip internal rotation and knee valgus (Barker-Davies et al., 2018). Furthermore, females have been found to land in more knee valgus position during single leg step landing (Russell et al, 2006) and double leg drop jump (Ford, et al, 2003; Hewett et al., 2005). Excessive DKV is believed to explain the higher incidence of ACL injury and PFPS in females (Cowan & Crossley, 2009) and (Herrington & Munro, 2010). However, knee valgus alignment on SLS has also been associated with other trainable deficits such as reduced flexibility and strength (Barker-Davies et al., 2018). These modifiable risk factors are amenable to physical therapy that could result in improved outcomes. Correcting excessive knee valgus on the SLS in PFPS has associated decreases in pelvic obliquity, hip adduction and internal rotation and pain (Barker-Davies et al., 2018). Neuromuscular training for four weeks improved quality of SLS, pain and function in single leg squat deficits and these improvements were maintained

at three months follow up (Barker-Davies et al., 2018). Hence, by studying the differences of knee mechanics during SLS among physically active females with and without excessive DKV, we may identify important biomechanical factors which could be trained to reduce risks of lower limb injury.

To the best of our knowledge, knee kinematics during SLS across those with and without DKV have not been studied. Hence, current study evaluates the knee kinematics during SLS at squat depth of 45˚ and 60˚ among physically active females with or without DKV.

1.2 Problem Statement

SLS is a commonly used clinical assessment of lower limb function and a common motion in sports (i.e., running, landing from jumps, stepping) and daily activity (i.e., gait). The SLS is used to evaluate DKV which can be applied to identify a potential risk factor for injury, a predictor for recovery and an outcome measure of rehabilitation. Moreover, females showed greater risks of knee injury compared to males due to DKV. However, to the best of our knowledge, no studies have compared knee mechanics during SLS among physically active females with and without excessive DKV. Through observing the variations in knee mechanics during SLS between physically active females with and without excessive DKV, we can recognize essential biomechanical factors that can be trained to reduce the risks of lower limb injuries.

1.3 Significance of the Study

Prevention and intervention have become a priority for researchers and clinicians, therefore screening for injury risks is warranted. SLS is a clinical test that may assess the risk of lower limb injuries. Poor dynamic alignment such as excessive trunk lateral flexion, pelvic drop, hip adduction and internal rotation, knee internal or external rotation and foot hyper pronation which affected knee valgus could be evaluated from SLS (Dingenen et al, 2014). The objectives of this current study are to study the knee kinematics during SLS with or without DKV in physically active females. Participants will gain information regarding their risks for lower limb injury, and knee mechanics through participation in the study. This information will increase their awareness about the risk of injuries and they may take preventive actions. Findings from this study may provide the exposure of occurring dynamic knee valgus of the individual and how it may affect their knee kinematics during SLS in physically active females. Moreover, this study may benefit the participants by reducing their risk of injuries, which may be costly in terms of money, time and psychological.

1.4 Objectives of the Study

1.4.1 General Objectives

To compare the knee kinematics during single leg squat at 45° and 60° among physically active females with or without dynamic knee valgus.

1.4.2 Specific Objectives

1. To compare knee kinematics during single leg squat at 45° among physically active females with or without dynamic knee valgus.
2. To compare knee kinematics during single leg squat at 60° among physically active females with or without dynamic knee valgus.

1.5 Hypothesis of the Study

Specific Objective 1: To compare knee kinematics during single leg squat at 45° with or without dynamic knee valgus in physically active females.

Null Hypothesis (H_{O1}): There are no significant differences of knee kinematics during single leg squat at 45˚with or without dynamic knee valgus in physically active females.

Alternative Hypothesis (H_{A1}): There are significant differences of knee kinematics during single leg squat at 45˚with or without dynamic knee valgus in physically active females.

Specific Objective 2: To compare knee kinematics during single leg squat at 60° with or without dynamic knee valgus in physically active females.

Null Hypothesis (H_{O2}): There are no significant differences of knee kinematics during single leg squat at 60˚with or without dynamic knee valgus in physically active females.

Alternative Hypothesis (H_{A2}): There are significant differences of knee kinematics during single leg squat at 60˚with or without dynamic knee valgus in physically active females.

1.6 Operational Definition

Table 1.1 : Operational Definitions

Abbreviations	Operational Definitions
Physically Active	Participants must participate actively in sports and train for at least three times per week.
Female Athletes	30 physically active female university athlete students age between 19-25 years old and free from any lower limb injuries at the time of data collection and six months prior will be encouraged to take part in this study.
Dynamic Knee Valgus	Dynamic knee valgus is a kinetic chain motion whereby excessive frontal and transverse plane motions at the hip cause medial motion of the knee joint, tibia abduction, and foot pronation. For normal group, participants must have normal values of 2D knee FPPA (Frontal Plane Projection Angle) during DVJ (Drop Vertical Jump) screening test which is 7°-13° for females.

	For dynamic knee valgus group, participants must exceed the normal values of 2D knee FPPA during DVJ screening test which is more than 13° for females.
Knee Kinematics	Knee angles in three planes (i.e., frontal, sagittal and transverse) are compared at the squat depth of 45° and 60° during SLS trials.

CHAPTER 2

LITERATURE REVIEW

2.1 Dynamic Knee Valgus

Dynamic Knee Valgus (DKV) is known not only as frontal plane movement (i.e., hip adduction, knee abduction and ankle eversion), but also horizontal plane movement (i.e., femoral internal rotation and tibial internal or external rotation) (Figure 2.1). During complex knee valgus motions, there are no consensus on the course of tibial rotation although ankle and foot kinematics will significantly affect tibial rotation. Ankle eversion induces tibial internal rotation and potentially tibial internal and external rotations of the foot through the ankle joint (Ishida, et al 2014).

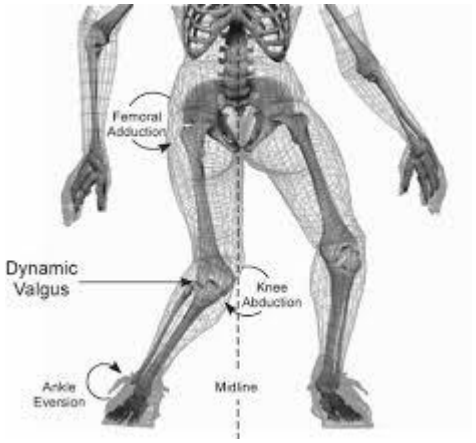

Figure 2.1 Dynamic valgus was defined as the position or motion, of the distal femur toward and distal tibia away from the midline of the body (adopted from (Hewett et al., 2005)

Excessive knee valgus has been shown to be related to diminished hip muscle strength and has been implicated in contributing to numerous knee

injuries, including ACL injury and patellofemoral joint dysfunction (Powers, 2010). Furthermore, excessive DKV was consistently reported to cause non-contact lower limb injuries such as ACL tear and PFPS making it a crucial biomechanical factor to be assessed during screening tests (Herrington, 2014; Kristianslund et al., 2014; McLean et al., 2005; Hewett et al., 2005; Malinzak et al., 2005). Abnormal lower limb biomechanics during activity, such as excessive DKV has been widely postulated as a factor in the aetiology of both traumatic and overuse knee injury (Munro et al., 2012). Non-contact injuries usually occur during cutting, pivoting, landing, sudden deceleration prior to direction changes in sports and in any position and motion (Powers, 2010).

3D motion analysis is the gold standard for recording and analysing dynamic motion. Additionally, 2D knee FPPA during DVJ test among 20 recreationally active university students showed good within-day and between-days reliability (Munro et al., 2012). Majority of lower limb kinematic variables showed good and excellent reliability for within-day and between-days in five lower extremity functional screening tests among 25 participants (Whatman et al., 2011). Therefore, in this study, we applied 2D motion capture for DVJ screening test, and then we proceeded with 3D motion capture for SLS.

Excessive hip adduction and internal rotation during weight bearing has the potential to affect the kinematics of the entire lower extremity (Powers, 2010). Specifically, excessive hip adduction and internal rotation can cause the knee joint centre to move medially relative to the foot. This is because the foot is fixed to the ground, thus the inward movement of the knee joint causes the tibia to abduct and