CORRELATION OF SELECTED ANTHROPOMETRIC VARIABLES WITH HAMSTRING FLEXIBILITY AMONG UNDERGRADUATES OF UNIVERSITY OF BENIN

BY

OGIERIAKHI, EHIREMEN FRANKLYN

(BMS1702302)

A PROJECT SUBMITTED TO THE DEPARTMENT OF PHYSIOTHERAPY, SCHOOL OF BASIC MEDICAL SCIENCES, COLLEGE OF MEDICAL SCIENCES UNIVERSITY OF BENIN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF PHYSIOTHERAPY DEGREE

SEPTEMBER, 2023

CERTIFICATION

This dissertation by Ogieriakhi, Ehiremen Franklyn is accepted in its presented form as satisfying the dissertation requirement of the degree of Bachelor of Physiotherapy of the School of Basic Medical Sciences, College of Medical Sciences of the University of Benin.

PROF. JOSEPH UMUNNAH ……………………………..

Supervisor Signature And Date

………………………………

EXTERNAL EXAMINER Signature And Date

APPROVED

………………………………..

REV SIS (DR) HENRIETTA FAWOLE

ACTING HEAD

DEPARTMENT OF PHYSIOTHERAPY

COLLEGE OF MEDICAL SCIENCES

UNIVERSITY OF BENIN

DEDICATION

This dissertation is dedicated to God and to my parents, Mr & Mrs Hilary Ogieriakhi Omoregie.

ABSTRACTS

Background: The hamstring muscles are primarily the flexors of the knee and can also take part in the extension of the hip and require a good degree of flexibility to do so. The sit-and-reach test is a field test used to measure hamstring and low back flexibility.

Aim: This study was aimed at evaluating hamstring flexibility among undergraduates of the University of Benin.

Method: This ex-post-facto study recruited 400 volunteers (200 males and 200 females) healthy undergraduates, aged between 17-30 years old. A tape measure and digital weighing scale were used to collect data for the selected anthropometric variables -Height, Weight, BMI, Upper limb length, Lower limb length, and Trunk length. Sit-and-Reach test was performed on a mat; a goniometer was used to assess for Active Hip range of motion. Data collected were summarized using descriptive statistics of mean and standard deviation, An Independent T-test was used to ascertain the difference between males and females for the Sit-and-Reach test and Active Hip active range of motion, and A Pearson's product-moment correlation was used to examine the relationship between some anthropometric variables on Sit-and-Reach test and Active Hip active range of motion. Level of significance was set at 0.05.

Result: The findings revealed that there were no significant gender differences in Sit-and-Reach test scores (p=0.063) and Active Hip Range of Motion (p=0.096). There was positive significant correlations between sit-and -reach test scores and Upper limb length (p=0.0001), lower limb length (p=0.0001) and trunk length (p=0.005), and between Active Hip Range of Motion and height (p=0.0001), lower limb length (p=0.0001) and trunk length (p=0.005), There was positive significant correlation between BMI (P=0.004) and active hip range of motion but no significant correlation with Sit-and-Reach test (p=0.258), trunk length (p=0.143) showed no significant correlation with active hip range of motion. Height showed no significant correlation with both tests.

Conclusion: This study provided the average value of hamstring flexibility among male and female were within the normal range. Anthropometric factors such as upper limb length, lower limb length, BMI and trunk length correlated with hamstring flexibility among Nigeria adults. However, the pattern of correlation varies between sit and reach test and active hip range of motion. There was no significant correlation between height and both tests

Key words: *Sit-and-Reach test, Active Hip range of motion, Anthropometric variables*

ACKNOWLEGDEMENTS

My deepest gratitude to God Almighty for making this dream to become a reality and for the success of this project.

I sincerely appreciate my project supervisor, Prof Joseph O. Umunnah, for his invaluable guidance, attention, suggestions and comments, throughout the course of this project. His encouragement helped me in all stages of writing this dissertation. I am truly grateful for all the necessary corrections made despite his busy schedule.

My sincere gratitude to the Head of Department Rev. Sister (Dr) Henrietta Fawole for her immense help at the initial stages of this work and for her wonderful suggestions. I am deeply grateful Ma for your time and attention.

I really want to appreciate Prof. Kayode Oke who has been a great inspiration, and the department at large. God bless you, sir.

Special thanks to all my lecturers in the Department of Physiotherapy, University of Benin, Prof Kayode I. Oke, Rev Sis (Dr) Fawole, Prof Joseph Umunnah, Dr. Femi Ogundiran, Dr. Obinna Ezeukwu, Dr Nelson Ekechukwu, Dr.(Mrs) Rita Ativie, Dr Bolarinde who imparted knowledge to me during my undergraduate studies. A special thanks to the Head of Department, Physiotherapy, University of Benin Teaching Hospital, Mr Taiwo Oyewumi, the directors, Mr. R.E. Okhuahesuyi, Dr (Mrs). C. Obaseki and Mrs. S. Kubenje, Mr F.O Igbinovia and also to the Chief physiotherapist, Interns and other clinicians in the Department of Physiotherapy, University of Benin Teaching Hospital, I appreciate the knowledge and skills imparted on me during my clinical postings in the University of Benin Teaching Hospital. I also appreciate the non-academic staff, especially Mr Nosa Osunbor and Mrs Juliet Walters of the Department of Physiotherapy, University of Benin.

I also appreciate the great efforts of my friends-cum research assistants and partners Osakioyame Osahon, Ogbeni Raymond, Christian Clem-Oguah, Oluwatobi John Ojo and Felicity Okorie who assisted me during the data collection and was always there for me. I also appreciate the great efforts of my dearest friends, Fr, Simon, Chikezie, Sly, OgeneMarho, Toch, Oshomah, Osi, Henry, Anthony Ekezeh (HoD) and those from Isiuwa Study Centre. Thanks for all your encouragements. I would also like appreciate my beloved Siblings Ehis, Francis, Abies and Osasogie Ogieriakhi for all the love and support. Special appreciation to Theodora, Rita, Sorochi, David, Peter. My profound gratitude to my lovely parents Mr. & Mrs. Hilary Ogieriakhi Omorogie constant prayers and support.

To all my friends Jeffery Okosodo, Patrick Edevbaro and to my all my Classmates, thank you all very much for great support. My special gratitude also goes to all my classmates, and to the 400 persons who participated in my study and to everyone who the confines of this page will not permit me to state. And to my humble self for always staying motivated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Flexibility is defined as the sufficient three dimensional or tri-planar deformations of a muscle to permit the normal function of extensibility and recoil with adequate strength and at appropriate velocity, and ability to return to a normal length. Two types of flexibility include static flexibility which refers to full range of motion (ROM) of a specific joint and dynamic flexibility which refers to torque or resistance encountered as the joint moves through its ROM (McArdle & Katch, 2010). Flexibility and mobility are terms that can be used interchangeably to describe the capacity to move without restriction. Passive mobility depends on soft tissue extensibility. Mobility is the capacity of the body to move or be moved in order to occur range of motion for functional tasks. The hamstrings are primarily responsible for extension. Another lateral rotator is the gluteus maximus. So flexibility is the ability of muscle and other soft tissue to yield to a stretch force (Kisner & Colby, 2007). Static flexibility refers to the amount of movement obtained by passively moving a limb to a maximum degree, dynamic flexibility is concerned with the amount of active movement possible as a result of muscle contraction (Norris, 1997). Flexibility is joint specific and it depends on many factors like joint capsule distensibility, warm-up exercises, muscle viscosity, compliance of other tissues such as ligaments and tendons (Riebe et al, 2018).

The hamstring muscles are primarily the flexors of the knee and can also take part in extension of the hip. Any functional interference in length and strength of the hamstring muscles can have some effect in the flexibility of the hip and probably the trunk. This makes for the assessment of this muscle length necessary in clinical setting (Worell & Perrin, 1992). The two actions of the hamstring cannot be performed maximally at the same time: full flexion of the knee requires shortening of the hamstrings that they cannot provide the additional contraction that would be necessary for the simultaneous full extension of the thigh; similarly, full extension of the hip shortens the hamstrings so they cannot further contract to act fully on the knee (Moore & Dalley, 2006). The hamstring muscles play a significant role in the regulation of human movement and are used for a variety of motions including running, jumping, bending forward while sitting or standing, and a variety of postural control movements (Gannamaneni & Kakaraparthi, 2017). Hamstring muscle strains are the most common muscle injury in athletes (Kujala *et al.,* 1997; Stephens *et al.,* 2006). The proposed cause of hamstring strain includes insufficient flexibility, strength (force generating capacity) impairment, and dysynergic contraction that can place excessive strain on the hamstring muscles (Agre, 1985; Stephens *et al.,* 2006).

Several tests have been utilized to measure both hamstrings and low back flexibility and they include the active knee extension test, straight leg raise, passive knee extension test, toe touch test, sit and reach test, finger to floor test and goniometric testing. The sit and reach test is a field test used to measure hamstring and low back flexibility (Baumgartner & Jackson, 1995; Baltaci *et al.,* 2003). This test is important because it is believed that maintaining hamstring and low back flexibility may prevent acute and chronic musculoskeletal injuries and low back problems, postural deviations, gait limitations and risk of falling (Baltaci *et al.,* 2003).

Measuring hip active range of motion with a universal goniometer in conjunction with the sit and reach test, allows the examiner to more effectively assess the flexibility of the individual and removes the negative effect of anthropometric factor in the result. Hip active range of motion during the sit and reach test consist of lumbar flexion and pelvic rotation (movement of the pelvis around the hip as the leg is fixed) (Murray *et al.,* 2002). Due to the location of the hamstring originating at the ischial tuberosity, poor hamstring flexibility can restrict anterior pelvic tilt (Esola *et al.,* 1996). It is generally believed in order to obtain an accurate result in the sit and reach test, the subject has to control the position of his or her hips. A universal goniometer is an instrument used to measure joint range of motion.

Various researchers have observed that anthropometric factors such as limb length, height, body mass index are likely to affect the results of the sit-and-reach test (Kendall, 1965; Kendall & Kendall, 1948).

1.2 Statement of problem

The lifestyle of adolescents involves frequent use of the lower limbs in many ways which may predispose them to injury. Studies have shown that adolescent is at risk of developing musculoskeletal disorders especially strains (Cornbleet & Woolsty, 1996). Also, hamstring tightness has been shown to contribute to the occurrence of hamstring muscle strain, low back pain, increased tendency to fall, avulsion fractures, tendinitis etc. Hamstrings flexibility have been shown to contribute to the likely occurrence of low back pain. No study has been encountered in South South Nigeria that investigated the possible level of flexibility in adolescents/young adults as possible predictor of low back pain.

Few studies have shown the influence of some anthropometric variables on sit and reach test and goniometry measure of the hip active range of motion, thus the need to incorporate the influence of anthropometric variables on sit and reach tests and goniometry tests.

1.3 Aim of the study

This study is aimed at evaluating hamstring flexibility among undergraduates of University of Benin.

1.4 Objectives

1. To determine the average value of hamstring flexibility among male and female undergraduate participants.

2. To ascertain the relationship between height and hamstring flexibility in the study population.

3. To examine the relationship between Body Mass Index (BMI) and hamstring flexibility in the selected sample.

4. To establish the relationship between upper limb length and hamstring flexibility in the research participants.

5. To determine the relationship between lower limb length and hamstring flexibility within the chosen group.

6. To investigate the relationship between trunk length and hamstring flexibility in the studied undergraduate population.

1.4 Research Question

1. What would be the Average value of hamstring flexibility in male and female Undergraduates?
2. What would be the relationship between the height and hamstring flexibility?
3. What would be the relationship between the Body Mass Index and hamstring flexibility?
4. What would be the relationship between the Upper limb length and hamstring flexibility?
5. What would be the relationship between the Lower limb length and hamstring flexibility?
6. What would be the relationship between the Trunk length and hamstring flexibility?

1.5 Research hypothesis

This research sought to hypothesize that

1. There would be no significant difference of hamstring flexibility using the sit and reach test between male and female Undergraduates of University of Benin.
2. There would be no significant difference of hamstring flexibility using the active hip range of motion between male and female Undergraduates of University of Benin.
3. There would be no significant correlation between body mass index and hamstring flexibility the V sit and reach test scores.
4. There would be no significant correlation between height and hamstring flexibility using the V sit and reach test.
5. There would be no significant correlation between upper limb length and hamstring flexibility using the V sit and reach test.
6. There would be no significant correlation between lower limb length and hamstring flexibility using the V sit and reach test.
7. There would be no significant correlation between trunk length and hamstring flexibility using the V sit and reach test.
8. There would be no significant correlation between body mass index and hamstring flexibility using the active hip range of motion.

9. There would be no significant correlation between height and hamstring flexibility using the active hip range of motion.
10. There would be no significant correlation between upper limb length and hamstring flexibility using the active hip range of motion.
11. There would be no significant correlation between lower limb length and hamstring flexibility using the active hip range of motion.
12. There would be no significant correlation between trunk length and hamstring flexibility using the active hip range of motion.

1.6 Delimitation

This study is delimited to:

1. Male and female Undergraduates of University of Benin the ages of 18-30.
2. The use of sit and reach test and active hip range of motion as an index of hamstring flexibility.
3. Individuals with no previous orthopedic or neurologic conditions.

1.7 Significance of study

Most people can sustain their mobility through regular, everyday utilization of their limbs and joints in typical activities. Nonetheless, prolonged periods of maintaining a single posture (such as prolonged sitting) can lead to adaptive shortening, resulting in potential loss of mobility. The results of this study will add to the existing body of knowledge of the hamstring flexibility assessment test in the health sector. Unawareness of the importance of measuring hamstring flexibility can lead to short hamstring muscle length and tightness which predisposes an individual to certain musculoskeletal disorders, gait limitations and reduced athletic performance. This study may highlight a relationship between musculoskeletal injuries and hamstring flexibility thus may help to indicate the need for adolescents to engage in more physical conditioning and flexibility exercises to reduce the possibility of occurrence and intensity of musculoskeletal injuries.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the hamstring muscles

The hamstrings are the group of muscles found at the posterior compartment of the thigh. Three of the four muscles in the posterior aspect of the thigh are the hamstrings: semitendinosus, semimembranosus and biceps femoris (long head) (Moore & Dalley, 2006) share common features:

Proximal attachment: the ischial tuberosity deep to the gluteal maximus.

Action: It acts on the hip joint (extension) and the knee (flexion).

Innervation: by the tibial division of the sciatic nerve.

The fourth hamstring muscle, the adductor magnus met all above criteria.

2.1.1 Semitendinosus

This muscle is semitendinosus as the name implies. It has a fusiform belly that is usually interrupted by a tendinous insertion and a long cord-like tendon that begins approximately two-thirds of the way down the thigh (Moore & Dalley, 2006).

Origin: ischial tuberosity

Insertion: medial surface of superior part of the tibia

Innervation: tibial division of the sciatic nerve (L5, S1, S2)

Function: extend thigh and flex leg and rotate it medially when knee is flexed; when thigh and leg are flexed; semitendinosus with the semimembranosus can extend the trunk.

2.1.2 Semimembranosus

The semimembranosus is a broad muscle that is also aptly named because of the flattened membranous form of its proximal attachment to the ischial tuberosity. The tendon of the semimembranosus forms around the middle of the thigh and descends to the posterior part of the medial tibial condyle (Moore & Dalley, 2006).

Origin: ischial tuberosity.

Insertion: posterior part of the medial condyle of tibia; reflected attachment forms oblique popliteal ligament to lateral femoral condyle.

Innervation and main action are same with semitendinosus

2.1.3 Long head of biceps femoris

As its name indicates, the fusiform biceps femoris has two heads: a long head and a short head. In the inferior part of the thigh, the long head becomes tendinous and is joined by the short head. The rounded common tendon attaches to the head of the fibula and can easily be seen and felt as it passes the knee, especially when the knee is flexed against resistance. The long head of the biceps femoris crosses and provides protection for the sciatic nerve after it descends from the gluteal region into the posterior aspect of the thigh (Moore & Dalley, 2006). When the sciatic nerve divides into its terminal branches, the lateral branch (common fibular nerve) continues this relationship, running with the biceps tendon (Moore & Dalley, 2006).

Origin:

Long head: ischial tuberosity.

Short head: originates from the femur at the lateral lip of the linea aspera, proximal two thirds of the lateral supracondylar line of femur and lateral intra muscular septum. Lateral side of head of fibula; tendon is split at this site by fibular collateral ligament of knee

Innervations: Long head: tibial division of sciatic nerve (L5, **S1**, S2) Short head: common fibular division of sciatic nerve (L5, **S1**, S2).

Main function: Flexes leg and rotates it laterally when knee is flexed; extends thigh (e.g., when starting to walk) (Moore & Dalley, 2006).

2.1.4 Adductor Magnus

Origin:

Adductor part: inferior ramus of pubis, ramus of ischium
Hamstrings part: ischial tuberosity

Insertion:

Adductor part: gluteal tuberosity, linea aspera, medial supracondylar line
Hamstrings part: adductor tubercle of femur

Innervations:

Adductor part: obturator nerve (L2, **L3, L4**), branches of posterior division
Hamstrings part: tibial part of sciatic nerve (**L4**)

Main action: Adducts thigh
Adductor part: flexes thigh
Hamstrings part: extends thigh

The hamstrings are mainly type II fibers (Worell & Perrin, 1992). This means that they have relatively short twitch durations and are specialized for fine, skilled movement (Ganong, 2005). Hamstrings actions (two) cannot be maximally performed at the same time: Full extension of the hip shortens the hamstrings so much that they are unable to further contract to act fully on the knee; similarly, full flexion of the knee requires so much shortening of the hamstrings that they are unable to simultaneously provide the additional contraction needed for full extension of the thigh. The hamstrings can assist in extending the trunk at the hip joint while the thighs and legs are stationary. In all circumstances, with the exception of full knee flexion, they are active in thigh extension, including when maintaining the relaxed standing posture (standing at leisure). A person with paralyzed hamstrings tends to fall forward because the gluteus maximus muscles cannot maintain the necessary muscle tone to stand straight (Moore & Dalley, 2006).

The hamstrings are the hip extensors involved in walking on flat ground, when the gluteus maximus demonstrates minimal activity. However, rather than producing either hip extension or knee flexion per se during normal walking, the hamstrings demonstrate most activity when they are eccentrically contracting, resisting (decelerating) hip flexion and knee extension during terminal swing (between mid-swing and heel strike) (Moore & Dalley, 2006).
The length of the hamstrings varies, but this is usually a matter of conditioning. When the knees become extended, some people's legs are too short to reach their toes. Routine stretch exercise can lengthen these muscles and tendons (Moore & Dalley, 2006).

2.2 Gait contributions of the hamstring muscles

The gait cycle has two phases: 60% stance phase and 40% swing phase with two periods of double support that occupy a total of 25-30% of the gait cycle (Arbulu *et al,* 2009). The stance phase consists of heel strike, foot flat and toe off; the swing phase is described as the period from toe off to heel strike (Worell & Perrin, 1992). One complete gait cycle is described as heel strike to heel strike of the same leg. During walking, one limb is always in contact with the ground (Inman *et al.,* 1981; Worell & Perrin, 1992).
During running, a period of non-contact with the ground occurs that is called non-support or float (Worell & Perrin, 1992). With increasing running speed, the length of time in stance phase decreases while the amount of time in float phase increases (Worell & Perrin, 1992). Thus, these muscles must contract faster and absorb more force during a shorter period of time because the period of time in which the muscles of the lower limb work is reduced due to increased running speed (Mann 1982; Worell & Perrin, 1992).

Mann & Sprague (1980) describe the function of the hamstrings in walking as active at the end of the swing phase until foot flat has been completed. The hamstrings contract eccentrically to control knee extension in the swing phase while at heel strike, they provide stability and initiate flexion of the knee (Arbulu *et al,* 2009). During running, the hamstring muscles become active during the last third of the swing phase, at which time the tibia is being decelerated eccentrically and the hip flexes concentrically (Worell & Perrin, 1992). Just prior to foot contact, the hamstrings continue to be active for hip extension and knee flexion (Mann 1982; Worell & Perrin, 1992). During sprinting, Wood *et al.,* (1984) reported high eccentric forces (150J) by the hamstrings in the late swing phase in an attempt to decelerate the lower leg prior to ground contact.

2.3 Pathologies of the hamstring muscle

The hamstring muscles are important contributors to the control of human movement and are involved in a wide range of activities from running and jumping to forward bending during sitting or standing and a range of postural control actions (Stephen *et al.,* 2006). This means that when these muscles are affected, there is an alteration in the individual's level of activities and normal working. Hamstring muscle strains are the most common muscle injuries in athletes (Worell & Perrin, 1992; Kujala *et al.,* 1997; Stephens *et al.,* 2006; Clanton & Coupe, 1998). Muscle injury, whether partial or complete, occurs at the myotendinous junction, where force is concentrated (Clanton & Coupe, 1998). The high incidence of injury in this muscle group may be partly because the group functions over two joints and is therefore subject to stretch at more than one point (Orchard & Seward, 2002; D1evlin, 2000; Hawkins *et al.,* 2000; Woods *et al.,* 2004). In addition, the hamstring has a higher percentage of fast twitch fibers than other thigh and leg muscles, which makes them capable of generating more force. Common muscle imbalance patterns may invoke the use of the hamstring as a slow twitch muscle which may predispose the muscle to injury when challenged to perform high velocity fast twitch actions (Woods *et al.,* 2004). It is therefore worthwhile addressing any muscle imbalances when assessing and treating these injuries (Woods *et al.,* 2004).

Some factors are believed to interfere with hamstring flexibility and predispose individuals to hamstring injury. These include having muscular strength imbalances between the hamstrings in the left versus the right leg or between the quadriceps and hamstrings in the same leg, genetic factors (some people are born with shorter hamstrings). Certain medical conditions such as sciatica, hamstring syndrome, piriformis syndrome, Scheurmann's disease etc. can result in hamstring tightness. Prolonged sitting can shorten the hamstrings over time and cause tightness during standing activity and also improper or absent stretching prior to participating in exercise or sports can predispose one to injury.

Potential damage includes hamstring sprains, strains, avulsion fractures, tendinitis, pulled hamstrings and bursitis (mainly ischial bursitis and popliteal cysts). It has also been found that shortened hamstring can result in low back pain. Reduced hamstring muscle flexibility has been implicated in lumbar spine dysfunction, with a number of studies showing a strong positive correlation between decreased hamstring flexibility and low back pain (Agre, 1987; Esola *et al.,* 1996; Tafazzoli & Lamonagne, 1996; Halbertsma *et al.,* 2001; Stephens *et al.,* 2006). This can be explained as thus: due to the fact the hamstring cross two joints, when the hamstring shortens, they pull the buttocks down causing a "tucking under" which flattens the lumbar curve (a cause of low back pain). They also prevent the knees from extension, which encourages stooping and poor posture. A tightened hamstring can also pull the knee out of its natural alignment, thereby leaving it open to an array of injuries. The most common hamstring injury is during non-contact sports especially during running, jugging, dribbling etc. The biceps femoris was the most commonly strained muscle of the hamstring complex (Woods *et al.,* 2004).

Short hamstrings can be improved upon by the intervention of a physiotherapist. This involves muscle strengthening. Variety of methods have been used to increase hamstring muscle flexibility, including static stretch, proprioceptive neuromuscular facilitation, dynamic range of motion and active motion in the neural slump position (Stephens *et al.,* 2006). Additionally, awareness through movement, which verbally directs or guides a person through an activity where movement is often performed slowly and gently, can be used. This process has been shown to improve the learning strategies for improving organization and coordination of body movement by developing spatial and kinesthetic awareness of body segment relationships at rest and during motion, awareness of ease of movement, reducing effort in action and learning the feeling of longer muscles in action (Feldenkrais, 1972; Stephens & Feldenkrais, 2000; Stephens *et al.,* 2006). This process has been shown to improve balance and coordination in people with multiple sclerosis and balance and mobility in people with chronic cardiovascular accident (Stephens *et al.,* 2006).

2.3.1 Pathophysiology and healing/treatment of hamstring injuries

When hamstring injuries occur, often the athlete describes a sharp pain during sprinting, kicking or jumping. Occasionally, the athlete will describe a gradual onset of symptoms, such as dull ache, burning and/or tightness (Worell & Perrin, 1992). These vague symptoms are usually seen after several days or weeks of strenuous workouts. General evaluation of hamstring muscle injuries reveals point tenderness in the proximal hamstring region near the ischial tuberosity, painful active knee flexion, and painful restricted passive knee extension (Worell & Perrin, 1992). The most common site of injury is in the proximo-lateral portion of the hamstring (Worell & Perrin, 1992). Ecchymosis and swelling may be observed extending distally to the mid posterior thigh or in some cases, to the popliteal space (Worell & Perrin, 1992). Physicians, physical therapists, and athletic trainers are well aware of the frequent occurrence of this noncontact injury (Worell & Perrin, 1992). Muscle injury, where partial or complete, occurs at the myotendinous junction, where force is concentrated (Clanton & Coupe, 1998). The healing response begins with inflammation, associated edema, and localized hemorrhage. After an initial period of reduced tension, the healing muscle regains strength rapidly as long as re-injury does not occur (Clanton & Coupe, 1998). Although the use of anti-inflammatory medication is a keystone of treatment, a certain degree of inflammation is necessary for removing necrotic muscle fibers and re-scaffolding to allow optimal recovery (Clanton & Coupe, 1998). The protocol of rest, ice, compression, and elevation is still the preferred first-aid approach. After a brief period of immobilization (usually less than 1 week for even the most severe strain), mobilization is begun to properly align the regenerating muscle fibers and limit the extent of connective tissue fibrosis (Clanton & Coupe, 1998). Concurrent pain-free stretching and strengthening exercises (beginning with isometrics and progressing to isotonic and isokinetic) are essential to regain flexibility and prevent further injury and inflammation (Clanton & Coupe, 1998). Readiness for return to competition can be assessed by isokinetic testing to confirm that muscle-strength imbalance has been corrected, the hamstring-quadricep ratio is 50% to 60%, and the strength of the injured leg has been restored to within 10% of the unaffected leg (Clanton & Coupe, 1998). The only indication for surgery is a complete rupture at or near the origin from the ischial tuberosity or distally at its insertion (either soft-tissue avulsion with a large defect or bone avulsion with displacement by 2cm) (Clanton & Coupe, 1998).

2.4 The hip joint

2.4.1 Articular Surfaces of the Hip Joint

The round head of the femur articulates with the cup-like acetabulum of the hip bone. The head of the femur forms approximately two thirds of a sphere (Moore & Dalley, 2006). Except for the pit or fovea for the ligament of the femoral head, all of the head is covered with articular cartilage, which is thickest over weight-bearing areas.

The acetabulum, a hemispherical hollow on the lateral aspect of the hip bone, is formed by the fusion of three bony parts (Moore & Dalley, 2006). The heavy, prominent rim of the acetabulum consists of a semilunar articular part covered with articular cartilage, the lunate surface of the acetabulum. The acetabular rim and lunate surface form approximately three quarters of a circle; the missing inferior segment of the circle is the acetabular notch (Moore & Dalley, 2006).

The fibro cartilaginous acetabular labrum (lip) attaches to the acetabular rim, increasing the acetabular articular area by nearly 10%. The transverse acetabular ligament, a continuation of the acetabular labrum, bridges the acetabular notch. As a result of the height of the rim and labrum, more than half of the femoral head fits within the acetabulum. In other words, the acetabular labrum enables the acetabulum to grasp the femoral head beyond its equator (Moore & Dalley, 2006).

Centrally, a deep non-articular portion known as the acetabular fossa is primarily shaped by the ischium. This fossa possesses a delicate wall (often displaying translucency) and remains contiguous with the acetabular notch in the lower region. Optimal congruence of the articular surfaces of the acetabulum and femoral head is achieved when the hip is flexed at a 90° angle, abducted by 5°, and laterally rotated by 10° – a configuration aligning the axes of the acetabulum and the femoral head and neck. This specific alignment is akin to the quadruped position. In essence, the transition to an upright posture involves a slight compromise in joint stability to enhance the capacity for weight-bearing in the erect stance (Chulabhorn International College of Medicine, 2018). Even so, the hip joint is our most stable joint, owing also to its complete ball and socket construction (depth of the socket); the strength of its capsule; and the attachments of muscles crossing the joint, many of which are located at some distance from the center of movement (Moore & Dalley, 2006).

2.4.2 Joint Capsule of the Hip Joint

The hip joints are enclosed within robust yet loose joint capsules, comprised of an exterior fibrous layer (fibrous capsule) and an internal synovial membrane. Proximally, the fibrous layer attaches to the acetabulum, just peripheral to the rim to which the labrum is attached, and to the transverse acetabular ligament (Moore & Dalley, 2006). Distally, the fibrous layer attaches to the femoral neck only anteriorly at the intertrochanteric line and root of the greater trochanter. Posteriorly, the fibrous layer crosses the neck proximal to the intertrochanteric crest but is not attached to it (Moore & Dalley, 2006).

The majority of fibers within the fibrous layer follow a twisting path from the hip bone to the intertrochanteric line. However, certain inner fibers take a circular route around the neck, creating what's known as the orbicular zone. The denser portions of the fibrous layer in the capsule create the hip joint ligaments, which also traverse in a spiral manner from the pelvis to the femur. Extension winds its spiraling ligaments and fibers more tightly, constricting the capsule and drawing the femoral head tightly into the acetabulum (Moore & Dalley, 2006). The tightened fibrous layer increases the stability of the joint, but restricts extension of the joint to 10-20° beyond the vertical position (Moore & Dalley, 2006). Flexion increasingly unwinds the spiraling ligaments and fibers. This permits considerable flexion of the hip joint with increasing mobility.

Of the three intrinsic ligaments of the joint capsule below it is the first one that reinforces and strengthens the joint:

i. Positioned at the front and top is the robust Y-shaped iliofemoral ligament, also known as the Bigelow ligament. This ligament connects proximally to the anterior inferior iliac spine and the rim of the acetabulum, while its distal attachment is at the intertrochanteric line. Recognized as the body's most resilient ligament, the iliofemoral ligament plays a specific role in preventing excessive extension of the hip joint when standing, achieving this by securing the femoral head within the acetabulum through the mechanism described earlier.

ii. In the anterior and lower region, we find the pubofemoral ligament, originating from the obturator crest of the pubic bone. This ligament extends laterally and downward, merging with the fibrous layer of the joint capsule. It melds with the medial segment of the iliofemoral ligament and becomes taut during both hip joint extension and abduction. By doing so, it effectively restrains excessive abduction of the hip joint.

iii. Positioned at the rear is the ischiofemoral ligament, which emerges from the ischial portion of the acetabular rim. Among the three ligaments, this one is the least sturdy.

It takes a spiral path, moving upwards and laterally towards the femoral neck, and then curves medially toward the base of the greater trochanter.

The medial and lateral rotators of the thigh, which are periarticular muscles, are crucial in preserving the joint's structural integrity.

The femoral head is pulled medially into the acetabulum by muscles and ligaments, and these forces are reciprocally balanced. The anterior ligaments are stronger than the medial flexors, which are smaller, weaker, and less mechanically advantageous. the orbicular zone, which is formed in a circle around the neck. The hip joint's ligaments are made up of thick sections of the capsule's fibrous layer, which spiral from the pelvis to the femur. Conversely, the ligaments are weaker posteriorly where the medial rotators are abundant, stronger, and more mechanically advantaged (Moore & Dalley, 2006).

In all synovial joints, synovial membrane lines all internal surfaces of the fibrous layer as well as any intra-capsular bony surfaces not lined with articular cartilage. Thus in the hip joint, where the fibrous layer attaches to the femur distant from the articular cartilage covering the femoral head, the synovial membrane of the hip joint reflects proximally along the femoral neck to the edge of the femoral head (Moore & Dalley, 2006). Longitudinal synovial folds (retinacular) occur in the membrane covering the femoral neck. Sub-synovial retinacular arteries (branches of the medial and a few of the lateral, circumflex femoral artery) that supply the femoral head and neck course within the synovial folds.

The ligament of the head of the femur, primarily a synovial fold conducting a blood vessel, is weak and of little importance in strengthening the hip joint. Its wide end attaches to the margins of the acetabular notch and the transverse acetabular ligament; its narrow end attaches to the fovea for the ligament of the head (Moore & Dalley, 2006). Usually, the ligament contains a small artery to the head of the femur. A fat pad in the acetabular fossa fills the part of the acetabular fossa that is not occupied by the ligament of the femoral head. Both the ligament and the fat-pad are covered with synovial membrane (Moore & Dalley, 2006). The malleable nature of the fat-pad permits it to change shape to accommodate the variations in the congruity of the femoral head and acetabulum as well as changes in the position of the ligament of the head during joint movements (Moore & Dalley, 2006). A synovial protrusion beyond the free margin of the joint capsule onto the posterior aspect of the femoral neck forms a bursa for the obturator externus tendon (Moore & Dalley, 2006).

2.4.3 Movements of the Hip Joint

Hip movements are flexion, extension, abduction, adduction, medial and lateral rotation, and circumduction. Movements of the trunk at the hip joints are also important, such as those occurring when a person lifts the trunk from the supine position during sit-ups or keeps the pelvis level when one foot is off the ground (Moore & Dalley, 2006).

The degree of flexion and extension possible at the hip joint depends on the position of the knee. If the knee is flexed, relaxing the hamstrings, the thigh can be actively flexed until it almost reaches the anterior abdominal wall, and can reach it via further passive flexion (Moore & Dalley, 2006). Not all this movement occurs at the hip joint; some results from flexion of the vertebral column. During extension of the hip joint, the fibrous layer of the joint capsule, especially the iliofemoral ligament, is taut; therefore, the hip can usually be extended only slightly beyond the vertical except by movement of the bony pelvis (flexion of lumbar vertebrae) (Moore & Dalley, 2006).

From the anatomical position, the range of abduction of the hip joint is usually somewhat greater than for adduction. About 60° of abduction is possible when the thigh is extended, and more when it is flexed. Lateral rotation is much more powerful than medial rotation. The main muscles producing movements of the hip joint are listed below (Moore & Dalley, 2006). Note that:

- The hip's flexor (iliopsoas) muscle is the strongest muscle.
- Beyond its role in adduction, the adductor magnus also functions as a flexor (anterior or aponeurotic portion) and an extensor (posterior or hamstrings section).
- Multiple muscles are involved in both flexion and adduction, including the pectineus and gracilis, as well as all three adductor muscles.
- In addition to their function as abductors, the front segments of the gluteus medius and minimus muscles also contribute to medial rotation.
- The gluteus maximus acts as the primary extensor, moving from a flexed position to a straight (standing) posture. Further posterior extension is mainly accomplished by the hamstrings. The gluteus maximus also plays a role in lateral rotation

2.5 Hamstring flexibility

Flexibility is the ability of tissues surrounding a joint to yield to stretching without interference or opposition then relax (Kathryn, 1997). Flexibility is an important factor influencing health and quality of lifestyle. Limitations in flexibility whether globally or of individual joints appears as the first symptom of dysfunction of the musculoskeletal system preceding either pain or insufficiency or both. Many tests have been developed for measuring hamstring flexibility. These include active knee extension test, straight leg raise, passive knee extension test, toe touch test, sit and reach test, finger to floor test and goniometric testing.

2.5.1 Sit and reach test

This is a test for assessing hamstring flexibility. It has the following types: traditional sit and reach, modified sit and reach, V-sit and reach, back saver sit and reach and the chair sit and reach. A score is given based on the most distant point reached by both hands on a standardized box as the individual being tested leans forward in a long-sitting position. Passing scores are given when individual can reach at least 2cm beyond their toes. A box called sit and reach box was placed in front of the individual's leg on which he stretched his hands as far as possible as he bends the hip forward. The test is objectively read on the ruler scale on the box calibrated in centimeters (cm). The marking on the ruler was positioned so that the 23cm mark represented the point at which the subject's fingertips were in line with their toes (Cornbleet & Woolsty, 1996).

In this way, the SRT score was always a positive number, even for individuals who were unable to reach their toes. The minimal accepted score to pass, as determined by Americans Alliance for Health. Physical Education, Recreation and Dance AAHPERD), is 25cm or 2 cm beyond the toes, for all ages and both genders and without consideration of anthropometric variables (Cornbleet & Woolsty, 1996). The hamstrings are mostly stretched when the opposite of their actions is performed. This is applied in the sit and reach test.

Normative date for Sit and Reach Test Scores

Male - results in centimeters (cm)

- Above 29 = Excellent
- 23 to 28 = Above average
- 19 to 22 = Average
- 14 to 18 = Below average
- Below 13 = Poor (ACSM, 2018)

Female - results in centimeters (cm)

- Above 30 = Excellent
- 26 to 29 = Above average
- 22 to 25 = Average
- 17 to 21 = Below average
- Below 16 = Poor (ACSM, 2018).

2.5.2 Hip active range of motion using a universal goniometer

The term "goniometer" is derived from two Greek words, Gonia meaning angle and Metron meaning measure. It is an instrument used to measure angles. In physical therapy, it is used to measure the total amount of available motion at a specific joint. Goniometer can be used to measure both active and passive range of motion. It is usually constructed of either plastic or metal and produced in a variety of shapes and sizes. It consists of three parts- the body, the stationary arm and the movable arm. The body of the goniometer is designed like a protractor and may form a full or half circle. A measuring scale is located around the body. The scale can extend either from 0° to 180° and 180° to 0° for the half circle models, or from 0° to 360° and from 360°- 0° on the full circle models. The intervals on the scales can vary from 1° to 10°. The stationary arm is structurally a part of the body and therefore cannot move independently of the body. The moving arm is attached to the fulcrum in the center of the body by a rivet or screw-like device that allows the moving arm to move freely on the body of the device. It can be used to obtain the hip range of motion at the end of the reach when the movable arm is placed vertical to the midline of the trunk (the pointer at 90°), the body is placed at the iliac crest (the point at which the pelvis begins to rotate) and the stationary arm aligned to the lateral midline of the thigh as the student sits upright and as he leans forwards. It is a good assessor of the hamstring muscle length since the hamstring muscle expresses its full length on forward bending during long sitting. As the trunk progresses forward during the reach, the hip active range of motion changes. It is used as criterion measure of hamstring muscle length if applied when an individual performs the sit and reach test. This is because the hamstring muscle length is greatly expressed in this long sitting and reaching position as the hip joint flexes and the knee kept extended on a flat surface. This will now record the angle of inclination of the hip joint during the reach (hip flexion). The average hip flexion according to Igwe (2004) is 113^0. When an individual is on long sitting, it is assumed that the hip flexion is on 90. So using the manual goniometer, the average angle from long sitting can be determined from $113^0 - 90^0 = 23^0$. Therefore, for the purpose of this work, an individual passes this goniometer test if he or she is able to make at least above 23^0.

2.6 Factors affecting hamstring flexibility

Also an individual joint flexibility is determined by certain factors. These factors include:

1. Joint structure: Some joints have greater range of motion than the others. Example, the ball and socket joint of the shoulder has the greatest range of motion and moves in all anatomical planes. The hinge joint of the knee allows movement only in one plane (Thompson & Osness, 2004).
2. Age and Gender: Range of motion and flexibility decreases with age. This is due in part to the fibrous connective tissue that takes the place of muscle fibers through a process called fibrosis. It is also known that females are more flexible than males.
3. Previous injury: injury to the muscle and connective tissue can lead to thickening and fibrosing of the affected area. Fibrous tissue is less elastic and can lead to limb shortening and reduced range of motion.
4. Bulk of the muscle: An increase in muscle bulk or percentage body fat can limit joint range of motion and flexion. The additional tissue mass acts as an obstruction to joint motion limiting bone segments movement.
5. Muscular Imbalance: muscle strength and length imbalances reduce flexibility.

2.7 Benefits of hamstring flexibility

Good flexible joint has the following benefits:

1) Releases tension built up during the activity and lessens stress on the muscles that are exercising.
2) Aids in posture by balancing the tension in the muscles that cross the joints. Reduced stress and increased joint mobility strength are also benefits of good posture.

3) Because flexible muscles are more pliable, the risk of damage during exercise and daily activities is decreased (pre-habilitation of injury).
4) Enhances performance in everyday tasks, exercise, and sports.
5) Enhances body performance and complements the advantages the body has obtained through aerobic and anaerobic training, resulting in a faster and better body movement.

Flexible hamstring muscles can benefit the overall health of the body. By strengthening and stretching the hamstring muscles as part of everyday fitness routine, one can achieve stronger thigh that will support the rest of the muscle groups, preventing injuries and improving physical abilities. It can also prevent lower back pain. Hamstring muscles will better support the back and pelvis while carrying out movement if they are flexible. Strong and flexible hamstring muscles can support the body during exercise and help prevent injury, especially during running. Flexibility is important in the ability to perform daily life activities, as well as in athletic performance.

2.8 Consequences of reduced hamstring flexibility

Also an individual's joint flexibility is determined by other factors. These factors include:

1. Hamstring strain: These occur most commonly during eccentric contraction and are caused by forceful hip flexion while the hamstring is working to slow the extension of the knee especially during kicking or running.

2. Poor posture: Tight hamstring muscle causes the pelvic area to tilt forward, called posterior pelvic tilt. Here, there is little or no curvature on the lower spine and the sitting bones are pulled under while the thigh and hip jut forward placing excessive strain on the lower back muscles.

3. Avulsions: This occurs when the muscles and tendons tear away from the bone.

4. Bursitis: Tight hamstring muscle can cause bursitis (Pes Anserine bursitis). The bursa is located between the tibia and the three tendons of the hamstring muscle at the knee.

5. Low back pain: Individuals with tight hamstrings tend to develop low back pain and those with lower back pain tend to develop tight hamstrings. This is because hamstring tightness limits motion in the pelvis and so the motion gets transferred to the lumbar segments and increases stress on the low back.

6. Training in a Limited Joint Range of Motion: Some authors have proposed that training through a full ROM is necessary to maximize the value of an exercise (Haff & Triplett, 2015), thus, to achieve strength throughout a full ROM, training must involve complete excursion of the joint.

2.9 Improvement of flexibility

Joint and muscle flexibility is an important element of general health and physical fitness. Adequate flexibility is desirable for every individual and it (flexibility) is considered to be a possible preventer of low back pain and some of the aches and pains that accompany aging (Kathryn, 1997). In addition, improved performance in many sports activities, as well as prevention of injury and soreness, can result from an improper programme of flexibility development.

A general flexibility exercise programme should include those that stretch the tissues crossing the lower back, hip, knee, and ankle (Kathryn, 1997). Flexibility in joints can be improved through Ballistic Stretching exercises and these must be avoided wherever possible or necessary to prevent wears and tears of the joint and the surrounding muscles. Stretching can be passive or active according to the source of the stretching force. Stretching should be part of the daily routine. Stretching helps keep the hamstrings from stiffness, which can become more of a problem especially for individuals whose job requires long sitting on a desk most of the day. Previous research suggests static stretching may help reduce injury rates (Hartig & Henderson, 1999; Cross & Worrell, 1999) and improve recovery from injury (Malliaropoulos et al, 2004; Mason et al, 2007; Petersen & Holmich, 2005). However other studies suggest that static stretching has little or no impact on injury prevention (Pope et al, 2000; Arnason et al, 2008; Thacker et al, 2004). Dynamic stretching has been recommended as an alternative to static stretching post warm up as evidence suggests that Dynamic stretching positively impacts on immediate physical performance (McMillian et al, 2006; Little & Williams, 2006). Dynamic stretches, however, appear to be less effective than static stretches at increasing flexibility in uninjured individuals (Chan et al, 2001; Davis et al, 2005; Bandy et al, 1998; De Weijer et al, 2003; Depino et al, 2000). There is also disagreement on how long the effect of stretching lasts, although the gains in flexibility are believed to decrease relatively quickly (De Weijer et al, 2003; Depino et al, 2000).

3.0 Empirical review

Jackson & Baker (1986) established that the validity of sit and reach test is based on a logical analysis of its requirements. They reported a study that examined the relations between the sit and reach test and criterion measures of hamstring and low back flexibility in girls of 13-15 years. They found validity coefficient of $r = 0.64$ between the sit and reach test and a criterion measure for hamstring flexibility, and $r = 0.28$ when compared with a criterion measure for low back flexibility (Jackson & Baker 1986). Jackson & Baker (1986) concluded that all sit and reach test protocols yield moderate validity for hamstring flexibility and poor validity for low back flexibility.

Cornbleet & Woolsty (1996) correlation of sit and reach tests scores and inclinometer measure of hip active range of motion and suggested differences in expectations for hamstring muscle length in boys and girls. Although scores for the sit and reach test and hip active range of motion were correlated, Cornbleet & Woolsty (1996) assessed hamstring muscle length using hip active range of motion scores because these scores are not influence by anthropometric factors or spinal mobility. They identified the anthropometric factors to be long arms or short legs relative to the trunk; and scapular abduction, which increases the reaching distance of the arms. Their participants were 410 school-aged children (211 girls, 199 boys). Hamstrings muscle length was found to be shorter in boys than in girls. They concluded that results of this study suggest that hip active range of motion measurements guide treatment more effective than do the sit and reach test measurements (Cornbleet & Woolsty, 1996).

Guy (1998) examined the impact of various anthropometric and flexibility measurements on the sit-and-reach test. He sought to determine which components of anthropometry and leg/back flexibility best contribute to performance of the sit and reach test. He also examined the relationships among selected back and lower extremity flexibility tests. Guy, (1998) with Thirty-four healthy college-age women performed 5 flexibility tests:(a) S&R, (b) Schober-L for lumbar spine flexibility, (c) Schober –L+T for thoracic and lumbar spine flexibility, (d) straight leg raise (SLR) for hamstring flexibility, and (e) ankle dorsiflexion (DF) for ankle plantar-flexor flexibility. Statistical analysis included the use of correlation matrices among all measurements of flexibility and anthropometry. Also a stepwise regression model was used to establish the best flexibility and anthropometric predictors of performance on the S&R. The level of association between S&R and SLR performance was found to be $r = 0.78$ ($p < 0.01$). He continued that all other flexibility tests and anthropometry variables (leg and arm length) were not as well associated with S&R performance. He concluded that S&R performance was almost exclusively determined by hamstring flexibility (Guy, 1998). Also, ankle plantar- flexion, hamstring, and back flexibility were poorly correlated, indicating a need for specific flexibility measurement on each joint or muscle group (Guy, 1998).

Baltaci *et al*. (2003), compared three different sit and reach tests (traditional sit and reach, chair sit and reach CSR and back saver sit and reach test BSSR) as a measure of hamstring flexibility in 102 female student with mean age 22 (1.46) years, height of 168.3 (8.9) cm, and weight of 59.7 (11) kg. Their analyses indicated that the traditional SR and BSSTR tests were highly related to hamstring flexibility. In contrast, the CSR test was not related to hamstring flexibility for either the right or the left leg (r =0.22 and 0.21 respectively) (Baltaci *et al*., 2003). These findings show that both SR and BSSR tests are valid for measuring hamstring flexibility.

However, Youdas *et al.* (2008) in their work; "validity of hamstring muscle length assessment during the sit and reach test using an inclinometer to measure hip active range of motion" were of the view that using an inclinometer to measure hip angle during the sit and reach test is not a valid method for assessing hamstring muscle length in men and women who can independently assume a long-sitting position on a hard surface. There was a statistically significant correlation ($R=0.59$, $P < 0.01$) between performance sit and reach (SRT) as measured by HJA and the supine passive straight leg raise (PSLR), but the SRT only accounted for 35% of the variability in the

PSLR. SRT performance in men (mean ± SD, 80±9°) was significantly less (P<0.001) than in women (mean ± SD, 92 ± 10 degree).

Castro-Pinero *et al.* (2009) examined the criterion-related validity of the sit and reach test (SRT) and the modified sit and reach test (MSRT) for estimating hamstring flexibility in children and adolescents as well as to determine whether the MSRT is more valid than SRT. A total of 87 children (45 boys and 42 girls) (6-12 years old) and adolescents (13-17 years old) performed the SRT and MSRT. The flexibility of the hamstring was measured with goniometry for the passive straight leg raise test. The SRT was associated with hamstring flexibility in both children (performed the SRT and MSRT). Regression analysis was done to study the association of SRT and MSRT with hamstring flexibility (criterion measure). The SRT was associated with hamstring flexibility in both children (B=1.089, R^2=0.298, p<0.001) and adolescents (B=0.588, $R^2$0.243, p=0.027). It is concluded that the criterion-related validity of the SRT and MSRT for estimating hamstring flexibility is weak. The present data do not support that the MSRT is a more valid method than SRT in children and adolescent. (Castro-Pinero *et al.,* 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research design

This study was an ex post facto.

3.2 Research population

The population of this research comprised male and female Undergraduates of University of Benin between the ages of 18-30 years.

3.3 Sample size and sample technique

The consecutive sampling technique was employed involving male and female students (undergraduates) of University of Benin. The students that participated in this study will be between 18-30 years of age. Population data to be obtained from the University CPRU (Central Processing and Records Unit).

3.4 Selection criteria

Inclusion criteria

1. Only full time undergraduates of University of Benin.
2. Only students without any previous orthopedic or neurologic problems will be selected.
3. Only students within age range of 18 – 30 years will participate.

3.5 Ethical considerations

Ethical approval was sought and obtained from the School of Basic Medical Sciences Research and Ethics Committee of University of Benin **(CMS/REC/2023/374)**, Benin City and all participants was asked for consent before they were enlisted to participate in the study. Throughout the course of the research study, the ethical principles guiding the use of human participants in research as stipulated by the Belmont report was strictly adhered to as follows

Confidentiality: All information collected was securely kept and all research assistants were made to sign a declaration of non-disclosure of all information provided by participants in the course of the data collection.

Beneficence: this amount to the idea of "do no harm" while take full advantage of benefits of the study and curtailing hazards to the participants. The information that was collected will help to ascertain the relationship the correlation of some selected anthropometric variables and hamstring flexibility among undergraduates of University of Benin. Participants may be informed about the outcome of the research through a publication

Justice (Non-Maleficence to Participants): This study was conducted with trained assistants who understood the aim of the study. Participants who met the selection criteria was selected randomly without any special preference or undue influence.

Respect for persons (Voluntariness): Each participant in this study was provided with information about the study and its objectives. Participation in the study was completely voluntary and participants was informed that they are at liberty to decline at any stage of the study without any consequence.

3.6 Materials

1. Tape rule (butterfly brand): this was used to measure the height, limb and trunk lengths.
2. Bathroom weighing scale: this was used to measure the weight in kilogram.
3. Goniometer: this instrument was used to measure active range of motion of the hip joint.
4. A mat: this was used by the participants to perform the V sit and reach test.

3.7 Procedure for data collection

The students that met the inclusion criteria were present for the following:

Before the tests:

- Bio-data: participants were observed for their gender while information concerning their ages was obtained from them. The reported ages were recorded to the last birthday age.
- The participants were measured bare-footed and with minimal clothing.
- The student first climbs the weighing scale; the researcher viewed the weight directly by squatting before the student. Height was measured by tracing the vertex with a book/flat surface and a measuring was used to measure to sole of the foot.
- The body mass index was calculated using: weight/height$^{2.}$
- Upper limb measurement was taken from the acromion to the tip of the middle finger in an erect standing position with the arms by the sides.
- The lower limb length was determined by measuring from the anterior superior iliac spine to the heel of the foot in the same standing position.
- The trunk length was measured from the acromion to the anterior superior iliac spine on the ipsilateral side.
- The student sat on a mat on the floor with the back against the wall, knees fully extended and spread apart at 12inches like a V shape and ankles in dorsiflexion with a tape in-between the patella.
- The student was instructed to place one hand on top of the other and slowly reach forward as far as possible while keeping the knees extended.

During the test;

- The hands were kept aligned evenly as the subject reaches forward along the surface of the tape.
- Each student practiced the movement twice, and on the third repetition, the Sit and Reach Test score in centimeters was recorded as the final position of the finger tips on the calibrations of the box.
- During the same trial, the goniometer body was placed three finger breadths below iliac crest found as the bony prominence as the pelvis rotates. The arms were placed with the stationary arm placed horizontally on the lateral midline of the thigh and pointing to the lateral malleolus and the movable arm placed vertical to the lateral midline of the trunk.
- The goniometer was first placed when the person is sitting upright and initial reading is recorded.
- When the person bends forward during the reach, the movable arm was replaced and realigned and the final reading noted**.**
- The hip active range of motion was then determined by subtracting the initial goniometer reading from the final reading.

3.8 Data analysis

The data obtained from this study was summarized using the descriptive statistics of mean and standard deviation, difference between male and female for the sit and reach test and hip active range of motion using the Independent T-test. A Pearson's product moment correlation was used to examine the relationship between some anthropometric variables on sit and reach test and hip active range of motion. Level of significance shall be set at 0.05.

CHAPTER FOUR

RESULTS

4.1. CHARACTERISTICS DISTRIBUTION OF PARTICIPANTS

Four hundred participants were involved in this study, comprising 200 males and 200 females. These participants were aged between 18 and 30 years. The physical characteristics of the participants are presented in Table 1. The mean height, weight, Body Mass Index (BMI), upper limb length, lower limb length, trunk length, Sit and Reach test score, and Active range of motion score were 1.72 ± 0.09133 meters, 65.3 ± 11.85 kilograms, 21.97 ± 3.78 kilograms per square meter (kg/m^2), 75.79 ± 5.47 centimeters, 103.57 ± 6.68 centimeters, 40.82 ± 4.61 centimeters, 52.61 ± 10.53 centimeters, and 40.22 ± 12.77 degrees (°), respectively.

Table 1:Descriptive characteristics of all participants (N = 400)

Parameters	Minimum	Maximum	Mean ± S.D
Height (m)	1.48	1.94	1.72 ± 0.09133
Weight (kg)	39.60	117.10	65.3 ± 11.85
BMI (kg/m²)	13.64	39.97	21.97 ± 3.78
Upper Limb Length (cm)	57.00	96.00	75.79 ± 5.47
Lower Limb Length (cm)	46.00	118.00	103.57 ± 6.68
Trunk Length (cm)	23.00	71.00	40.82 ± 4.61
SRT Score (cm)	21.00	81.00	52.61 ± 10.53
Active Hip Range of Motion (°)	15.00	75.00	40.22 ± 12.77

SRT Score = Sit and Reach Test Score

SD = Standard Deviation

4.1.1 COMPARISON OF SIT-AND-REACH TEST SCORE (SRT SCORE) AND ACTIVE HIP RANGE OF MOTION BETWEEN MALE AND FEMALE USING INDEPENDENT T-TEST

The independent t-test was used to compare both gender differences in sit-and-reach test scores and active hip range of motion, as shown in Table 2. There were no significant differences between males and females in sit-and-reach scores ($p = 0.063$) and Active Hip Range of Motion scores ($p = 0.096$).

Table 2:Independent T-test comparison of Sit-and-Reach test and Active Hip range of motion (N=400)

Parameters	Gender		t-value	p-value
	Male	Female		
SRT Score	53.62±11.02	51.60±9.94	1.919	0.063
Active Hip range of motion	43.9±12.18	33.55±12.31	-6.000	0.096

SRT Score= Sit and Reach test score

SD= Standard deviation

4.1.2 CORRELATION OF SIT-AND-REACH TEST SCORE (SRT SCORE) AND ACTIVE HIP RANGE OF MOTION AND SELECTED ANTHROPOMETRIC VARIABLES USING PEARSON'S PRODUCT MOMENT CORRELATION.

Sit and Reach test score (SRT Score) and selected anthropometric variables of Height ($p=0.912$), BMI ($p=0.258$) showed no significant correlation while Upper limb length ($p=0.0001$), Lower limb length ($p=0.0001$) and Trunk length ($p=0.005$) showed a significant correlation using the Pearson's product moment correlation.

Active Hip range of motion and selected anthropometric variables of Height ($p=0.736$), Lower limb length ($p=0.127$) and Trunk length ($p=0.143$) showed no significant correlation while BMI ($p=0.004$) and Upper limb length ($p=0.019$) showed a significant correlation using the Pearson's product moment correlation. (Table 3).

Table 3: Pearson's product moment correlation showing the relationship between selected anthropometric variables and sit and reach score and Active Hip range of motion.

Variables	r-value	p-value
Height vs SRT	-0.006	0.912
BMI vs SRT	-0.057	0.258
Upper limb length vs SRT	0.194	<0.0001*
Lower limb length vs SRT	0.195	<0.0001*
Trunk length vs SRT	0.140	0.005*
Height vs Active Hip ROM	0.017	0.736
BMI vs Active Hip ROM	0.146	0.004*
Upper limb length vs Active Hip ROM	-0.117	0.019*
Lower limb length vs Active Hip ROM	-0.076	0.127
Trunk length vs Active Hip ROM	-0.073	0.143

SRT Score = Sit and Reach test score

ROM = Range of Motion

*** Significant**

4.2 Hypothesis testing

Hypothesis 1: There would be no significant difference of hamstring flexibility using the sit and reach test between male and female Undergraduates of University of Benin.

Alpha level: 0.05

Test statistic: independent t-test

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

Hypothesis 2: There would be no significant difference of hamstring flexibility using the active hip range of motion between male and female Undergraduates of University of Benin.

Alpha level: 0.05

Test statistic: independent t-test

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

Hypothesis 3: There would be no significant correlation between body mass index and hamstring flexibility the sit and reach test scores.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

Hypothesis 4: There would be no significant correlation between height and hamstring flexibility using the V sit and reach test.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

Hypothesis 5: There would be no significant correlation between upper limb length and hamstring flexibility using the V sit and reach test.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 6: There would be no significant correlation between lower limb length and hamstring flexibility using the V sit and reach test.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 7: There would be no significant correlation between trunk length and hamstring flexibility using the V sit and reach test.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 8: There would be no significant correlation between body mass index and hamstring flexibility using the active hip range of motion.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 9: There would be no significant correlation between height and hamstring flexibility using the active hip range of motion.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 10: There would be no significant correlation between upper limb length and hamstring flexibility using the active hip range of motion.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p<0.05$

Since the observed p value was greater than 0.05 Alpha level. The hypothesis was therefore REJECTED

Hypothesis 11: There would be no significant correlation between lower limb length and hamstring flexibility using the active hip range of motion.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

Hypothesis 12: There would be no significant correlation between trunk length and hamstring flexibility using the active hip range of motion.

Alpha level: 0.05

Test statistic: Pearson product moment correlation

Observed: $p>0.05$

Since the observed p value was greater than 0.05 Alpha level, therefore I failed to reject the hypothesis

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS, RECOMMEDATION

5.1 Discussions

The present study sought to investigate the hamstring flexibility among male and female undergraduates of the University of Benin, focusing on the relationship between hamstring flexibility and selected anthropometric variables. The results of this study revealed several important findings that contribute to our understanding of hamstring flexibility in this population. The descriptive characteristics of the participants provided insight into the physical attributes of the studied group. The mean height, weight, BMI, upper limb length, lower limb length, trunk length, Sit and Reach test score, and Active range of motion score were within expected ranges for young adults (ACSM, 2018). These baseline characteristics are essential for contextualizing the subsequent analyses.

There were no significant differences between gender in both the Sit and Reach test score and Active Hip Range of Motion scores. This agrees with works by Deshmukh *et al.* (2020) who reported no significant correlation in hamstring flexibility between gender among Indian children age 6-12 years but it inconsistent with the findings of Cornbleet & Woolsty (1996).

There was no significant correlation between BMI and sit and reach test score. This agrees with the findings of Mukkamala *et al.* (2021) among young adults. There was also no significant correlation with height. There is scarcity of data on correlation of factors like Upper limb length, lower limb length and trunk length. The present study showed that there was a significant correlation between Upper limb length, lower limb length and trunk length and Sit and Reach test scores for hamstring flexibility.

There is scarcity of data on correlation of factors like Height, BMI, Upper limb length, lower limb length and trunk length with Active Hip range of motion. The present study showed that there was a significant correlation between BMI, upper limb length with Active Hip range of motion and no correlation with Height, lower limb length and trunk length.

5.2 Conclusion

In conclusion, the average value of hamstring flexibility among male and female were within the normal range. Anthropometric factors such as upper limb length, lower limb length, BMI and trunk length were found to have correlation with hamstring flexibility in young Nigeria adults. However, the pattern of correlation varies between sit and reach test and active hip range of motion. There was no significant correlation between height and both tests

5.3 Recommendations

Future studies could explore additional factors that may influence hamstring flexibility, such as muscle strength, joint stability. Longitudinal studies may also provide insights into the changes in flexibility over time and their relationships with various factors.

Future studies could explore effect of sports performance of these anthropometric variables with hamstring flexibility among sports athletes e.g. gymnast, track and field, karate and football etc.

REFERENCES

ACSM. (2018). ACSM's Guidelines for Exercise Testing and Prescription, 10th ed. Wolters Kluwer: New York, NY, USA.

Agre, J., Magness, J.L., & Hull, S.Z. (1987). Strength testing with a portable dynamoter: Reliability for upper and lower extremities. Archives of Physical Medicine and Rehabilitation. 68, pp.454-458.

Agre, J.C. (1985). Hamstring injuries. Proposed aetiological factors, prevention, and treatment. Sports Medicine. 2, pp.21-33.

Arbulu, M., Kaynov, D., Ormaechea, C., Maria, L., & Balaguer, C. (2009). The Rh-1 Full-Size Humanoid Robot: Design, Walking Pattern Generation and Control. Applied Bionics and Biomechanics, 6, pp.301-344.

Arnason, A., Andersen, T.E., Engebretsen, L., & Bahr, R. (2008). Prevention of hamstring strains in elite soccer: an intervention study. Scandinavian Journal of Medicine & Science in Sports. 18, pp.40-48.

Baltaci, G., Un, N., Tunay, V., Besler, A., & Gerçeker, S. (2003). Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. British Journal of Sports Medicine. 37(1), pp.59–61.

Bandy, W.D., Irion, J.M., & Briggler, M. (1998). The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. Journal of Orthopaedic Sports and Physical Therapy. 27, pp.295-300.

Baumgartner, T.A., & Jackson, A.S. (1995). Measurement for Evaluation in Physical Education and Physical Exercise.

Castro-Pinero, J., Chillon, P., Ortega, F.B., Montesinos, J.L.G., Sjostrom, M., & Ruiz, J.R. (2009). Criterion-related validity of Sit-and-Reach and Modified Sit-and-Reach Test for Estimating Hamstring Flexibility in Children and Aldolescents Aged 6-17 Years. International Journal of Sports Medicine. 30(9), pp.658-62.

Chan, S.P., Hong, Y., & Robinson, P.D. (2001). Flexibility and passive resistance of the hamstrings of young adults using two different static stretching protocols. Scandinavian Journal of Medicine & Science in Sports. 11, pp.81-86

Chulabhorn International College of Medicine. (2018). Deluxe Functional Hip Joint Model. Available on:

https://eptumed.com/skillLab3/modelShowOrgan.php?catalog=MzcmMTA0NQ%3D%3D
Accessed 27 July, 2023,

Clanton, T.O., & Coupe, K.J. (1998). Hamstring Strain in Athletes: Diagnosis and Treatment. Journal of the American Academy of Orthopaedic Surgeons. 6(4), pp.237-248.

Cornbleet, S.L., & Woolsty, N.B. (1996). Assessment of Hamstring Muscle Length in School-aged Children using the Sit-and-Reach Test and the inclinometer measure of Hip joint angle. Physical Therapy. pp.76.

Cross, K.M., & Worrell, T.W. (1999). Effects of a static stretching program on the incidence of lower extremity musculotendinous strains. Journal of Athletic Training. 34, pp.11-14.

Davis, D.S., Ashby, P.E., McCale, K.L., McQuain, J.A. & Wine, J.M. (2005). The effectiveness of 3 stretching techniques on hamstring flexibility using consistent parameters. Journal of Strength and Conditioning Research. 19, pp.27-32.

De Weijer, V.C., Gorniak, G.C., & Shamus, E. (2003). The effect of static stretch and warm-up exercise on hamstring length over the course of 24 hours. Journal of Orthopaedic Sports and Physical Therapy. 33, pp.727-733.

DePino, G., Webright, W., & Arnold, B. (2000). Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. Journal of Athletic Training. 35, pp.56-59.

Deshmukh, A.A., Mankar, P.V., Malu, M.V., & Mahore, R.D. (2020). The lumbar and hamstring flexibility between crossed leg sitting and bench sitting posture in school children of 6 to 12 years – a cross sectional study. International journal of science and healthcare research. 5, pp.4.

Devlin, L., (2000). Recurrent posterior thigh symptoms detrimental to performance in rugby union: predisposing factors. Sports Medicine. 29(4), pp.273-87.

Esola, M.A., McClure, P.W., Fitzgerald, G.K., & Siegler, S. (1996). Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. Spine. 21, pp.71-78.

Feldenkrais, M., (1972). Awareness through movement. Harper & Row. New York, NY

Gannamaneni, V.K., & Kakaraparthi, V.N. (2017). Effect of traditional sitting on flexibility of hamstring and calf muscle among arab people. Saudi journal of sports medicine, 17(1), pp.36-39.

Ganong, W.F., (2005). Review of Medical Physiology. 22nd Edition, McGraw-Hill Medical. New York.

Guy, S.G. (1998). The impact of various anthropometric and flexibility measurements on the sit-and-reach test. Journal of Strength Conditioning Research. 12(4), pp.232–7.

Haff, G.G., & Triplett, N.T. (2015). Essentials of strength and conditioning. Human Kinetics. (Eds). Champaign, IL.

Halbertsma, J.P., Goeken, L.N., Hof, A.L., Groothoff, J.W., & Eisma, W.H. (2001). Extensibility and stiffness of the hamstrings in patients with nonspecific low back pain. Archive of Physical Medical Rehabilitation. 82(2), pp.232-8.

Hartig, D., & Henderson, D. (1999). Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. The American Journal of Sports Medicine. 27, pp.262-266.

Inman, V.T., Ralston, H.J., & Todd. F. (1981). Human Walking. Williams & Wilkins. Baltimore, London. pp.154.

Jackson, A.W., & Baker, A.A. (1986). The Relationship of the Sit and Reach Test to Criterion Measures of Hamstring and Back Flexibility in Young Females. Research Quarterly for Exercise and Sport. 57(3), pp.183-186.

Kathryn, L., (1997). Kinesiology: scientific basis of human motion, Hamilton NA. United States of America: Mc-Graw Hills.

Kendall, F.P., & Kendall, H.O. (1948). Normal flexibility according to age groups. The Journal of Bone and Joint Surgery. 30(3), pp.690-4.

Kendall, F.P., (1965). A Criticism of current tests and exercises for physical fitness. Physical Therapy. 45, pp.187-97.

Kujala, U.M., Orava, S., & Järvinen, M. (1997). Hamstring injuries. Current trends in treatment and prevention. Sports Medicine. 23(6), pp.397-404.

Little, T., & Williams, A. (2006). Effects of differential stretching protocols during warm-ups on high- speed motor capacities in professional soccer players. Journal of Strength and Conditioning Research. 20, pp.203-207.

Malliaropoulos, N., Papalexandris, S., Papalada, A., & Papacostas, E. (2004). The role of stretching in rehabilitation of hamstring injuries: 80 athlete's follow-up. Medicine & Science in Sports & Exercise. 36, pp.756-759.

Mann, R., & Sprague, P. (1980). A kinetic analysis of the ground leg during sprint running. Research Quarterly for Exercise Sport. 51(2), pp.334-48.

Mann, R.V., (1981). A kinetic analysis of sprinting. Medicine & Science in Sports & Exercise. 13(5), pp.325-328.

Mason, D.L., Dickens, V., & Vail, A. (2005). Rehabilitation for hamstring injuries. Cochrane Database of Systematic Reviews.

McArdle, W.D., Katch, F.I., & Katch, V.L. (2010). Exercise Physiology: Nutrition, Energy, and Human Performance. Lippincott Williams & Wilkins. Philadelphia.

McMillian, D., Moore, J., Hatler, B., & Taylor, D. (2006). Dynamic vs. Static-Stretching Warm Up: The Effect on Power and Agility Performance. Journal of Strength and Conditioning Research. 20, pp.492-499.

Moore, K.L., & Dalley, A.F. (2006). Clinically Oriented Anatomy. 5th Edition, Lippincott Williams and Wilkins. Baltimore, pp.556-717.

Mukkamala, N., Gite, A.A., & Parmar, L. (2021). Relationship between body mass index and flexibility in young adults. Journal of pharmaceutical research international. 33(32A), pp.119-126.

Murray, R., Bohannon, R., Tiberio, D., Dewberry, M., & Zannoti, C. (2002). Pelvifemoral rhythm during unilateral hip flexion in standing. Clinical Biomechanics. 17, pp.147-151.

Murray, S.M., Lord, S.R., Chapman, K., Munro, B., & Tiedemann, A. (2002). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. Journal of Gerontology Series A, Biological Sciences and Medical Sciences. 57(8), pp.539-43.

Norris, C.M., (2011). Managing Sports Injuries: a guide for students and clinicians. Churchill Livingstone; 4th edition. London. pp.67.

Orchard, J., & Seward, H. (2002). Epidemiology of injuries in the Australian Football League, seasons 1997-2000. British Journal of Sports Medicine. 36(1), pp.39-44.

Petersen, J., & Holmich, P. (2005). Evidence based prevention of hamstring injuries in sport. British Journal of Sports Medicine. 39, pp.319-323.

Pope, R., Herbert, R., Kirwan, J., & Graham, B. (2000). A randomized trial of pre-exercise stretching for prevention of lower limb injury. Medicine and Science in Sports & Exercise. 32, pp.271-277

Riebe, D., Ehrman, J.K., Liguori, G., & Magal, M. (2018). American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription, 10th ed. Wolters Kluwer: New York, NY, USA.

Stephens, J., (2000). Feldenkaris Method. Background, research, and orthopaedic case studies. Orthopaedic Physical Therapy Clinics of North America. 42, pp.35-46.

Stephens, J., Davidson, J., DeRosa, J., Kriz, M., & Saltzman, N. (2006). Lengthening the Hamstring Muscles Without Stretching Using “Awareness Through Movement”. Physical Therapy & Rehabilitation Journal.86(12), pp.641-1650.

Tafazzoli, F., & Lamonagne, M. (1996). Behaviour of hamstring muscles in low-back pain patients and control subjects. Clinical Biomechanics. 11(1), pp.16-24.

Thacker, S.B., Gilchrist, J., Stroup, D.F., & Kimsey, C.D. (2004). The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. Medicine & Science in Sports & Exercise. 36, pp.371-378.

Thompson, C.J., & Osness, W.H. (2004). Effects of an 8-week multimodal exercise program on strength, flexibility, and golf performance in 55- to 79-year-old men. Journal of Aging & Physical Activity. 12(2), pp.144-56.

Wood, G., Marshall, R., & Strauss, G. (1984). Electro-musculomechanical action of the lower limb in sprinting—Insights into hamstring injury potential. Presented at the fourth meeting of the European Society of Biomechanics, Davos, Switzerland, September.

Woods, C., Hawkins, R.D., Maltby, S., Hulse, M., Thomas, A., & Hodson, A. (2004). The Football Association Medical Research Programme: An audit of injuries in professional football-analysis of hamstring injuries. British Journal of Sports Medicines. 38, pp.36-41.

Worell, T.W., & Perrin, D.H. (1992). Hamstring muscle injury: the influence of strength, flexibility, warm-up, and fatigue. Journal of Orthopaedic Sports and Physical Therapy. 16(1), pp.12-8.

Youdas, J.W., Krause, D.A., & Hollman, J.H. (2008). Validity of hamstring muscle length assessment during the sit-and-reach test using an inclinometer to measure hip joint angle. Journal of Strength Conditioning Research. 22(1), pp.303-9.

APPENDIX

Figure 1:participant performing Sit-and-Reach test

Figure 2: Participants performing Sit-and-Reach test with Active Hip range of motion