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YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCE
DEPARTMENT OF PHYSIOTHERAPY & REHABILITATION

INVESTIGATING THE MUSCLE IMBALANCE IN LOWER EXTREMITY WITH GENU RECURVATUM

MASTER THESIS

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by the Administrative Board of Institute with decision dates..................... and numbered ....

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DECLARATION

I declare that this thesis is an original report of my research, and has been composed by myself, it contains no material previously published or written by another person or institute, and has not been submitted previously for any other award except where indicated by referencing.

24/Nov/2021

Abdelrahman M. Ajam

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LIST OF SYMBOL AND ABBREVIATION

GR	Genu recurvatum
ACL	Anterior Cruciate Ligament
PCL	Posterior cruciate ligament
MCL	Medial Collateral Ligament
LCL	Lateral Collateral Ligament
S-EMG	Surface Electromyography
WHO	World Health Organization
CVA	Cerebral Vascular Accident
ROM	Range of Motion
ADL	Activity of Daily Living
JPS	Joint Position Sense
H:Q	Hamstring:Quadriceps

ABSTRACT

Ajam A. (2021) Investigating the Muscle Imbalance in Lower Extremity with Genu Recurvatum, Yeditepe University, Institution of Health Sciences, Department of Physiotherapy and Rehabilitation, Master Thesis.

Genu recurvatum is defined by hyperextension of the knee in the stance phase. GR is a knee malalignment that causes the knee to bend backwards. Multiple factors can cause GR, including weakness of the muscles around the knee joint, excessive plantar flexion, a proprioceptive disorder, spasticity of the quadriceps and neurological or musculoskeletal injury. GR is observed in 40% to 68% of stroke patients. Thus the purpose of this study is to assess GR on healthy people in relation to muscle activity in lower extremity, knee joint position sense and knee stability in order to prevent GR. 33 participants 9F/22M, mean age of 22.8 ±2.6SD were included in this study after signing a consent form. The degree of GR was measured with a goniometer, knee joint position test was used to assess the proprioception and sEMG was used to assess the activity of four major muscle; biceps femoris, anterior tibialis, rectus femoris, and gastrocnemius. 21 participants were found with GR and 12 participants without GR. The participants were divided into two groups according to the GR test. There was a significant difference in terms of GR degree between the two groups. Data showed when there's more than 10° the muscle activity ratio shifts to favor rectus femoris with 64.3%. Consequently, when there's less than 10° the muscle activity ratio shifts to biceps femoris with 51.8%. Additionally, the muscle activity ratio remained the same percentage for the anterior tibialis and gastrocnemius when we compared the two groups. Therefore, we concluded that having weaker activity in the posterior muscles of the thigh, specifically the biceps femoris could be a factor in developing GR. Thus, assessing the biceps femoris muscle activity is a valid assessment to indicate people at risk of developing GR.

Keywords: Genu recurvatum, Knee joint, and Muscle activity in lower extremity

ÖZET

Ajam A. (2021) Genu rekurvatumlu alt extremitenin kas dengesizliğinin araştırılması. Yeditepe Üniversitesi, Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü, Yüksek Lisans Tezi.

Genu recurvatum, dizin duruş fazında hiperekstansiyonu ile tanımlanır. GR dizin geriye doğru esnemesine neden olan bir diz dizilim bozukluğudur. Diz eklemi çevresindeki kasların zayıflığı, aşırı plantar fleksiyon, propriyoseptif bozukluk, kuadriseps spastisitesi ve nörolojik veya kas-iskelet yaralanması dahil olmak üzere birçok faktör GR'ye neden olabilir. İnme hastalarında %40 ila %68 oranında GR saptanmıştır. Bu nedenle bu çalışmanın amacı, GR'yi önlemek için alt ekstremite kas aktivitesi, diz eklem pozisyon hissi ve diz stabilitesi ile ilgili olarak sağlıklı kişilerde GR'yi değerlendirmektir. Onam formu imzalandıktan sonra bu çalışmaya 9K/22E, ortalama yaşı 22.8 +2.6 SD olan 33 katılımcı dahil edildi. GR derecesini gonyometre ile ölçüldü, biceps femoris, anterior tibialis kası, rectus femoris ve gastrocnemius'un kas aktivitesini değerlendirmek için bir sEMG kullanıldı. Propriosepsiyonun değerlendirilmesi için diz eklemi pozisyon testi kullanıldı. Katılımcılar; GR'li 21 katılımcı ve GR'siz 12 katılımcı olmak üzere GR testine göre iki gruba ayrıldı. İki grup arasında GR derecesi açısından önemli derecede anlamlı fark vardı ($p<0.05$). Veriler, 10°'den fazla olduğunda kas aktivite oranının %64,3 ile rektus femorise kaydığını gösterirken; 10°'den az olduğunda kas aktivite oranının %51,8 ile biseps femorise kaydığını gösterdi. Ek olarak, veriler, iki grubu karşılaştırdığımızda ön tibialis ve gastroknemius için kas aktivite oranının aynı yüzdede kaldığını gösterdi. Bu nedenle uyluğun arka kaslarında daha zayıf aktiviteye sahip olmanın GR gelişimi için bir faktör olabileceği sonucuna vardık. Sonuç olarak, veriler uyluğun arka kaslarının daha zayıf aktivitesine sahip olmanın, GR gelişimi için bir faktör olabileceğini göstermiştir. Sonuç olarak, biseps femoris aktivitesini ölçmek, GR geliştirme riski taşıyan hastaları belirlemenin güvenilir bir yoludur.

Anahtar Kelimeler: Alt ekstremite kas aktivitesi, Genu recurvatum ve Diz eklemi

1. INTRODUCTION AND PURPOSE

GR is a deformity or malalignment in the knee joint. GR is defined as knee hyperextension in the stance phase shown in Figure 1. It is common in hemiplegic patients, detected in 40% to 68% of patients with post stroke hemiplegia. GR can be caused by a number of factors. Including muscle weakness, spasticity of the quadriceps, proprioceptive disorder, and an excessive plantar flexion. Physical therapists usually are called to address this condition following an injury or post CVA when there is already a problem with knee muscle control.[1,2]

The increasing number of geriatric population and high unfulfilled current treatment, will promote the research for the GR treatment. According to the statistics provided by the World Health Organization (WHO) in 2015. It has been found that one in every eight individuals over the age of 60 have GR, and by the year 2030 older individuals would account for one in every six people globally. a significant increase in GR. [4]

The questions of whether individuals with GR differ in functional testing of the lower extremity. Or in a test of postural control when compared to those without GR remains unanswered. and the cause effect relationship between genu recurvatum and knee pain has been questioned. Further insight into these relationships might suggest a possible deficiency in mechanical or neuromuscular control of the knee. and the ability to predict injury or disability risk effectively is an important contribution to preventive health care. [3,5]

Our purpose for this study is to examine the knee joint and have a better understanding of the muscle imbalance in lower extremity which causes the GR. in addition to investigating the knee stability and the knee joint position sense (proprioception), this study is aiming to shed some light on GR.

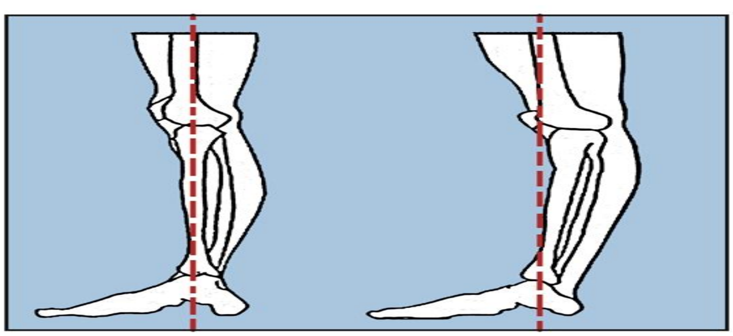


Figure 1. Knee hyperextension lateral view. [44]

2. GENERAL INFORMATION

Genu recurvatum is a common condition that usually has a negative consequence to knee structure), GR is described as knee extension greater than 10 degree. Individuals who display GR may have an extension gait pattern, and poor proprioceptive control of terminal knee extension, and may experience knee pain. GR clinically is more common in females than male. And may exist as a result of a poor posture, increased joint laxity, or knee injury. [3]

2.1 Anatomy

The knee joint is one of the largest and most complicated joints in the body. The knee joins the (femur) thigh bone to (tibia) the shin bone. The other bones that make up the knee joint are the fibula which is the smaller bone that runs alongside the tibia and the patella which is known as the kneecap. [6,7]

2.1.1 Bones

There are four **bones** that make up the knee joint

-Femur is the bone of the thigh, it is the longest bone in the body. The knobs at the end of the bone on the distal side are called condyle, lateral and medial condyle. And it articulate with the proximal part of the Tibia. [8]

-Tibia is the shin bone. The proximal part of the tibia consists of two flat surfaces covered in articular cartilage, here lies the attachment of two C-shaped absorbing carriages called menisci. The patella ligament attaches at the tibial tubercle which is the front anterior aspect of the knee.

-Fibula is a thin small bone on the lateral side of the lower leg. While the tibia carries roughly most of the weight, the fibula also helps to carry some of the weight. More importantly, it mainly functions as an attachment for muscles like the lateral collateral ligament and biceps femorıs. furthermore on the distal side it forms the ankle joint. [9]

-Patella known as kneecap, located in front of the knee joint. The patella is able to move as the knee bends. It amplifies the grip that the quadriceps tendon can apply on the femur, The patella also protects the knee joint. The patella sits and glides in the patellofemoral grove, which is formed by the two femoral condyles.

2.1.2 Ligaments

Ligaments connect the bones and give it stability and support, ligaments appear as criss cross bands that attach bone and help stabilize joints. Ligaments are strong, bands that are slightly elastic, so they can be stretched and gradually lengthen. A total of 4 ligaments and joint capsule covers the knee joint. [11,6,12,13]

-Anterior cruciate ligament (ACL) is found deep within the knee and in front of the posterior cruciate ligament, connected to the femur and the tibia. Its main function is to restrict forward motion of the tibia in relation to the femur, Acl also restricts rotation and sidway motion. The ACL can be ruptured or torn with sudden rotation motions of the knee.[11]

-Posterior cruciate ligament (PCL) is located behind the anterior cruciate ligament, the PCL is attached to the tibia and the femur. Its main function is to restrict the backward motion of the tibia in relation to the femur. In addition PCL limits some sideways motion of the knee. A hyperextended knee can tear down the PCL

-Medial collateral ligament (MCL) attached to the medial side of the femur and to the medial side of the tibia. Its main function is to limit sideways motion of the knee.

-Lateral collateral ligament (LCL) attached to the lateral side of the femur and to the lateral side of the fibula. Its main function is to limit sideways motion of the knee.

-Joint capsule is a thick fibrous structure that surrounds and covers the knee joint. Inside the joint capsule there is the synovial membrane which acts as the lubricant for the knee.

-Patellar ligament (or tendon) connects the tibia to the patella. It is more of an extension of the quadriceps tendon than a ligament. [14,15]

Cartilage of the knee is a protective cushioning between the bones.

The medial and lateral meniscus is composed of fibrocartilage, which makes them robust and rubbery allowing them to provide additional stability to the knee. [16]

Other cartilages of the knee.

cartilage is flexible and slippery. Which makes them act as a shock absorber. Hyaline cartilage surrounds the end of the femur, tibia and the undersurface of the patella. Within the joint a “synovial fluid” is produced which makes it even more slippery. This enables the two bones to glide smoothly on each other without causing pain. Cartilage has a very limited blood supply which affects its ability to self repair. If the articular cartilage wears out, the joint movement can become limited and painful.

2.1.3 Muscles

The hamstring, quadriceps and the calf muscles are all part of the knee muscles. These muscles work together to flex, extend, and stabilize the knee joint.[17,18,19]

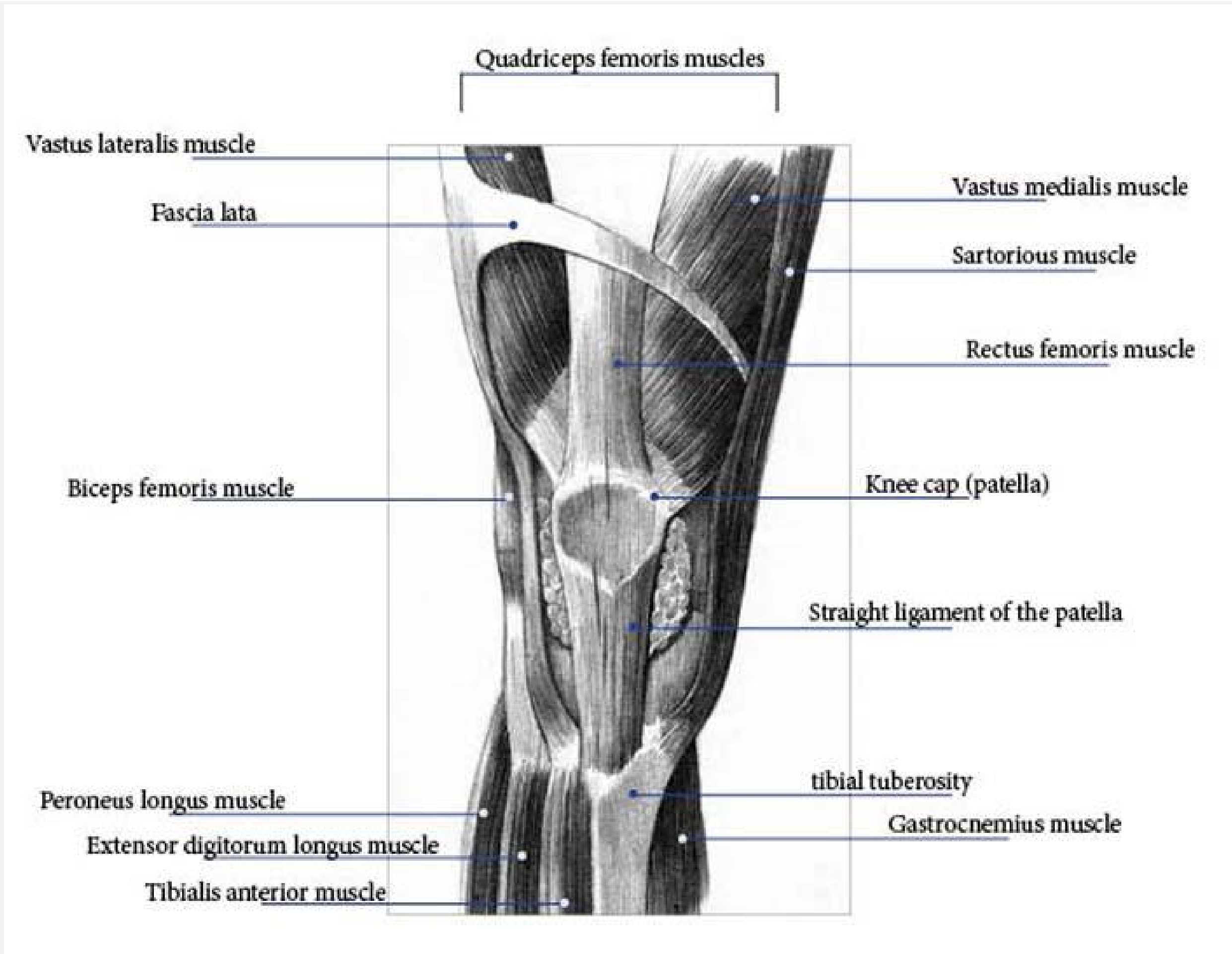


Figure 2. Anterior view of the quadriceps femoris muscles. [45]

The Quadriceps is a collection of four muscles on the anterior part of the thigh, they are involved for extending the knee. [19]

Include:

- Rectus femoris:it passes over two joints:the knee and hip. Its main function is to extend the knee. It’s also a weak flexor of the hip.
- Vastus lateralis: Located on the anterior lateral side of the thigh. It’s found underneath the rectus femoris.

- Vastus intermedius: Located on the anterior and middle part of the thigh. It is found underneath the rectus femoris.
- on the inferior pelvis and insert into the medial tibial condyle. Its main function is knee flexion
- Semitendinosus: also originate from the ischial tuberosity and insert into the medial tibia.
- Biceps femoris: it has two heads hence the name biceps. The long head originates from ischial tuberosity, and the short head from Linea aspera of femur. And insert into the head of the fibula

Gastrocnemius muscle: is the larger calf muscle, it has two origins; medial and lateral.
The lateral head starts from the lateral epicondyle of the femur, while the medial head originates from the medial condyle of the femur. Both heads of the gastrocnemius insert into a long common muscle "aponeurosis" which forms the achilles tendon. Its function is to permit you to stand on your tiptoes, while also assiVastus medialis: Located on the medial side of the anterior thigh. It aids in the stabilization of the patella.
These muscles are connected with the knee via the quadriceps tendon.

Sartorius is a narrow and slender muscle that runs from the anterior part of the pelvis and attaches to the medial part of the tibia. Although it is not a particularly powerful muscle, it aids in many hip and knee motions. [15]

Gracilis is another long and narrow muscle that runs from the pelvis and connects to the medial tibia. Because its connections to the tibia, the Gracilis can flex the knee, adduct the thigh, and rotate the tibia on the femur medially. [20]

The Hamstring is a group of three muscles on the posterior side of the thigh. The hamstring muscles function as knee flexors from a straightened position. [21]
Include: Semimembranosus: its origin is the ischial tuberosity sting in knee flexing. [22]

Tibialis Anterior is located within the anterior compartment of the lower leg. Muscles of this compartment assist in flexing the foot in an upward direction at the ankle and also extend the toes. [23]

2.1.4 Tendon

Tendon connects the bones to the muscles that move the joints. tendons located at each end of a muscle and they attach muscles to bones. Tendon are elastic tissues made up of collagen.

2.1.5 Movement

The knee joint is capable of four major movements;

1. Extension; the quadriceps femoris, which inserts into the tibial tuberosity, produces extension.
2. Flexion; the hamstring, gracilis, popliteus and sartorius produce flexion.
3. Lateral rotatıon; the biceps femoris is mainly responsible for lateral rotation.
4. Medial rotation; five muscles can create medial rotation semimembranosus, semitendinosus, gracilis, and sartorıus and popliteus

Only when the knee is flexed can lateral and medial rotation occur. [24]

2.2 Knee stability

During the loading phase in gait, the interaction of the menisci, ligament, knee capsule, muscles and the location of the articular surfaces determine the over stability of the knee. These are all interdependent between them. Thus, allowing a normal mobility and at the same time an effective stability. [6]

The structures of the knee provide support to the posterolateral compartment of the knee. Including the posterior capsule, arcuate complex, fabellofibular ligament, lateral meniscus, and biceps femoris muscle. These structures are shown in (figure 3). Individuals with GR are most likely stressing these posterior structures.

The knee can be thought of as two different joints. a tibiofemoral and a patellofemoral joint. The tibiofemoral joint permits the body weight to be transferred from the femur to the tibia while providing hinge-like, sagittal plane joint rotation along with a limited amount of tibial axial rotation. In terms of function, the quadriceps muscle group and patellofemoral, and with the tibialis anterior and ankle joint they act to reduce forward force when the individual enters the stance phase of the gait cycle.1 [17]

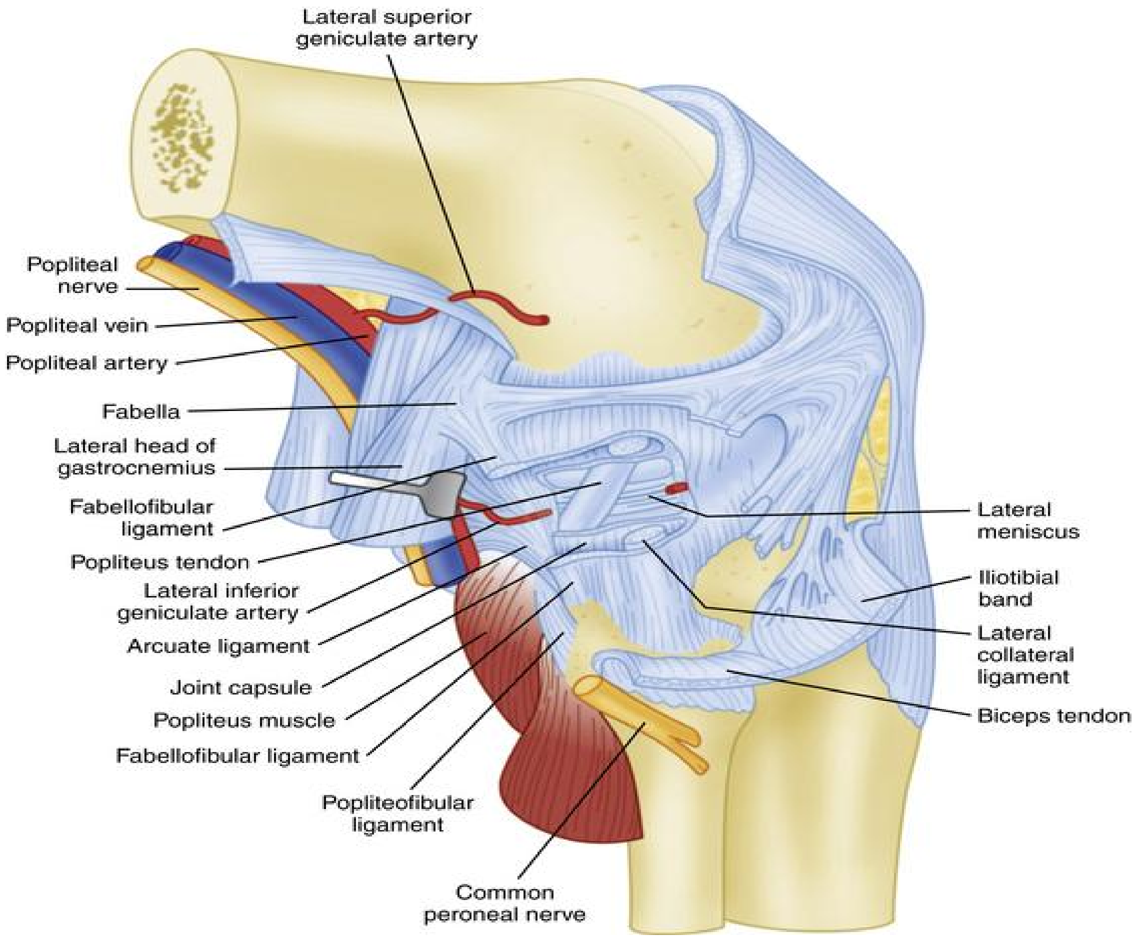


Figure 3. Ligaments of the knee joint, posterior side. [46]

2.3 Biomechanics of the knee joint

The knee joint is not just a simple hinge like joint. It is an intricate joint made up of different layers of three dimensional biomechanical constraints that allows it to undergo high forces to support normal kinematics with 0° to 10° of extension motion.

The knee stability depends on a balance of both primary and secondary restraints for coronal, sagittal, and rotational stability. If these structures fail, it can result in painful loss of function that can usually lead patients to other soft tissue injuries. Furthermore, knee dislocations with ligament injuries can lead to drastic biomechanical risk factors. [25]
Knee joint mechanics is affected by movement at either the knee, hip or ankle joint. The femur rolls anteriorly and glides posteriorly on the fixed tibia as it moves from flexion to extension.

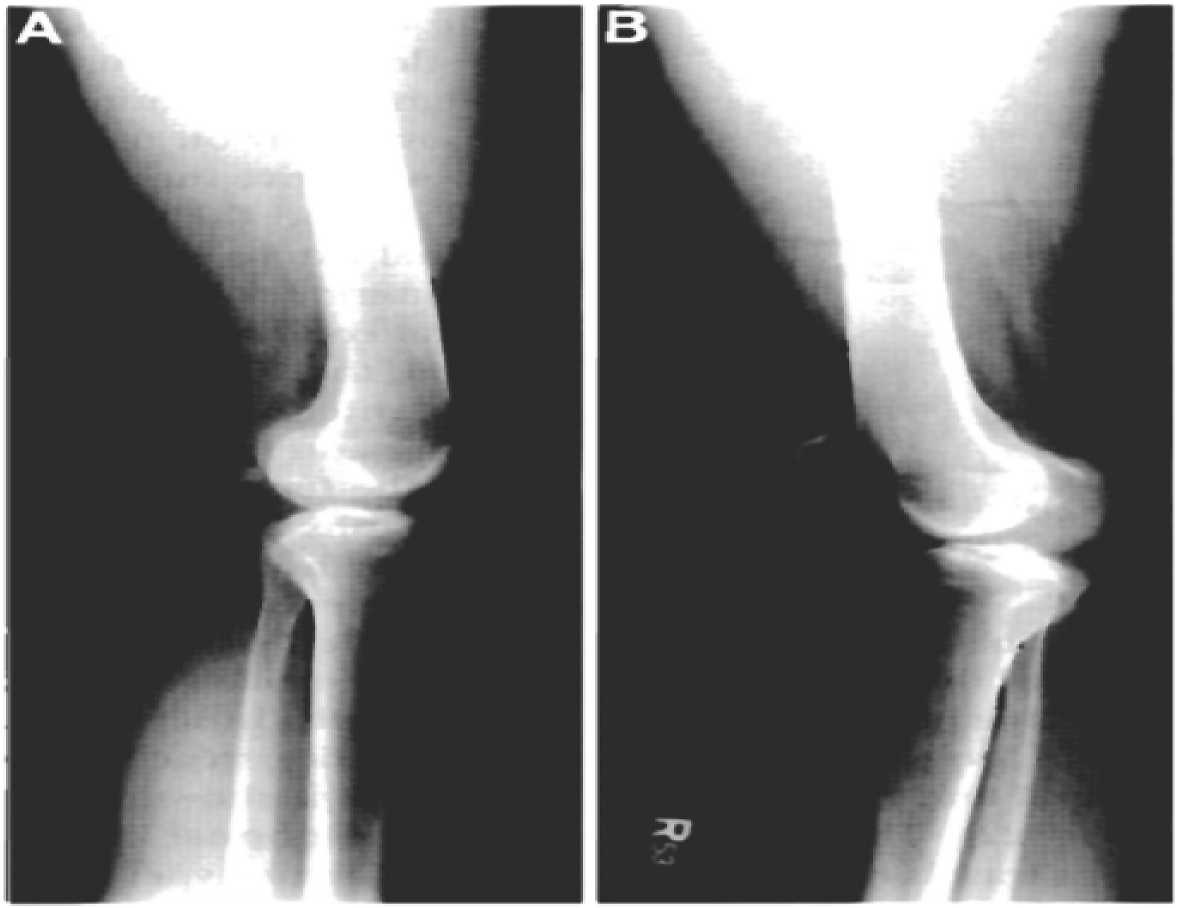


Figure 4 (a) individual with normal knee alignment . B) individual with GR. [3]

Near the final extension point, due to the continuous anterior roll of the lateral femoral condyle, a minor internal rotation of the femur on the tibia occurs. During knee hyperextension, the femur stops rolling anteriorly and starts to tilt forward producing anterior compression between the femur and tibia. Shown in figure 4. Tension on the ACL and the posterior tissues of the knee is caused by hyperextend position combined with normal femoral internal rotation. shown in figure 5.

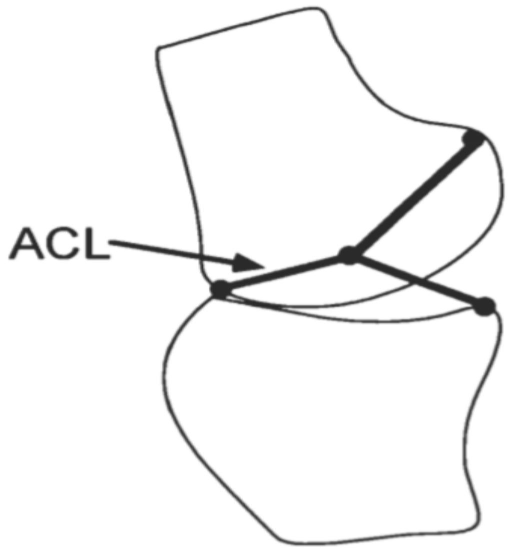


Figure 5. Hyper-extension and anterior cruciate ligament (ACL) stress. [3]

Bone contact does not limit hyperextension in the normal knee as it does in the elbow joint, instead soft tissue structures of the knee stops hyperextension, which causes more stress on the posterior side. Because the directed force is behind the knee in a relaxed standing position with the knee straight or slightly flexed, there is a possibility for greater knee flexion unless the quadriceps contract. During hyperextension of the knee, the axis of the thigh runs obliquely inferiorly and posteriorly, which places ground reaction force in the anterior side of the knee. Therefore the posterior structures are placed in high tension which secure the knee joint without necessary activity of the quadriceps muscles. Like we see in patients after a CVA or hemiplegic patients who lose motor control of the quadriceps and are still able to stand.

Additionally, GR can affect the gait pattern. The understanding of anatomy and knee biomechanics is important for gait analysis. During gait's loading response. The body weight is transferred straight from the femur to the tibia in an individual with GR, which lacks the normal muscular energy absorption and cushioning provided by a flexed knee. This may cause tension in the posterolateral ligamentous structures and pain in the medial tibiofemoral. Individuals with GR may compensate for weakness of the quadriceps by hyperextending the knee for additional knee stability. Moreover, increased GR alters the gait pattern by increasing knee angle in the stance phase and extension moment in the early stance phase. [3,6,26]

2.4 Clinical implication

GR implications are not just on the knee, it also affects the posture. Not only should the physical therapist improve the muscles around the knee, but he/she should also address knee posture and other knee components.

As a result from GR the ACL, anterior joint and/or posterolateral side of the knee may be stressed as a result of GR. Additionally, GR can be caused from spasticity or weakness in the knee extensors muscles, weakness in the hip extensors, decreased ankle ROM, damaged proprioception, or a mix of these factors. GR can be linked to decreased gait efficiency caused from increased energy expenditure due to improper biomechanical and more importantly, because it may be linked to increased risk of knee injuries and pain, which is why rehabilitation practitioners should focus on treating GR. [27]

2.5 General assessment of the knee joint

A careful assessment must be performed to determine the subject's overall knee alignment and if there is any cruciate ligament tear, posterolateral corner injury or medial knee injury. Individuals with GR may have any of the previously mentioned lower extremity diagnosis. However, Genu recurvatum probably would not be their main diagnosis. Symptoms related to GR include pain in the anteromedial side of the knee or posterolateral side of the knee. The reason behind the anterior medial pain is due to the stress on the medial tibiofemoral compartment and the pain is highlighted if there is an inward alignment(varus). Additionally, During the weight bearing phase, any stress on the posterior structures can lead to posterior pain and is increased by taking steps or vigorous knee extension. [28]

GR can be easily recognized in static standing. Additionally, increased femoral internal rotation, genu varum or valgus or tibial varum may also be present which is more visible in the frontal plane. Varus extension may be noticeable during walking, which is predictable in chronic injuries to the posterolateral structures of the knee. Additionally, femoral internal rotation past the mid stance of gait will increase GR. Individuals with GR may also have knee instability during ADL. Conducting activities such as step ups will cause the individuals with GR to use the momentum to straighten the leg, which makes them unable to control weight bearing in the end point of extension. Furthermore, there may be a reduction of functional strength in the quadriceps or gastrocnemius which allow for knee hyperextension. The gastrocnemius controls knee extension during weight bearing.

Lastly, Proprioception may be affected near the end range of extension in individuals with GR.

To assess the posterolateral instability, the physical therapist should use the external rotation recurvatum test. The tibia usually rotates around the axis of the PCL duo to external rotational subluxation. As the knee extends, posterior subluxation of the lateral tibial surface is minimized, as the knee overextends, subluxation increases, the tibia then rotates externally. As the subluxation develops, the tibia can be seen rotating externally, and the lateral tibial surface can be felt becoming apparent posteriorly. The varus stress test and the drawer test are clinically significant tools to assess GR. The physical therapist should focus on identifying any posterolateral instability. [3]

3. MATERIALS AND METHODS

This research was approved by the Medical Ethics Committee of Medical, Surgical and Drug Researches of Yeditepe University Medical Faculty (Registration no: 1761 Decision no: 1121). Appendix 1.

3.1 Study design

Descriptive Research Design: a researcher using descriptive research design is only concerned in explaining the circumstance or case under investigation. It is a theory based research design that is formed via the collection, analysis, and presentation of data. Descriptive research design can provide insights into the why and how of study by using an in depth research strategy. [29]

3.2 Sample size

The sample size of this study was estimated by using G power software . with the effect size of 0.5 and effect power of 0.95 . The estimated sample size to be 50 included in two groups.

3.3 Participants

The number of participants were 33 (24-male, 9-female).(mean age22.8, ±2.69SD), recruited from "yeditepe university". All participants volunteered and signed a consent form to participate in the study.

3.3.1 Inclusion criteria

For our inclusion criteria we recruited participants working or studying in yeditepe university, had no history of knee surgery, and were adults in general good health. However, some participants were excluded due to the following criteria:

3.3.2 Exclusion criteria

- History of knee ligament surgery.
- Knee, hip, ankle or back injury within six weeks.
- Musculoskeletal injury one month before testing, which can alter normal activity for more than two days.
- Medication that affects balance

- Condition or injury that affects balance
- History of an injury that caused the individual to hyperextend the knee, such as landing from a jump on overextended knee or a hit to the anterior medial part of the knee.

3.5 Statistical methods

Statistical analyses will be performed using SPSS software version 25. Descriptive analyses will be introduced using means and standard deviation for continuous data, frequencies, and percentage for categorical data. The variables investigated using Kolmogorov Smirnov test to determine whether or not they are normally distributed. Since the variables are normally distributed. [30]

3.6 **Assessment methods overview**

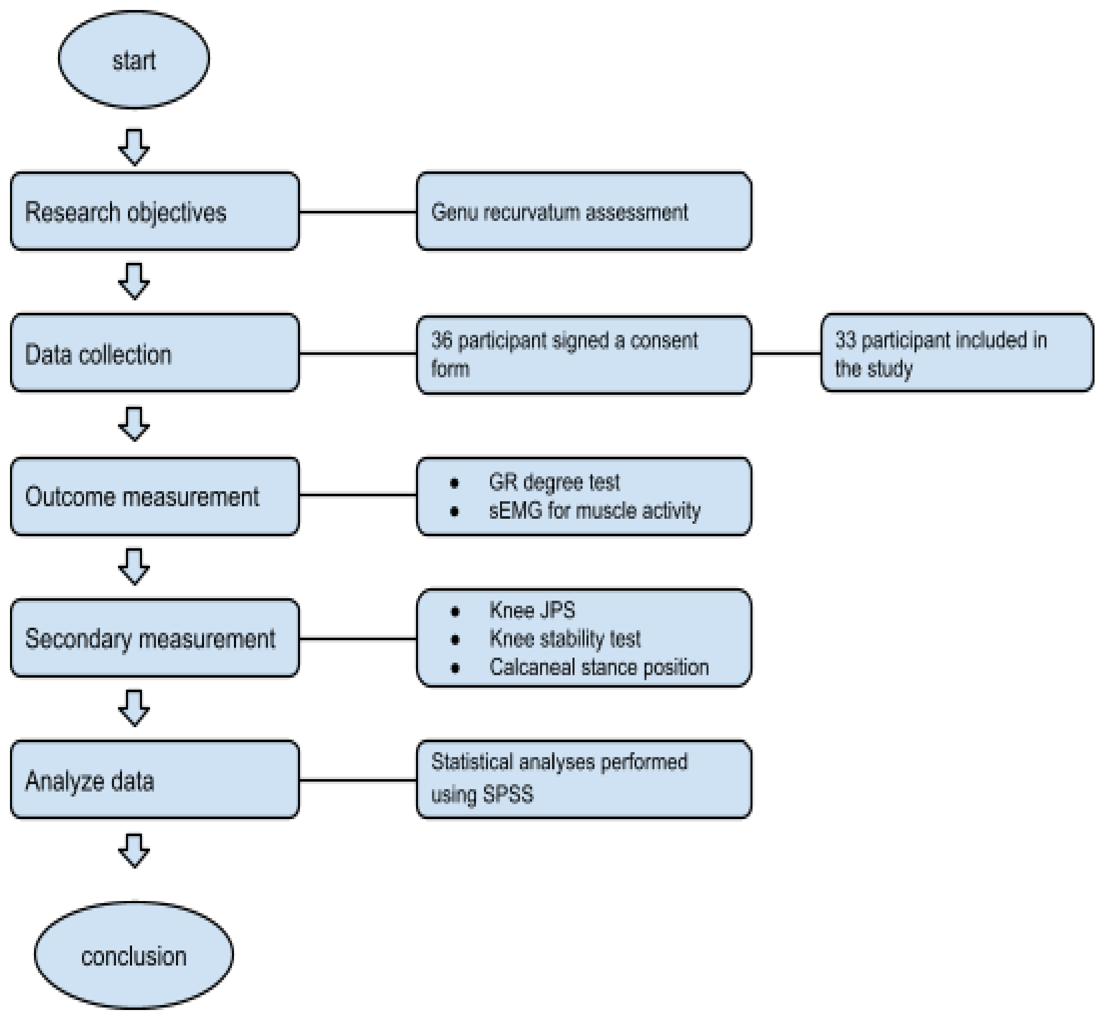


Figure 6. Research process flowchart

Participants in the study went through the same procedure in the same order, each participant was given his own time, first a consent form was handed to the participant to read and sign, the examiner was sitting next to them while they were reading the consent form to answer any questions. After signing the consent form, the examiner asked the participant questions for the inclusion criteria, participants who met the inclusion & exclusion criteria went through the assessment as follows below.

1. Participants were given information about the study and consent form
2. Using the data collection form, the examiner took the history related to knee injury
3. Based on history, participants were included or excluded
4. All instructions were demonstrated and verbally explained to the participants.

Outcome measurement was carried next starting with

1. Genu recurvatum test
2. Surface-EMG to test the following muscles
    - Biceps femoris muscle
    - Rectus femoris muscle
    - Anterior tibialis muscle
    - Gastrocnemius
3. Knee stability test for
    - ACL
    - PCL
    - MCL
    - LCL
4. Knee joint position test (proprioception).
5. Calcaneal stance position test.

3.7 Outcome measures

3.7.1 Main outcome measurement

We assessed GR with a Goniometer, in one earlier study, they utilized a Smart Kema motion sensor, while in another study, they used a ruler to measure one's heel height by pressing the thigh against the table and lifting the great toe up, then measuring the distance in centimeters between the bottom of the heel and the table, which correlates to the amount of GR, in general 1 centimeter heel height correlates to 1 degree of hyperextension.

All methods are reliable and valid, though we chose this method as it was easier and less time consuming and yields accurate results.

1. Genu recurvatum degree test

The patient lie supine with the tested leg elevated 30-40 degree from under the ankle, the therapist take the measurement with goniometer by aligning the the goniometry to the anterior superior iliac crust from the hip point, and the other end to the calcaneus, the measurement is taken for both legs and recorded in the data collection form, shown in figure 7. [31,32,33,50]

Figure 7. Genu recurvatum measurement

2. Muscle activity with surface EMG

S-EMG provides a non-invasive technique to assess muscle activity, muscle strength, muscle fatigue, and type of muscle contraction. S-EMG is linearly associated to the amount of muscle contraction as well as the number of contracted muscles, the stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be. S-EMG allows researchers to estimate the amount of muscle force exerted across a joint. S-EMG is measured in microvolts.[34.35.36]

In this study we are using S-EMG to assess the muscle activity of 4 muscles in a concentric contraction with isotonic resistance. The four muscles are:

- Rectus femoris (figure 8)
- Biceps femoris (figure 9)
- Anterior tibialis (figure 10)
- Gastrocnemius (figure 11)

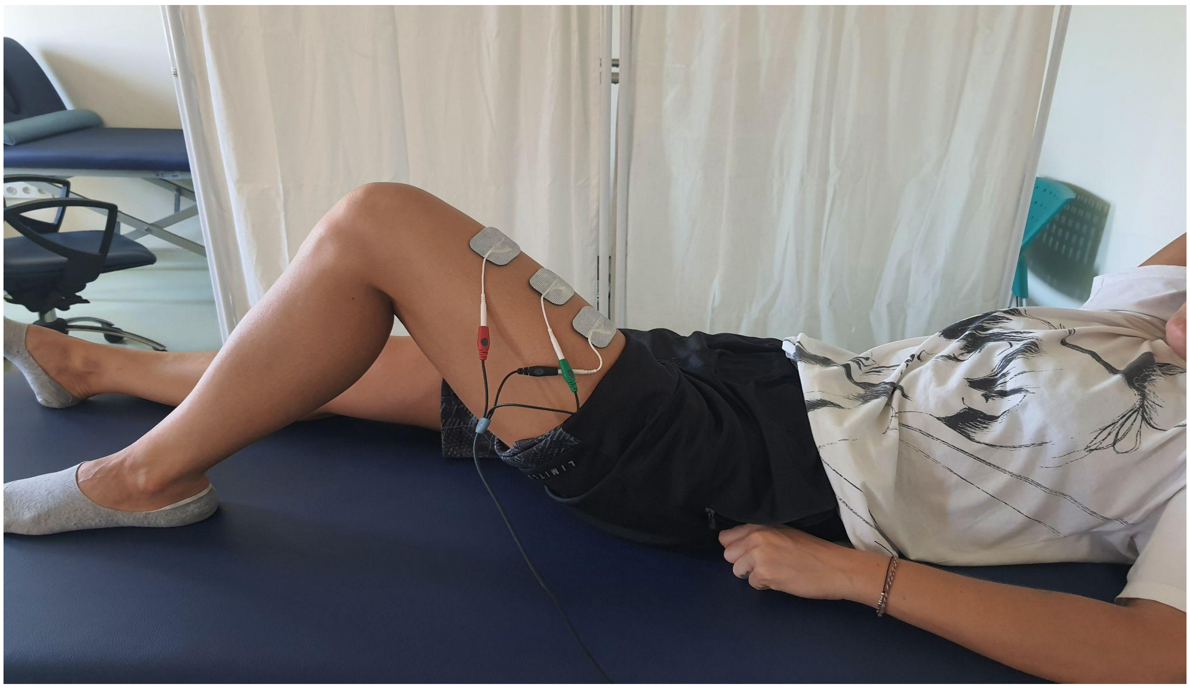


Figure 8. placement of electrodes for rectus femoris

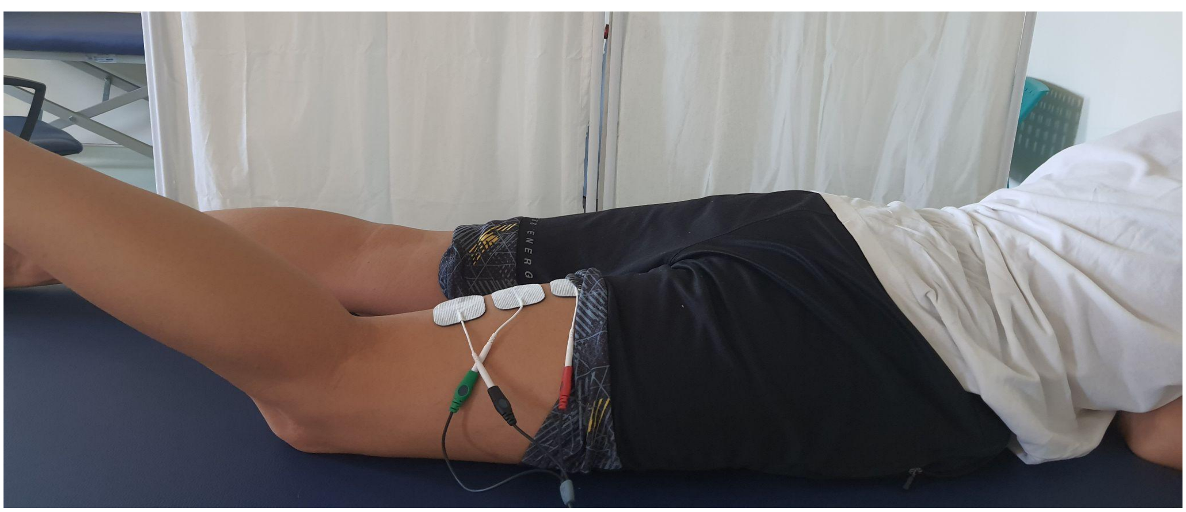


Figure 9. placement of electrodes for biceps femoris

Figure 10. placement of electrodes for anterior tibialis

Figure 11. placement of electrodes for Gastrocnemius

3.7.2 Secondary outcome measurement

1. Knee joint position test (proprioception)

   The JPS measures the individual ability to reproduce the same position in the knee. The difference between the target and the estimated angle is the result. The test is demonstrated and explained verbally to the participants. [37,38,39]

   The participant is seated at the end of the physical therapy table, eyes covered. The dominant leg is passively moved by the examiner from a 90° of knee flexion to 30° to 60° of knee extension. The leg is then passively returned to the starting angle position of 90° knee flexion and the participant is instructed to actively move the same leg to the target angle and hold the leg in this position. The participant is instructed to move their leg back to the starting position. The angle and range of motion is approximated by the examiner using the goniometer while the participant is actively moving his/her leg. This process is repeated 3 times on the dominant leg and the result is averaged. The choice of these target positions and range of motion are based on the reliability and validity of previous studies. [48]

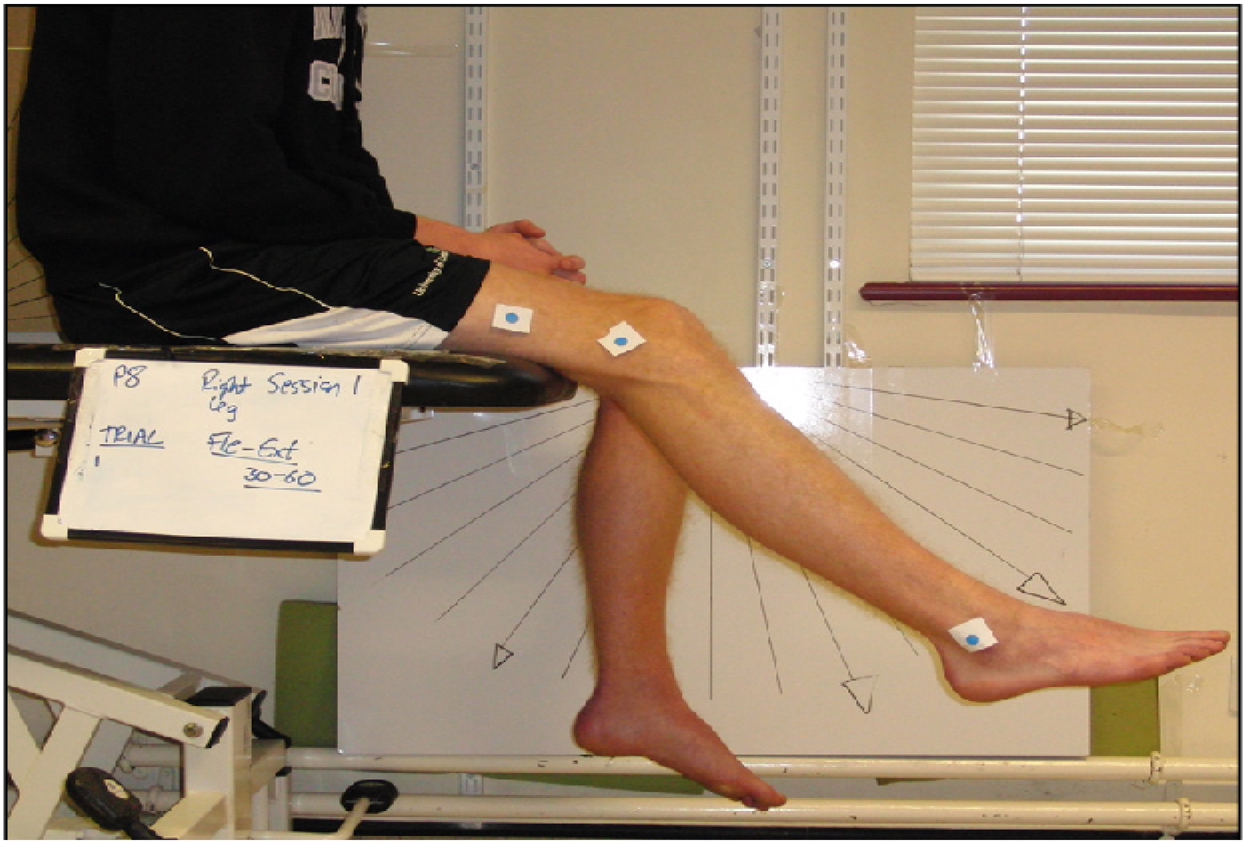


Figure 12. Set up for knee JPS [48]

2. Knee stability test (ligament)
   Four ligaments help to keep the knee joint stable: ACL, PCL, MCL and LCL.
   To assess the ligament we used four different tests. [40,41]

   - **Anterior drawer test** is used to assess ACL. The test is performed while the participant is lying supine with the knee bent, the examiner gently pulls forward on the tibia right behind the knee. A positive test is indicated by excessive mobility of the tibia beneath the femur.
   - **Posterior drawer test** is used to assess PCL. The test is performed while the participant is lying supine, the examiner bends the knee to ninety degrees and stabilizes the foot on the table. The examiner grabs the anterior aspect of the tibia above the tibial tuberosity and presses forward. A positive test is indicated if the tibia moves posteriorly.
   - **Valgus stress tes**t the valgus or abduction stress test is used to evaluate the MCL. The test is carried out with the knee in thirty degree flexion. while the knee is being stabilized, the examiner press gently against the lateral area of

the knee. The test is indicated positive if the knee gaps on the inner side of the joint are greater than normal.

- **Varus stress test** The varus or adduction stress test is used to evaluate the LCL. The test is carried out with the knee in thirty degree flexion. The examiner adducts the ankle while stabilizing the knee. The test is positive if the knee joint adducts more than normal/

3. Calcaneal stance position

- A static evaluation to test and compare the resting calcaneal stance position to neutral calcaneal stance position, while the participant is standing.
- The angle of the calcaneal bisection to the vertical while the patient is standing relaxed is the resting calcaneal stance posture.
- Normal feet have two to three degrees of calcaneal valgus and are vertical slightly everted, the examiner looks for valgus or varus in the heels.
- In this position, the examiner asks the participant to externally or internally rotate his or her tibia or manipulate the ankle while palpating the talus. The natural position is when the talus head is equally notable on the lateral and medial sides.
- The examiner measures the angle of the calcaneal bisection to the vertical position. A normal foot will be vertical or slightly inverted by two to three degrees in neutral calcaneal stance.

4. RESULTS

This study was conducted in Yeditepe university in the physical therapy laboratory. IBM SPSS Statistics 24 software is used. Data distributed normally. That is why parametric tests that include t-test and Pearson correlation test are used. The data collected will be presented using means and standard deviations for continuous data and frequencies, percentages for categorical data.

Participants were allocated into two groups based on their GR test on the dominant side. The value of mean age, height, weight. BMI and Gender are given in Table 1.

Table 1. Participant's Socio-Demographic Variables

	N	%
Age		
Mean ±Sd	22.81±2.69	
Min-Max	19-29	
Gender		
Male	24	72.7
Female	9	27.3
Height		
Mean ±Sd	1.75±.06	
Min-Max	1.60-1.87	
Weight		
Mean ±Sd	70.96±13.92	
Min-Max	55-110	
BMI		
Mean ±Sd	22.99±3.68	
Min-Max	18.59-32.18	
Dominant side		
Left	5	15.2
Right	28	84.8
Groups		
No GR Group	12	36.4
GR Group	21	63.6

Table 2. GR test scores

GR Test		
	M (SD)	**t**
Groups		
No GR Group	**7.83 (1.33)**	**-6.421***
GR Group	**10.85 (1.23)**	

Table 2: Means, Standard Deviation and Independent Sample t-Test(t) Results of Dominant Side GR Test, *p<0.05

Table 2 shows the differences between the two groups in terms of GR° based on the dominant side. We considered participants who scored more than 10° on their dominant leg to be in the GR group. Between the two groups, there was a significant difference in terms of GR angle. The "non-GR group" scored on average 7.83±1.3 SD while the "GR group" scored 10.85±1.2

Table 3. Pearson Correlation: Height, BMI, GR Test, Biceps Femoris, Rectus Femoris, Anterior Tibialis, Gastrocnemius, Knee Joint Position Test and Calcaneal Stance Position for Dominant Side

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*	**,221**	**-,235**	**,158**	**-,485****	**,093**	**-,120**	**-,350***	**,234**
2		*	**-,246**	**,256**	**-,490****	**-,045**	**-,338**	**,170**	**,209**
3			*	**-,222**	**,437***	**-,022**	**-,314**	**-,135**	**-,165**
4				*	**-,263**	**,222**	**-,157**	**,145**	**,091**
5					*	**,320**	**,249**	**-,281**	**-,346***
6						*	**.309**	**-,342**	**-,116**
7							*	**-,064**	**-,161**
8								*	**-,018**
9									*

**p<0,01 , *p<0,05 , 1-Height, 2-BMI, 3-GR Test, 4-Biceps Femoris, 5-Rectus Femoris, 6-Anterior Tibialis, 7-Gastrocnemius, 8-Knee Joint Position Test, 9-Calcaneal Stance Position,

Considering correlation between Height, BMI, GR Test, Biceps Femoris, Rectus Femoris, Anterior Tibialis, Gastrocnemius, Knee Joint Position Test and Calcaneal Stance Position for Dominant Side, there is a negative correlation between height and rectus femoris (r= -.485; p< .01).

Table 4. Muscle activity with S-EMG

Biceps Femoris		
	M (SD)	**t**
Groups		
No GR Group	**347.91 (122.90)**	**2.009***
GR Group	**271.95 (92.81)**	

Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Biceps Femoris, *p<0.05

Rectus Femoris		
	M (SD)	**t**
Groups		
No Gr group	**326.66 (167.11)**	**-3.049***
GR Group	**500.28 (138.54)**	

Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Rectus Femoris, *p<0.05

Anterior Tibialis		
	M (SD)	**t**
Groups		
No Gr group	**451.25 (117.80)**	**.211**
GR Group	**442.00 (126.40)**	

Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Anterior Tibialis, *p<0.05

Gastrocnemius		
	M (SD)	**t**
Groups		
No Gr group	**332.91 (179.27)**	.612
GR Group	**300.95 (121.02)**	

Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Gastrocnemius, *p<0.05

Table 4 showed a significant relation between GR and biceps femoris. And a negative significant relation between GR and rectus femoris. The data showed no meaningful relation between GR and the anterior tibialis or gastrocnemius.

Table 5. Knee joint position test (proprioception)

Knee Joint Position Test		
	M (SD)	**t**
Groups		
No Gr group	**61.86 (4.48)**	.206
GR Group	**61.50 (5.17)**	

Table 5: Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Knee Joint Position Test. *p<0.05

There is no meaningful relationship between No GR Group and GR Group with the Knee Joint Position Test (**p>0.05).**

Table 6. Calcaneal stance position test

Calcaneal Stance Position		
	M (SD)	**t**
Groups		
No Gr group	**1.91 (1.24)**	1.171
GR Group	**1.41 (.97)**	

Table 6: Means, Standard Deviation and Independent Sample t-Test(*t*) Results of Dominant Side Calcaneal Stance Position *p<0.05

There is no meaningful relationship between No GR Group and GR Group with Calcaneal Stance Position (**p>0.05).**

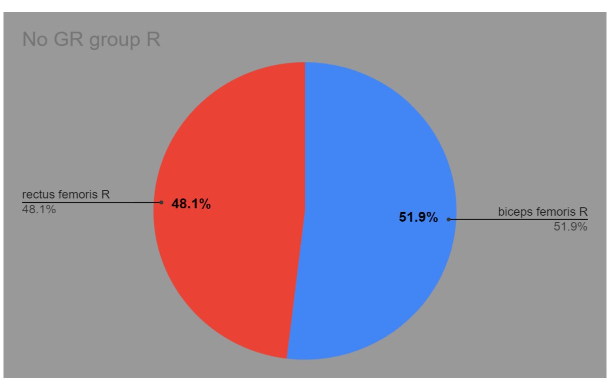


Fig 13. muscle activity ratio, No GR group.

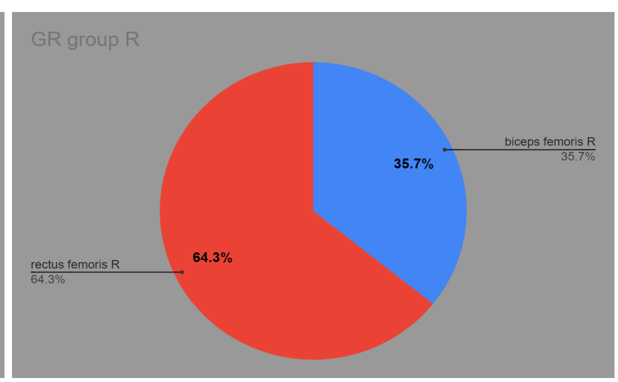
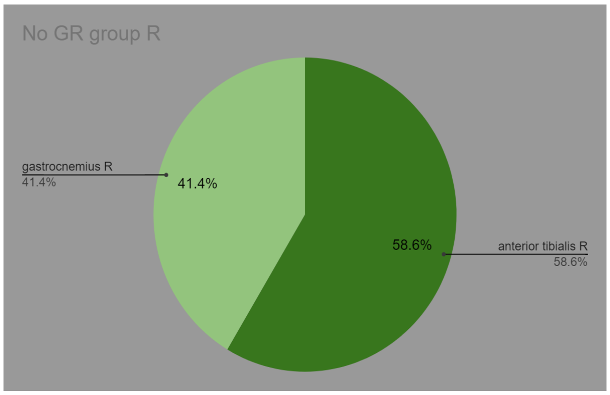


Fig 14. muscle activity ratio, GR group.



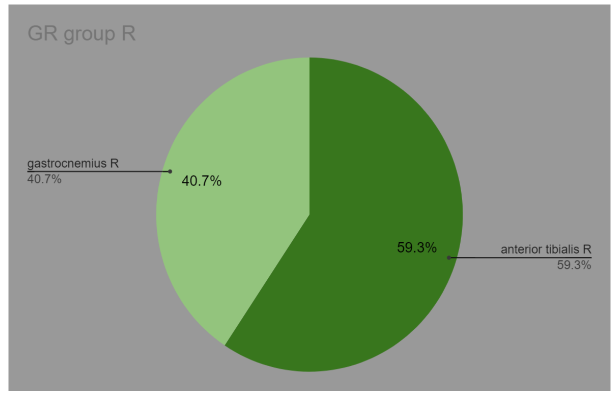


Fig 15. muscle activity ratio, No GR group.

Fig 16. muscle activity ratio, GR group.

Fig13. showed the muscle ratio shifted to biceps femoris in the NO GR group 51.9%. Consequently, Fig 14 showed the muscle ratio shifted to rectus femoris in the GR group at a 64.3.%.

In Fig 16 and 17 the muscle ratio is the same for both groups between 54% to 57% for anterior tibialis.

5. DISCUSSION AND CONCLUSION

5.1 Discussion

The objective of this current research was to investigate Genu Recurvatum and its relationship between other variables such as muscle power with surface electromyography (sEMG) and knee proprioception among young healthy adults. To the best of our knowledge, few papers discuss the relationship between muscle power and Genu Recurvatum.

In the present study we assessed the knee joint in 33 participants and we allocated the participants into two groups based on the GR test. Participants who scored on their dominant leg 10° and more in the GR test were put into "the GR group", and those who scored less than 10° were put in the "non-GR group". Between the two groups, there was a significant difference in terms of knee hyperextension. The Minimum age was 19 and maximum was 29 with no significant differences between the groups in terms of height, weight, BMI. although we had a significant difference in Gender where 72% of participants were male.

Another study investigated the gender related difference in lower limb injuries and found that Genu Recurvatum affects the knee the same way between genders. Additionally, their survey revealed that a significantly higher proportion of females had a history of lower limb sport injuries. However, the same study concluded that females tend to experience more injury in the foot/ankle and an increased range of motion and a significantly higher Q-angle (Q-angle is The measurement of lateral line of pull of the quadriceps relative to the patella), implying that females have a greater knee valgus than males which can increase the chances of developing GR. This is also consistent with our study since 40% of the participants in the GR group were females. [42]

In addition to this, another study examined the lower extremity alignment and compared between genders, they found females on average tend to experience greater pelvic tilt, thigh internal rotation, knee valgus and genu recurvatum than male. These findings are in line with our study and this suggests that lower extremity alignment has a greater role as a potential injury risk factor. [58]

In terms of muscle activity, surface electromyography is widely used for rehabilitation purposes and provides quantifiable information on the myoelectric output of a muscle in real time. Which is why the surface EMG was ideal for our research. Each muscle we selected and tested represented a specific action, either extension or flexion of the knee. Interestingly, in our study a positive correlation was found between GR and biceps femoris, where the participants in the “GR group” scored lower in the sEMG test. Furthermore, in our study a negative correlation was found between GR and rectus femoris, meaning the participants in the “GR group” scored higher in the sEMG test. However, no meaningful correlation was found with the anterior tibialis and gastrocnemius in relation to GR. [56]

Regarding muscle activity, in our study a significant correlation was found between muscle strength of the anterior compartment (rectus femoris) and posterior compartment (biceps femoris) with GR in our sample of college students as indicated in Table 7 where the participants in the “GR group” have a higher rectus femoris activity and participants in the “Non GR group” has lower rectus femoris activity.

This is in line with another study that was done in a recent study, they examined the association between GR angle and muscle strength of the knee and hip. They found the muscle strength ratios are more important than the weakness of any particular muscle. between the quadriceps and the hamstrings, there is a delicate balance of power. However, having an imbalance in the lower extremity could mean that the hamstring is not strong enough to support the action of the quadriceps. This strength deficit can happen for many reasons. When the quad-hamstring strength ratio becomes unbalanced, people may experience more injury and increased risk for hamstring strain or tears which can lead to hyperextension of the knee.[26][55]

In another study done by Allison Cooper where they tested 20 stroke patients, they found the weak ankle plantar flexors in particular gastrocnemius. Although they concluded that the role of gastrocnemius during the stance phase needs more research to determine if strengthening weak gastrocnemius reduces knee hyperextension. In our present study no correlation was found, perhaps in stroke patients the gastrocnemius plays an important role in GR. [47]

While in another study investigated the role of the calf muscles on CP patients with GR, they found the shortening of the gastrocnemius is the reason behind GR, and a calf muscle lengthening is a successful procedure to correct GR. Understanding the role of the gastrocnemius in GR is not about muscle actively alone, but the muscle length is also a factor to consider. [57]

In terms of proprioception, in both groups there is no meaningful relationship between GR and the knee joint position test. Both groups scored similarly in the knee joint position sense test. This is also consistent with the study by Barry C Stillman where they concluded position sense accuracy and reliability were normal in young adults with asymptomatic increased hypermobility. Although previous research done by Loudon suggests that the deficiency in Proprioception is diminished at the end range. In addition, proprioception is most affected when there is muscular fatigue. Meaning the proprioception is most affected while in the standing phase. The association between proprioception and GR is most noticeable near the full range of extension. In the knee joint position sense test, a target ROM of 60° extension from 90° knee flexion was used which is nowhere near the end range of extension. Which is why we did not find any significant correlation. [49][53]

In another study that investigated the knee joint mobility and position sense, they mentioned knee extension mobility and position sense were poorly correlated. The study analysis revealed that there is a greater accuracy and reliability in knee joints with less than 6° passive extension beyond straight. Which is consistent with our finding, at the end range proprioception is most affected. More research should compare the proprioception in standing, midstance phase and in sitting position. [59]

Additionally in the Pearson correlation test, significant correlation between rectus femoris and BMI was found. Which is consistent with another research that was investigating the association between knee alignment, BMI and physical fitness. In which they concluded with a positive association between malalignment of the knee's, BMI and physical fitness. GR had a significant correlation between height as well as BMI which correspond to height and weight, consequently this means that tall people are at risk of developing GR when having a slightly weaker biceps femoris. [43]

In another study conducted to assess the knee joint alignment in overweight and obese chidldren, they concluded that increased body mass index in children may lead to adverse effects on the knee joint in the form of genu valgus and recurvatum which may progress to irregularity later in life. [54]

It is important to note that this research does not apply to all people, as we have mentioned in our limitation. For the athletic person this is entirely different, most studies agree that the H:Q ratio is influenced by sports-specific demands, for example Basketball players tend to focus heavily on the quadriceps when doing strength training often neglecting the hamstrings. While football players have different H:Q ratios. Ballet dancers are almost required to have GR. This is important to note, because we wanted to know the effects on the average person. Most research related to our topic is done on subjects with GR as it is not the main diagnosis, as a result there isn't a lot of information on GR discussing its causes and effects on the average individual. Hence why we think this research is an important contribution. [50][51][52]

Lastly, The reliability of this data is impacted by some limitations. Unfortunately due to the pandemic, the sample size was less than expected (n=33) and The sample was limited to a specific group of people. Furthermore, hypermobility was not assessed, although it was not observed in the participants in any noticeable way. Additionally, the analysis was done only on the dominant leg. A follow-up study with a larger sample size and a wider range of age groups, where we can test the ratios of older individuals affected by GR and compare them to a young age group, could be useful to confirm the findings. And the fact that recurvatum deformity tends to worsen overtime is another subject that needs more research.

Genu recurvatum is quite common as it is seen in our sample from the participants we picked at random in the university, roughly 60% of them had/have GR, keeping in mind our sample consists of healthy young adults studying/working in the university. In reality GR is a lot more common, especially in the elderly population. GR is often overlooked while assessing or evaluating patients, until it starts to cause other inconvenient issues. Our aim was to find a solution to predict or prevent GR, we hypothesized there would be a muscle imbalance between the anterior compartment and the posterior compartments of the thigh, and if there was imbalance what is the threshold or percentage of muscle power that would cause GR.

The present study indicates that the difference in muscle strength ratio between the biceps femoris and rectus femoris is a factor to develop GR. Its simple method to indicate and therefore prevent people who are more likely to develop GR. It's our belief these results could be easily implemented and taken into consideration while assessing injury related to GR. In a clinical setting we often see patients with GR. Although, usually GR is not the main injury. Using this method the physical therapist can assess the muscles with biofeedback and suggest the appropriate exercise according to the muscle power and ratio to correct and treat the injury.

5.2 Conclusion

This study provides clinically relevant information regarding the effects of GR on muscle activity in the lower limbs, These results suggest that muscle activity ratio between the anterior compartment and the posterior compartment could be a valid testing method for indicating GR. Our findings suggest that imbalance between the biceps femoris and rectus femoris is a factor in developing GR. Therefore, using this method can be taken into consideration to prevent or indicate people who are at risk of developing GR.

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7. APPENDICES

7.1 appendix - ethical committee approval

T.C. YEDİTEPE ÜNİVERSİTESİ

Sayı : 37068608-6100-15- 1776 **21/11/2019**
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

İlgili Makama (Abdulrhman Ajam)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü Doç. Dr. Feyza Şule Badıllı'nın sorumlu araştırmacı olduğu **"Investigating The Muscle Imbalance In Lower Extremity Among Genu Recurvatum"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası **(1761)** kayıt Numaralı KAEK Başvuru Dosyası ,Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **20.11.2019** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 1121**).

Prof. Dr. Turgay ÇELİK
Yeditepe Üniversitesi
Klinik Araştırmalar Etik Kurulu Başkanı

Yeditepe Üniversitesi 26 Ağustos Yerleşimi, İnönü Mahallesi Kayışdağı Caddesi 34755 Ataşehir / İstanbul
T. 0216 578 00 00 www.yeditepe.edu.tr F. 0216 578 02 99

7.2 Appendix - consent form

YEDİTEPE ÜNİVERSİTESİ

Consent to participate in a research

Title of the study: Investigating the muscle imbalance in lower extremity with Genu recurvatum

Investigator's name : A. Ajam
Advisor's name: Dr.Sule Demirbas
Department: Physiotherapy and rehabilitation
Contact information:

Introduction

- You are being asked to be assessed in a research study about the knee joint.

- We ask you to read this form and ask any questions that you may have before agreeing to be in this study.

Purpose of the study

- The purpose of this study is investigating *Genu recurvatum in a healthy group of individuals in relation to muscle power, knee stability.

****Genu recurvatum** is also called **knee hyperextension of the knee** or **back knee**, its where the knee bends slightly backward.*

- This research will be used for master degree thesis and may be used in external publications.

Description of the study procedures

1. The investigator will ask you a few questions about your history with knee injury for the inclusion criteria.
2. You will go through assessment to examine the knee joint, the muscles around the knee and the position of the ankle joint.

3. The muscles around the knee will be tested using an EMG* device.
   ****Electromyography (EMG)**: is a test used to record the electrical activity of muscles.*

4. Data will be collected in the data collection form for statistical analysis.

5. The procedure will be conducted by a physical therapist in the physical therapy department at Yeditepe University .

6. The procedure time will take approximately 15-25 minutes.

Risks/discomforts of beings in this study

- There are no foreseeable or expected risk.
- There may be some discomfort while assessing the ligaments of the knee.

Confidentiality

- This study is anonymous. We will not be collecting or retaining any information about your identity.
- The records of this study will be kept strictly confidential. Research records will be kept in a locked file, and all the electronic information will be coded and secured using a password protected file. We will not include any information in any report we may publish that would make it possible to identify you.

Right to refuse or withdraw

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study at any time without affecting your relationship with the investigators of this study or the institution. You have the right not to answer any single question, as well as to withdraw completely from the interview at any point during the process; additionally, you have the right to request that the interviewer not use any of your interview material.

Right to ask question and report concerns

- You have the right to ask questions about this research study and to have those questions answered by the invistagior before, during or after the research. If you have any further questions about the study , at any time feel free to contact me (A.Ajam) at Ajam91@live.com or by telephone number at +90 552 223 42 31. If you like, a summary of the results of the study will be sent to you. If you have any problems or concerns that occur as a result of your participation, you can report them to the investigator at the number above .

Consent

- Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep, along with any other printed material deemed necessary by the study investigators .

Participant's name : _______________

Signature : ______________________

Investigator's name : ______________

Signature : ______________________

7.3 Appendix - Data collection form

YEDITEPE UNIVERSITY

Data collection form

Today's Date ___/___/______   PT: ________________________

Participant information

First name: ______________   Middle: _______________

Last name: _____________

Date of birth: ___/___/______

Age: _____

Gender: ______

Current height: ____ cm   Current weight: ______ kg

BMI: ____________

If you were asked to shoot a ball on a target, which leg would you use to shoot the ball?

History

- History of knee ligament surgery **Yes/No**
- Ankle, knee, hip or back injury within the past 6 weeks **Yes/No**
- Known or diagnosed balanced condition **Yes/No**
- History of an injury that forced you into hyper extension **e.g.** landing from a jump on hard extended knee or blow to the anterior medial aspect of the knee
  Yes/*No*

- Musculoskeletal injury within the past month which altered normal activity for more than two days
  Yes/No
- Are you taking any medication, pills or drugs? **Yes/No**
- Any surgery in the past 3 years? If yes, when and where? **Yes/No**

Outcome measurement

- The external rotation recurvatum test:

  Score: L/side ______________, R/side ______________

- Knee-joint position test (proprioception)

  Score: L/side ______________, R/side ______________

- Muscle power test using an EMG

Biceps femoris: L/side ______________, R/side ______________

Rectus femoris: L/side ______________, R/side ______________

Anterior tibialis muscle: L/side ______________, R/side ______________

Gastrocnemius: L/side ______________, R/side ______________

- Knee stability test

ACL: L/side__________, R/side __________

PCL: L/side__________, R/side __________

MCL: L/side__________, R/side __________

LCL: L/side__________, R/side __________

- Calcaneal stance position test

  Score: L/side__________, R/side __________

7.4 Appendix - Raw data

age	gender	hight	weight	BMI = weight/height^2	Dominant side
23	M	1.75	64	20.90	R
29	F	1.7	60	20.76	R
22	F	1.6	58	22.66	R
24	M	1.78	68	21.46	R
25	M	1.72	55	18.59	R
28	M	1.84	65	19.20	L
21	M	1.8	96	29.63	R
19	M	1.7	62	21.45	R
19	M	1.82	74	22.34	R
22	M	1.87	110	31.46	R
23	M	1.7	93	32.18	R
20	M	1.85	80	23.37	R
20	M	1.8	64	19.75	R
22	M	1.72	66	22.31	L
27	M	1.68	61	21.61	R
21	M	1.67	59	21.16	R
26	M	1.76	69	22.28	R
21	F	1.73	59	19.71	R
24	F	1.82	69	20.83	R
21	F	1.74	76	25.10	L
20	M	1.72	63	21.30	R
20	M	1.82	76	22.94	R
24	M	1.85	105	30.68	R
24	M	1.73	90	30.07	R
20	M	1.84	83	24.52	L
23	M	1.78	61	19.25	R
21	F	1.72	66	22.31	R
27	F	1.69	69	24.16	L

22	F	1.64	56	20.82	R
24	M	1.76	66	21.31	R
25	M	1.71	60	20.52	R
26	M	1.8	67	20.68	R
20	F	1.75	72	23.51	R

GR test L	GR test R	BicFem L	BicFem R	RecFem L	RecFem R
9	11	160	176	495	465
10	8	145	245	400	480
9	10	335	435	820	865
10	11	235	280	255	315
11	10	405	205	485	516
11	10	210	245	605	554
9	9	395	400	480	485
8	11	235	245	445	345
12	7	275	165	545	640
8	8	390	450	105	115
8	8	400	245	100	280
7	8	445	460	200	180
5	4	460	450	340	330
8	10	165	170	490	470
9	8	150	240	405	475
12	13	340	430	650	720
11	11	240	275	260	320
10	12	410	220	475	520
12	11	220	250	600	560
12	12	390	395	485	480
9	10	240	255	440	340
12	13	280	170	550	635
9	8	395	445	110	105
8	9	395	250	115	275
9	8	450	465	205	190
7	8	465	455	335	340

12	11	170	185	490	470
10	9	150	255	410	490
12	12	350	450	610	595
10	10	245	290	260	325
11	9	410	215	490	520
13	12	205	240	590	535
9	10	390	395	475	480

AntTib L	AntTib R	Gastro L	Gastro R	knee joint position test L (60)	knee joint position test R (60)
320	500	145	160	69.67	60.00
345	545	415	640	65.00	67.00
565	532	450	300	56.00	60.67
205	365	220	280	65.67	63.00
245	185	205	320	62.00	64.67
480	550	290	210	51.00	47.33
520	560	150	255	66.33	67.67
375	450	290	260	64.67	67.33
515	605	395	585	59.33	52.67
325	435	370	140	60.33	66.67
230	350	150	275	60.67	58.33
245	410	230	285	60.00	61.00
455	575	490	520	57.33	59.33
330	510	140	165	67.67	62.67
350	545	420	630	64.67	66.00
560	535	455	295	57.00	61.00
210	370	210	265	65.67	63.00
250	190	210	315	61.33	64.33
475	545	280	215	55.33	49.00
515	545	145	245	64.33	66.00
380	455	295	265	64.33	65.00
510	600	390	580	60.00	57.00
335	445	380	150	60.67	62.33

215	335	135	260	60.33	60.00
255	420	240	295	61.00	60.67
450	570	485	515	58.00	59.67
325	495	150	180	68.33	58.67
355	550	420	645	65.00	67.00
540	515	455	315	57.33	61.00
215	370	230	295	66.67	64.00
250	190	215	335	61.33	65.67
475	545	285	205	53.67	53.33
510	545	145	240	65.67	66.67