UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
DIVISION OF PHYSICAL THERAPY

Biomechanics/Kinesiology

Unit 3: Lower Extremity

Hip:

1. Observe the contribution of pelvic motion to forward and backward bending by palpating the PSIS while your partner bends forward or backward.
   a. Starting in anatomical position, flex forward to bring your hands as close to the floor as you can. At what point does the pelvis begin to move with respect to the spine? At what part of the motion does the pelvis contribute most of the motion?
   The pelvis will begin to anteriorly tilt on the femurs after the trunk flexion has already begun (generally throughout the second half of the motion). This second half is where most of the motion is contributed by the pelvis (until limited by hamstring extensibility). However, if an individual is reluctant to move segmentally at the spine, the pelvis may initiate the movement (and be the major contributor through the entirety of the movement). Many of you, however, have trained yourselves to 'hip hinge' and may see pelvis motion fairly early in the process.

   b. Now from your forward flexed position, return to anatomical position. At what point does the pelvis begin to move with respect to the spine? At what part of the motion does the pelvis contribute most of the motion?
   The pelvis will generally begin to posteriorly tilt on the femurs immediately when initiating the extension movement (generally throughout the first half of the motion). This first half is where most of the motion is contributed by the pelvis. The extension is initiated by the pelvis, as the starting position is where the external moment arm of gravity is the largest (and the hip extensors are the strongest group of muscles controlling this extension).

2. In standing, assume a posteriorly tilted pelvis.
   a. Describe the movement of the hip joint as you performed the tilt and the position of the lumbar spine once you have assumed the position.
   Hip: extension (inferior roll, inferior slide of acetabulum on femur)
   Lumbar spine: decreased lumbar lordosis; lumbar flexion

   b. Describe how, in a closed kinematic chain, movement of the pelvis on the femur affects the posture of the lumbar spine
   In a closed kinematic chain, the legs are unable to move to create the posterior pelvic tilt. So, the pelvis must be what moves. In order to maintain an erect position of the head / arms / chest, and to maintain the center of mass over the

base of support, the L-spine must also move. As the pelvis tilts posteriorly on the femurs, the inferior vertebrae of the sacrum and lumbar spine shift posteriorly and inferiorly relative to the superior vertebrae (effectively placing the lumbar spine into flexion) as the superior vertebrae remain in place.

c. What are some possible reasons a patient may assume this posture?
Tight hamstrings
Tight rectus abdominis
Facet pain / spinal stenosis (pain with closing)

3. Special Test

Thomas Test for shortened hip flexors (iliopsoas and rectus femoris)
Have your partner lie supine at the very edge of the plinth so the legs are hanging off. Pull both knees to chest, and them hold one in place so the pelvis doesn't move (see picture). Slowly extend the knee of the other leg and begin to extend the hip while maintaining the knee in extension. Can the thigh reach the table (or go below the depth of the table)? _variable depending on muscle tightness_
If not, what does this indicate? _tight iliopsoas_
What happens if you repeat the movement with the knee flexed as you bring the leg down to the table? _variable depending on muscle tightness_

Does it feel different to your partner? _if tight, they should feel a stretch in the quad instead of anterior hip_
How does this affect the muscles you are testing? _With the knee extended, the rectus femoris is lengthened at the hip and shortened at the knee, eliminating ability to limit movement – allowing for you to bias the single joint hip flexors (iliopsoas) to assess flexibility. With the knee flexed, the rectus femoris is lengthened over the hip and the knee, inducing passive insufficiency – allowing contribution of the biarticular hip flexor / knee extensor when assessing flexibility (though, it is important to note that the single joint muscles can still contribute to observed tightness in the second position)._

4. Active insufficiency of the hip extensors. With your partner in prone, test the strength of the hip extensors with:
   1) the knee in extension
   2) the knee in full flexion

   a. Which muscles contributed to producing force in each position?
   Knee extended: hamstrings and glutes contributing to hip extension
   Knee flexed: glutes contributing to majority of hip extension torque (the hamstrings are shortened at the hip and the knee, inducing active insufficiency of hamstring contribution).

b. Did one position produce more force than the other?
Likely, the partner was able to produce more hip extension torque with the knee in extension due to both hamstrings and glutes producing hip extension force. If the patient felt they were able to produce equal force or more force with the knee flexed, consider the effect of bending the knee on the center of mass and external moment arm of gravity. As the knee bends, the center of mass is shifted closer to the axis of rotation at the hip, and the moment arm of gravity becomes shorter. This may make the patient feel it is easier to overcome similar resistance in this position.

c. What may be the advantage to muscle strength testing in either of these positions?
Testing with the knee in full flexion can allow you to bias force production of the glutes due to the active insufficiency of the hamstrings.

5. Position your partner in side-lying as shown with the hip in 0 degrees of flexion and the thigh in-line with the trunk. Make sure the knee and toes are pointed straight ahead. Add some weight to the ankle if needed. Ask your partner to go through half of the available ROM (see pic) in the frontal plane as many times as possible. When they start to fatigue do you notice them changing their hip position? What changes in motion or positioning do you notice when they complete the exercise? Why would they make those changes?

Potential compensations:
External rotation of the hip (toes pointing up) to use hip flexors
Hip flexion (thigh / knee / foot in front of trunk) to use hip flexors
Rolling top hip back (hips pointing toward ceiling) to use hip flexors
Bending the knee to decrease the length of the external moment arm

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Knee:

1. With your partner in sitting, knees flexed to 90 degrees, mark the skin over the tibial tuberosity. Now ask your partner to fully extend the knee actively. With the knee in full extension, mark the skin over the spot where the tibial tuberosity is now found. Was the tibial tuberosity displaced when moving from a flexed to extended position?
Tibial tuberosity is displaced laterally (the original mark on the skin moves medial to the tibial tuberosity). This is due to the tibial external rotation on the femur which occurs at terminal knee extension when in an open kinetic chain as part of the screw home mechanism.

What happens to the position of the tibial tuberosity when your partner moves from an extended to a flexed position?
Tibial tuberosity is displaced medially. This is due to the tibial internal rotation on the femur which occurs with the "unlocking" of the knee from extension (undoing the screw home mechanism) in open kinetic chain.

2. Special Tests:

Collateral Ligament Stability Tests:

With your partner in supine, create varus and valgus loads to the knee in an extended and semi flexed (~20-30°) position. What ligament is being tested with each force? Do you feel greater laxity in the extended or semi-flexed position?
Varus at 0 degrees: Lateral Collateral Ligament (LCL)
Varus at 20-30 degrees: LCL and Arcuate Ligament (due to the force being biased slightly posteriorly)

Valgus at 0 degrees: Medial Collateral Ligament (MCL)
Valgus at 20-30 degrees: MCL and Posterior Oblique Ligament (due to the force being biased slightly posteriorly)

You should feel greater laxity in the semi-flexed position, as ~25 degrees of knee flexion is the loose packed position of the knee in which the ligaments are lax (whereas full extension is closed packed and the ligaments are taut).

Lachman and Anterior Drawer for Ant Stability:

With your partner as relaxed as possible in supine, flex the knee to about 90° and place the foot flat on the plinth. Pull the tibia anteriorly on the femur. Do you feel an end-feel? What ligament is being tested?
This is the Anterior Drawer test for the Anterior Cruciate Ligament (ACL). With increased knee flexion, the anteromedial bundle of the ACL becomes tauter. Therefore, this test will bias the anteromedial bundle of the ACL.

Now bring the knee to about 30° of flexion and repeat the anterior translation force of tibia on femur. This is the Lachman test for the Anterior Cruciate Ligament (ACL). With increased knee extension, the posterolateral bundle of the ACL becomes tauter. Therefore, this test will bias the posterolateral bundle of the ACL.

Does one test feel different compared to the other? Why might this be?
Both bands of the ACL are lax at around 30 degrees of knee flexion. Therefore, this position allows for maximum excursion of the tibia to translate anteriorly

relative to the femur. As a result, you may feel more movement at 30 degrees compared to 90 degrees of knee flexion.

3. Ask your partner to flex and extend the knee through the full range of motion repeatedly while sitting. Note the gliding movement of the patella relative to the femur. Observe on your partner what happens to knee ROM if you manually block inferior gliding of the patella.
   If you block inferior gliding of the patella, you inhibit the ability of the knee to flex all the way.

   Observe on your partner what happens to knee ROM if you manually block superior gliding of the patella.
   If you block superior gliding of the patella, you inhibit the ability of the knee to extend all the way.

   Can loss of patellar motion contribute to decreased tibiofemoral motion? If so, what can you do about it?
   Yes, loss of patellar motion can contribute to decreased tibiofemoral motion. If a patient is lacking tibiofemoral motion (flexion and/or extension), you should assess patellar mobility. If appropriate, you can perform patellar mobilizations to facilitate an increase in tibiofemoral motion. Mobilize inferiorly to increase tibiofemoral flexion. Mobilize superiorly to increase tibiofemoral extension.

4. Stand with your knees extended and try to relax your quadriceps. How are you able to stay upright with your quadriceps relaxed?
   If you extend your knees to their end-range (potentially into hyperextension), you can shift the joint axis of the knee so that it is posterior to the line of gravity coming from your center of mass. As a result, gravity creates an external knee extension moment (taking the place of the quad extension moment) which needs to be countered by an internal knee flexion moment. The internal knee flexion moment is created by the passive structures on the posterior side of your knee which prevent/limit hyperextension.

   Have your partner palpate your quadriceps for relaxation. Now flex your knee as you squat down slowly and have your partner feel when the quadriceps become active? What happens to the quadriceps activity as you go further into your squat?
   Your quads should become active as soon as you start to flex at your knee (as the knee joint center/axis shifts anterior to the line of gravity). As you go further into your squat, the quadriceps activity should increase. This is a result of the knee joint center moving further away from the line of gravity, increasing the length of the moment arm of gravity (increasing the external flexion moment about the knee). To counter this change, your internal extension moment created by your quadriceps must also increase (meaning the force generated by your quads needs to increase).

5. Have your partner sit on the edge of the treatment table with feet dangling over the side. Passively extend your partner's tibia at the knee so that the knee is straight. Ask your partner to stay relaxed so that there is no active tension in the quadriceps as you gradually flex the knee. As you flex the knee, passively move the patella medially and laterally at various points in the range of motion.
   a. At what angle of knee flexion are you no longer able to move the patella
      ~45 degrees
      The patella moves most freely around full extension and gradually decreases excursion as the knee increases in flexion

   b. What is the relationship between the patella and femoral articular surfaces above and below this angle?
      Above 45 degrees (knee in more flexion), the patellar groove is deeper, creating more articulation between the patella and the femur. Lateral translations of the patella are limited by the bony prominences of the medial and lateral femoral condyles. Additionally, the passive lengthening of the quads with increased knee flexion increases the passive compression force on the patella into the femur (further increasing articulation).

      Below 45 degrees (knee in more extension), the patellar groove is more shallow, allowing the patella to sit above the groove. Here there is less articulation and increased lateral patellar mobility.

   c. Have your partner produce an isometric quadriceps contraction at this angle while you palpate the patella. Which direction does it move?
      Slightly superior with the quadriceps tendon pull
      Slightly posterior from the compressive angle the tendons are pulling

   d. Passively extend the knee fully and have your partner produce an isometric quadriceps contraction again while you palpate the patella. Which direction does it move?
      Superior translation from the pull of the quadriceps tendon

6. Lunge
   a. Perform a forward lunge as follows:
      (1) with the trunk perpendicular to the floor (chest straight up)
      (2) with the chest closer to the knee (forward flexed)

      Which motion requires more quadriceps force? Why?
      (1) will require more quadriceps force.
      Leaning forward (2) shifts the center of mass anteriorly, towards the axis of rotation about the knee (in which the quads are working). As the center of mass moves closer to the knee axis of rotation, the external moment arm of gravity

decreases in length, creating a smaller external knee flexion moment for the internal moment of the quads to overcome.
Keeping the chest upright (1) maintains increased distance between the center of mass and the axis of rotation (knee), thereby creating a larger external knee flexion moment from gravity which requires increased quadriceps force for the internal knee extension moment.

Which motion requires more gluteal force? Why?
(2) will require more gluteal force.
Leaning forward shifts the center of mass anteriorly, towards the axis of rotation about the knee, but away from the axis of rotation about the hip (in which the glutes are working). As the center of mass moves away from the axis of rotation, the external moment arm of gravity increases in length, creating a larger external hip flexion moment for the internal moment of the glutes to overcome.

Why may we see a patient performing lunges like (2) in the clinic?
They may be compensating for weak quads.
They may have increased anterior knee pain and are trying to decrease compression forces caused by increased quad activation when the knee is in greater amounts of flexion.

7. Squat: Perform a squat while your partner observes how much hip, knee, and ankle dorsiflexion occurs. Repeat with a 1-2 inch board (or book or weight or anything else you can find) under the toes and then again with the book under your heels. Which was easiest to squat? What did you change with the addition of the book under the different parts of your foot?
   Easiest to squat with the book/board under the heels. Having the book/board under the heels pre-sets the ankles into plantarflexion. This allows the ankles to have increased excursion into dorsiflexion with the squat by allowing the proximal tibias to shift forward more (and allowing for increased knee flexion to achieve depth of squat).

   Having the book/board under the toes pre-sets the ankles into dorsiflexion. This limits the available dorsiflexion excursion the ankles can go through with the squat. This limits the anterior shift of the proximal tibias, decreasing the amount of knee flexion. With decreased knee flexion, the squat will bias towards increased hip flexion (hip hinge) to increase depth. As a result, the squat will be “felt” more in the hip extensors.

8. Perform a hamstring curl in prone using ankle weights and consider how challenging it was. What part of the ROM was most challenging?
   The initiation of the curl should be the most challenging. This is the point of the motion where the external moment arm (of gravity) is the largest.

Now repeat this prone hamstring curl with 2-3 pillows under your pelvis. Did this position change your perception of how easy/hard it was? What changed?
This should make the hamstring curl easier. By placing pillows under your pelvis, you position yourself into hip flexion. This lengthens the hamstrings over the hips. So, as you shorten the hamstrings at the knee to perform the hamstring curl, the hamstrings are at a more optimal position on the length-tension curve (instead of being shortened at the hip and knee, which would induce active insufficiency) to perform the action.

Finally, perform the hamstring curl in standing. How does the force change through the ROM? Please compare to the prone position.
The most challenging part of the curl should be when the shin is parallel with the ground rather than the initiation of the movement (as with prone). This is the point where gravity is acting perpendicular to the lower leg and the external moment arm (of gravity) is the longest. The force should gradually increase as knee flexion increases.

9. Perform a unilateral step down from a box/step. Your partner should observe the position of your knee relative to the ipsilateral ankle and hip. Does it stay in line with the hip/ankle? Does it deviate medially or laterally? If so, what is happening at the patellofemoral joint? What is happening at the tibiofemoral joint?
   If deviate medially:
   
   The line of pull from the quad tendon on the patella is laterally-directed. This lateral net resultant force will result in lateral compression of the patella into the lateral femoral condyle.
   Additionally, medial deviation of the knee with the foot remaining planted can result in tibial and femoral internal rotation (a valgus posture at the knee), placing a valgus stress on the knee joint. This can cause increased compressive forces on the lateral side of the tibiofemoral joint articulation.

   If deviate laterally:
   
   The line of pull from the quad tendon on the patella is medially-directed. This medial net resultant force will result in medial compression of the patella into the medial femoral condyle.
   Additionally, lateral deviation of the knee with the foot remaining planted can result in tibial and femoral external rotation (a varus posture at the knee), placing a varus stress on the knee joint. This can cause increased compressive forces on the medial side of the tibiofemoral joint articulation.

10. Perform a 'wall sit' exercise with feet about shoulder width apart. Place the heel of the right foot about even with the toes of the left foot. After 30 seconds can you tell a difference? What about at a minute? Which side is fatiguing quicker? Why do you think this is the case?
    The left leg should fatigue quicker. By placing the right foot forward, you are biasing your weight towards the left side, preferentially loading the left lower extremity. This

weight shift is a technique often used in the clinic when a patient is unable to weight-bear evenly when performing a sit to stand transfer (such as after a total hip replacement or total knee replacement). Additionally, this technique can be used in exercise prescription to preferentially load and strengthen the involved leg.

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Foot/Ankle:

1. Work with an articulated skeleton (preferred) or a partner to complete the following. In a closed kinematic chain first a) externally rotate the tibia with the foot on the floor, then b) internally rotate the tibia with the foot on the floor. What happened at the foot? What other joints of the foot are affected by this closed chain motion of the tibia?
   Closed chain motion of the tibia affects the subtalar joint and the transverse tarsal (midtarsal) joint.
   With external rotation of the tibia, the talus is pulled into abduction. Due to the axes of the transverse tarsal joint, this talar abduction is coupled with talar dorsiflexion and calcaneal inversion to form closed chain supination.
   With internal rotation of the tibia, the talus is pulled into adduction. Due to the axes of the transverse tarsal joint, this talar adduction is coupled with talar plantarflexion and calcaneal eversion to form closed chain pronation.

2. Stand with your leg and foot exposed, foot flat on the ground and knee slightly bent to avoid the screw home mechanism at the knee. Pronate your right foot by depressing the medial longitudinal arch toward the floor. What movement occurs in the tibia as the foot pronates? What posture tends to occur at the knee with closed chain foot pronation?
   With pronation in a closed chain position, the talus adducts. Because the tibia moves with the talus, the tibia is pulled into internal rotation. As this occurs, the knee deviates medially, the femur is pulled into internal rotation, and the knee is typically positioned into a posture of genu valgus.

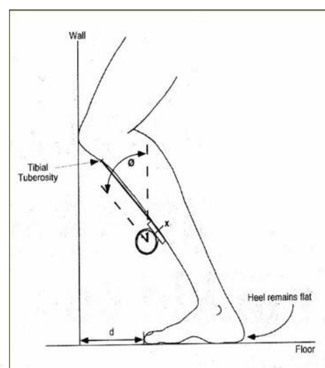
3. Observe a classmate while he or she walks barefoot slowly. Identify when their feet are pronating and when the feet are supinating. What part of the foot did they land on? What part did they push off of? What happened to the toes?
   Your classmate should initially land on the lateral aspect of their heel due to slight calcaneal inversion (supination). As their foot becomes flat on the ground and their weight shifts anteriorly, their midfoot should go through pronation (this allows for increased shock absorption). As their heel begins to rise from the floor, their foot should move into supination to allow for a rigid push-off. This push-off is characterized by extension of the toes while the metatarsal heads are still in contact with the ground.

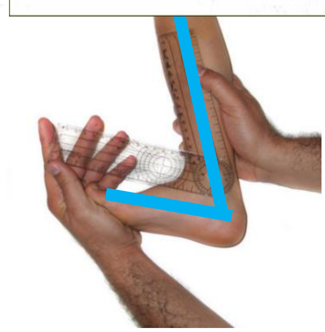
What do you think would happen if a patient was wearing a hard piece of plastic (like an AFO) under their foot that didn't allow the toes to bend?
If the sole is rigid to where the toes cannot extend, the patient would not be able to achieve as strong of a push-off. This would result in a shortened step length.

4. Have your partner lie prone with the feet hanging off the edge of the plinth. Have them perform a maximum plantarflexion contraction against your resistance. Are you able to resist them?
You will not be able to resist your partner's plantarflexion in this position. This is why we use single leg calf raises for plantarflexion MMT.

Now have them come up onto hands and knees (the feet should still be hanging over the edge of the plinth). Resist plantarflexion again. Does the force change? Did it feel different to your partner? Why?
The force your partner is able to produce in this position should be less. With the knee bent, the gastroc is now shortened at the knee and shortening at the ankle as they plantarflex. This places the gastroc into active insufficiency, efficiently biasing the plantarflexion from the soleus.

5. Place your partner's limb in the most effective position to lengthen (stretch) the gastrocnemius. Why did you pick this position?
The most effective stretch for the gastrocnemius would be lengthening the muscle across the knee and the ankle (as this is a two-joint muscle). This position includes the knee being in maximum extension and the ankle being in maximum dorsiflexion (note that this position is the opposite of the muscle's actions at these joints).



6. Measuring Dorsiflexion…
   a. Have your partner stand on one leg with the knee straight and shoes off. Then measure how far they can move into dorsiflexion by swaying forward in standing using your goniometer or the bubble inclinometers _variable per individual_.
   b. Then measure how much they can move into DF in Supine, with the knee straight on the table _variable per individual, though this motion should be more than part a._.
   c. Then measure how far they can go into DF when they squat down keeping their heel on the floor _variable per individual, though this motion should be the most_.

Which is the most motion and why?
Part c should be greater than part b which should be greater than part a.

In part a, your dorsiflexion is limited by the need to keep your center of pressure within your base of support to keep you from falling. You aren't able to flex your knee to alter the position of your center of pressure, so your motion needs to come from your ankle and hips/pelvis/spine.  Additionally, as you sway forward, your line of gravity moves further anterior to your ankle joint center.  This results in your gastroc/soleus complex increasing muscle force production as postural muscles to maintain standing.  As such, your dorsiflexion motion is being limited by both normal passive restraints as well as active muscular restraints.

In part b, you are no longer in a loaded / weight-bearing position.  So, your gastroc/soleus complex is no longer active as postural muscles (meaning your dorsiflexion motion is no longer limited by this active restraint).  Rather, the limitations are going to come from the normal passive restraints (such as ligaments, capsule, muscle-tendon unit length, etc.). However, because your knee is still extended, the gastroc is being lengthened over the knee and the ankle – effectively placing it into passive insufficiency and limiting motion.

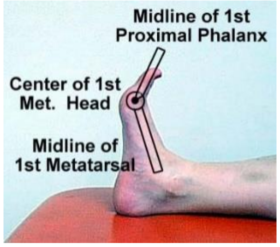
In part c, you are in a loaded position, but you are allowed to bend your knees.  Bending your knees allows you to effectively increase dorsiflexion while maintaining your center of mass over your base of support throughout the entirety of the motion.  Additionally, bending your knees shortens the gastroc at the knee, increasing the slack in the muscle-tendon unit and eliminating its previous role as a passive insufficiency dorsiflexion limitation.

What could be limiting the motion in the other tasks that created less DF?
See explanations above.

7. Balancing activity. Try to balance on one foot with your knee straight and your hands on your hips and your eyes closed.
    a. How long can you stay on one foot _variable per individual_ sec (stop at 60 sec for you acrobats out there who have excellent balance, if it is too hard try with eyes open to compare tests)
    b. Now try that again, but put your heel up on a sloped board or a 2x4" board. How long can you stand on the Board before you lose your balance? _variable per individual, but likely shorter than a._ seconds.
    c. Which is harder to do?  GROUND vs BOARD?
       Board should be harder

    d. Why is there potentially a difference between the techniques/tasks?
       As you stand on the sloped board, you are increasing the plantarflexion position of the ankle.  Plantarflexion is the open packed position of the Talocrural joint, where there is decreased bony congruency between the talus and the mortise, creating decreased stability.  Additionally, as you increase plantarflexion, your center of pressure shifts anteriorly, closer to your margin of stability.  This increases the difficulty of recovering a potential loss of balance.  Further, plantarflexion at the ankle shortens muscles posterior to the ankle joint and lengthens muscles anterior to the ankle joint – taking each out of their typical (and likely most optimal) length-tension relationship.

8. Great toe motion.




a. Measure the amount of dorsiflexion motion in the 1st MTP with the foot relaxed in *non-weightbearing* (so the foot/ankle is relaxed into relatively PF) _Variable per individual_°.

b. Then measure the amount of MTP motion that is available when the foot is in a max DF position by pressing firmly on the plantar surface of the met heads _Variable per individual, but should be less than a._°.

c. Finally, measure the available ROM of the 1st MTP when you are standing on the edge of a step stool with your toes hanging over the edge _Variable per individual, but should be less than a. and b._°

d. Which position has the greatest available motion?
a. should have the greatest available motion

e. Provide a rationale for why the motion may change between measurement positions:
The difference between part a and part b is the inclusion of maximal dorsiflexion. As you dorsiflex the foot, you are stretching the proximal insertion of the plantar fascia on the calcaneus. When extending the 1st MTP, you are stretching the distal insertion of the plantar fascia on the proximal phalanges. When stretching / lengthening the plantar fascia from both ends, you are effectively increasing the stress on the plantar fascia. This increase in stress (known as the Windlass mechanism) limits the amount of 1st MTP extension you will be able to achieve.

In part c you introduce a weight-bearing component. Weight-bearing results in separating the two insertion points of the plantar fascia as compared to non-weight-bearing, spreading the plantar fascia and increasing the stress within the structure. Additionally, in standing you introduce the activation of the gastroc/soleus complex as postural muscles. This activation creates a pull on the proximal insertion of the plantar fascia on the calcaneus. As you extend the 1st MTP and pull on the distal insertion of the plantar fascia, the extension is limited by both the Windlass mechanism stress and the weight-bearing stress throughout the plantar fascia.