The Conservative Management of Plantar Plate Injuries

By Tom Michaud, DC

The plantar plates are a series of fibrocartilaginous disks located beneath the lesser metatarsal heads. These plates play a key role in protecting the metatarsal heads from trauma and stabilizing the toes during the propulsive phase of gait. Anatomically, the plantar plates originate from the distal shafts of the lesser metatarsals and insert directly onto the proximal phalanges. Each plantar plate receives powerful attachments from the accessory collateral and transverse ligaments, and the longitudinal branches of the plantar fascia (Fig. 1). Importantly, the plantar plate does not attach uniformly to the proximal phalanx. Instead, its major attachments are on the medial and lateral sides of the base of the phalanx. This dual attachment allows the plantar plate to function like a cushioned sling (Fig. 1 A) that protects and cradles the metatarsal head as it rotates and slides in response to weight-bearing activities.

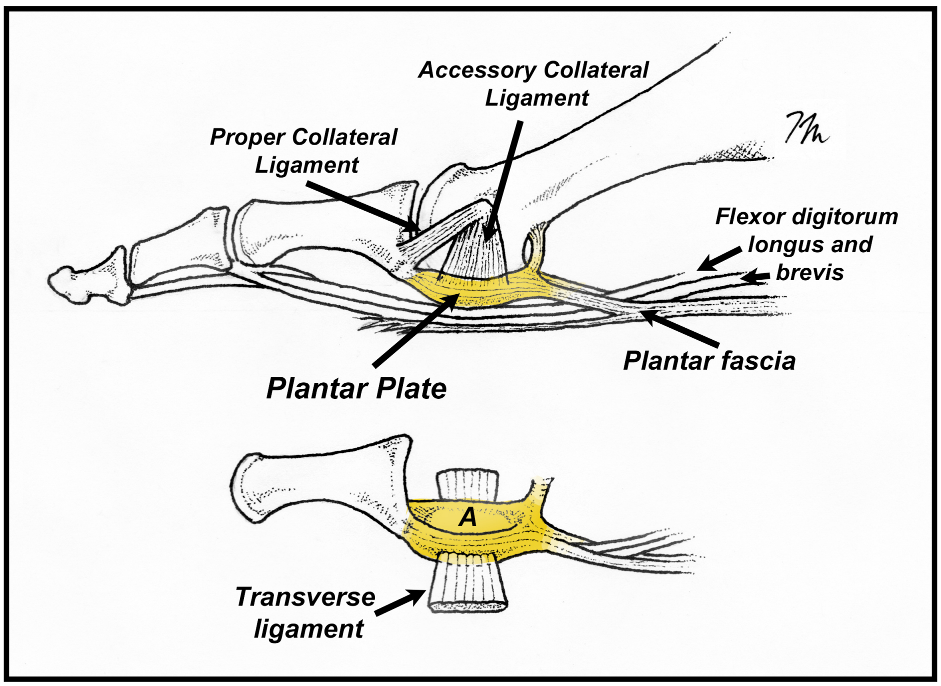


Fig. 1. The plantar plate originates from the distal metatarsal shaft and inserts into the base of the proximal phalanx. This fibrocartilaginous disk is an important stabilizer of the metatarsophalangeal joints as it receives fibrous reinforcements from the accessory collateral and transverse ligaments, and serves as the most substantial insertion for the distal plantar fascia. Histological studies show the upper fibers of the plantar plate are oriented longitudinally, while the lower fibers are oriented transversely, blending with the transverse ligaments. The longitudinal fibers resist tensile strains as the toes move upwardly during propulsion, pulling the toes down against the ground during propulsion. In contrast, the transversely oriented fibers prevent the toes from moving side-to-side when changing directions while walking and running.

Despite its strong stabilizing ligaments and powerful type I collagen fibers, injuries to the plantar plate are common and the plantar plate beneath the second metatarsal head is especially prone to injury. While the plantar plates can be injured secondary to trauma (usually a hyperdorsiflexion injury), there are various anatomical/biomechanical factors that increase the likelihood of injury. The most frequent biomechanical cause for plantar plate injury is an elongated second metatarsal (Fig. 2). This particular alignment pattern increases the compressive force centered beneath the second metatarsal head, which greatly increases the risk of plantar plate injury. Other biomechanical factors frequently associated with plantar plate injuries include hypermobile first rays, Morton's foot structure, and hammer toe deformities (1).

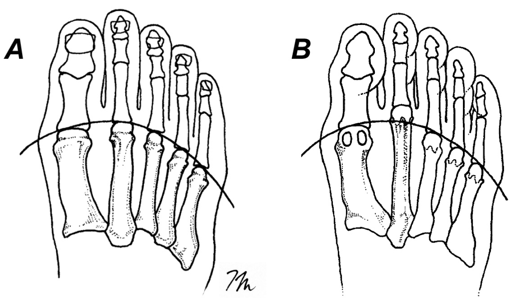


Fig. 2. An elongated second metatarsal. Ideally, the metatarsal heads are situated along the smooth parabolic curve illustrated in **A**. When the second metatarsal head projects beyond this curve (**B**), it is subject to tremendous force during the propulsive phase as the foot pivots from the lesser toes onto the big toe.

Plantar plate injuries can also be the result of limited ankle motion, as isolated contracture of the gastrocnemius produces an early heel lift that greatly increases the risk of forefoot injury. DiGiovanni et al. (2) demonstrate that people with less than 5° of ankle dorsiflexion are 3 times more likely to complain of pain in the forefoot/midfoot. Lastly, long-term use of high-heeled shoes increases the risk of plantar plate injury, explaining the higher prevalence in women (3).

Though rarely discussed as a possible etiological factor, toe weakness results in increased stress being placed on the central plantar plates. As demonstrated by Ferris et al. (4), the long toe muscles distribute pressure away from the second and third metatarsals onto the tips of the toes (Fig. 3).

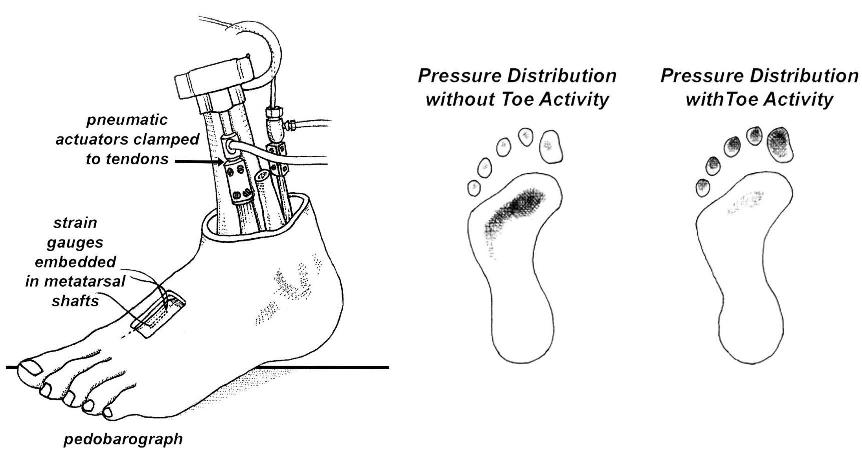
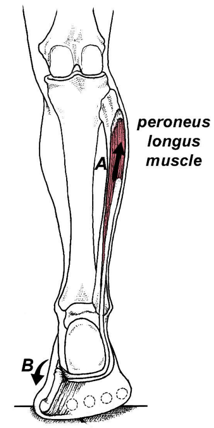


Fig. 3. By mounting cadaveric feet on a specially designed apparatus and measuring pressure beneath the forefoot with and without involvement of the toe muscles, Ferris et al. demonstrate that when the toe muscles are actively contracting, they redistribute pressure away from the metatarsal heads towards the tips of the toes. Toe weakness would cause a significant redistribution of pressure onto the central metatarsal heads, potentially perpetuating plantar plate injuries.

Additionally, a strong peroneus longus can also offload the central forefoot by transferring force to the first metatarsal head, which is twice as wide and 4 times as strong as the neighboring lesser metatarsals (Fig. 4). A thorough biomechanical examination should always include strength measurements beneath the greater and lesser toes and the medial forefoot using a toe strength dynamometer (Fig. 5). This device has proven reliability, which allows for accurate pre-and post-treatment assessment (5).

Fig. 4. Peroneus longus originates along the outside of the leg and attaches directly to the first metatarsal head. When this muscle contracts (**A**), it forcefully drives the first metatarsal head into the ground (**B**), which significantly offloads the second metatarsal head.



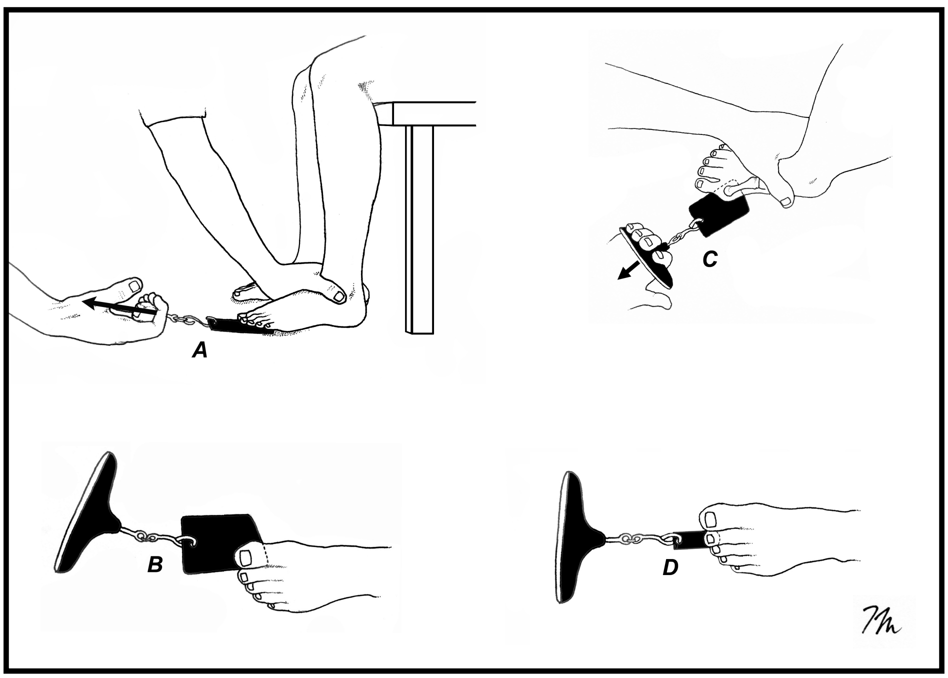


Fig. 5. Strength measurements using the Toe Strength Dynamometer. Strength beneath the lesser toes is measured by placing the dynamometer card beneath the second through fifth toes (**A**) and instructing the person to resist as the examiner slowly pulls out the card. Ideally, subjects will generate 7% of their body weight beneath these toes. The card is then moved beneath the big toe and the measurement is repeated (**B**). Most people can generate 10% of their body weight beneath this toe. Peroneus longus strength is measured by placing the card beneath the first metatarsal head (**C**) and people should generate 10% of their body weight with this test as well. When a plantar plate injury is present, it is important to measure strength beneath the involved toe (**D**), and it is not uncommon for a person to generate less than 2 or 3% body weight with this test. Because the dynamometer does not record scores less than 3 pounds, you have to look at the dynamometer while performing this test and record the highest number. Strength scores generated on the opposite side should be the target goal for rehabilitation.

Initial symptoms associated with plantar plate injuries include a mild aching beneath the metatarsal heads, which is often reported as a "bruised feeling." As the plantar plate injury worsens, the characteristic "crossover toe deformity" develops, and the involved toe becomes adducted and often hammered (arrow in Fig. 6). The most important diagnostic test confirming the presence of a plantar plate tear is the vertical stress test (Fig. 7), which has a sensitivity of 80.6% and a specificity of 99.8% for diagnosing plantar plate injuries (6).

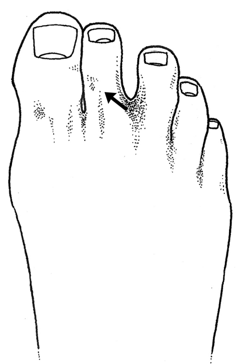


Fig. 6. Toe positions with a plantar plate rupture of the second metatarsophalangeal joint.

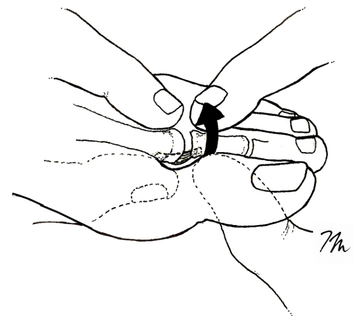


Fig. 7. Vertical stress test. While stabilizing the metatarsal head, the proximal phalanx is moved superiorly (**arrow**). Plantar plate laxity is present when the proximal phalanx can be displaced more than 2 mm.

Effective conservative management of a plantar plate injury involves minimizing tensile strain on the plantar plate during the healing process and addressing the biomechanical factors that contributed to its occurrence. The easiest way to reduce tension on the plantar plate is to incorporate a metatarsal pad and to add a modified Human Locomotion IDN Balance as illustrated in figure 8. The metatarsal pad elevates the neck of the metatarsal, distributing pressure away from the head, while the balance offloads the central metatarsal heads by transferring pressure to the medial forefoot and great toe. By lifting the metatarsal heads upward with the metatarsal pad and balance, the base of the toe moves down slightly, which approximates the plantar plate with its insertion. The metatarsal pad and balance should be worn in shoes possessing exaggerated toe springs, as an elevated toe spring reduces upward motion of the toes while walking and running (7) (Fig. 9).

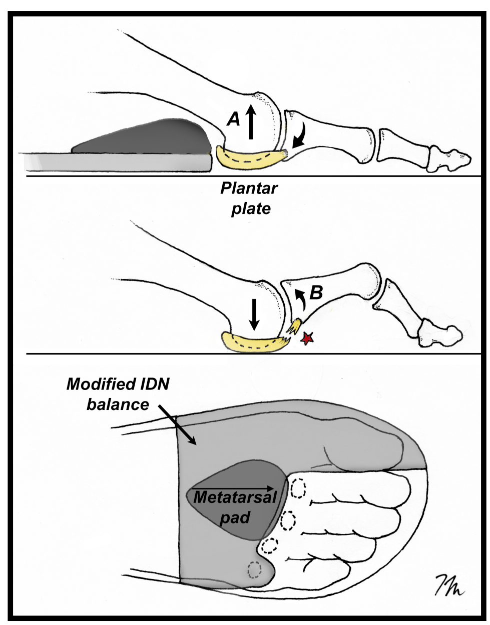


Fig. 8. The standard IDN balance, which is placed beneath the insole, is modified by cutting out the portion corresponding to the second toe so that only the big toe and the metatarsal heads are supported (light gray area). A metatarsal pad is then placed on top of the insole just behind the involved first metatarsal head. The combination of the IDN balance and metatarsal pad lift up the metatarsal head (**A**), allowing the base of the toe to move downward thereby reducing tension on the plantar plate. When the first metatarsal head is not supported, the toe moves upwardly (**B**), tractioning the plantar plate (**star**).

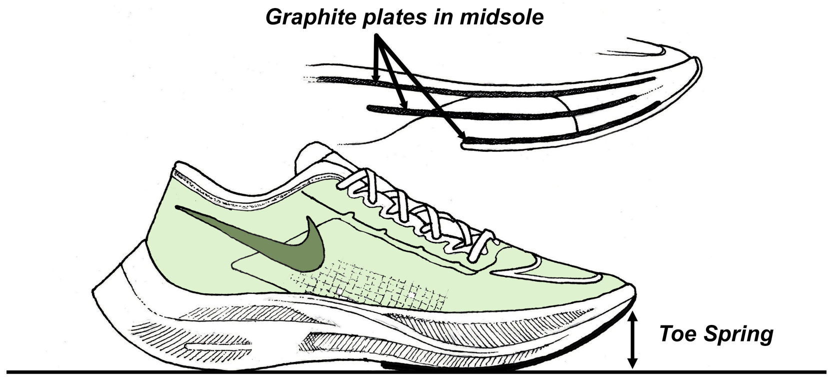


Fig. 9. The toe spring is an upward projection at the end of the running shoe that allows you to roll through the propulsive period with limited movement of your toes. Some of the modern running super shoes also possess graphite plates in their midsoles that also act to limit toe motion. Both of these components reduce strain on an injured plantar plate.

Individuals with substantially hammered toes should consider using the taping techniques illustrated in figure 10. Although effective at limiting upward motion of the proximal phalanx, these taping procedures are often relatively uncomfortable, and it is important to use a flexible tape and get feedback regarding tape placement. Taping is almost always more effective when combined with metatarsal pads (8).

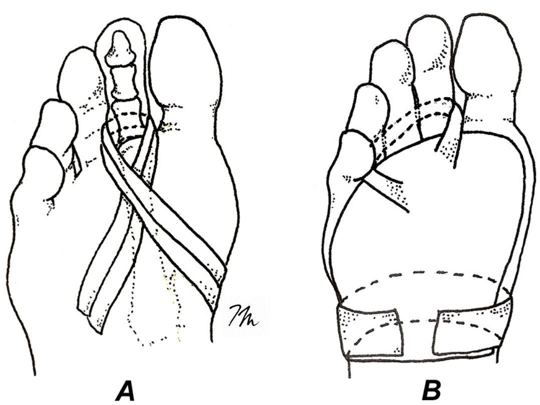


Fig. 10. Crossover taping techniques. In the presence of a plantar plate rupture, alignment of the proximal phalanx can be maintained by taping the top of the proximal phalanx. This can be done with tape alone (**A**), or with tape plus plantar cushioning (**B**). *Reproduced from Dilnot and Michaud (14).*

Within the first week or so following injury, gentle foot/ankle strengthening exercises should be encouraged, and a progressive strength training program is outlined in figure 11. To reduce strain on the plantar plates, it is important to limit upward motion of the toes to less than 20° while performing these exercises. Also, it is essential to specifically address the toe affected by the plantar plate tear, as this toe frequently exhibits significant weakness due to the cortical inhibition that is commonly linked with chronic pain. Studies show that exercising to the beat of a metronome, especially during isometric contractions, can reduce cortical inhibition and improve motor output (9,10). The exercises illustrated in figure 11 typically restore toe strength in 4-6 weeks and strength gains can be monitored with pre-and post-strength measurements using the plantar plate dynamometer card.

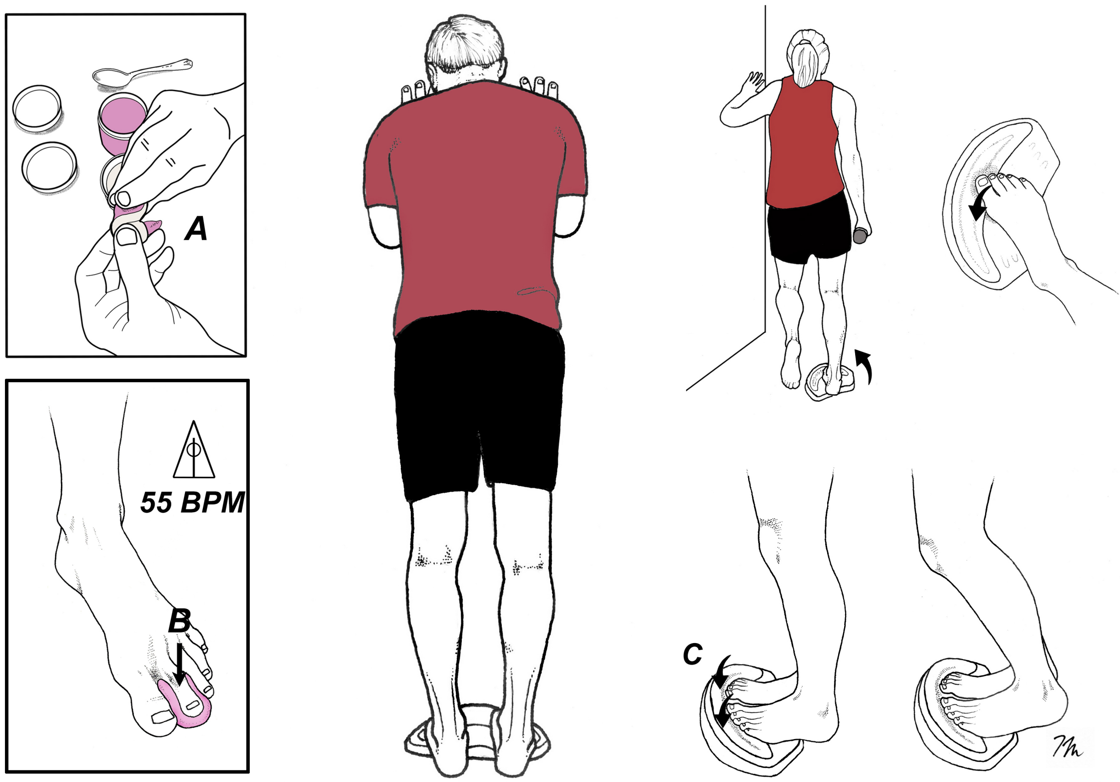


Fig. 11. Strength training program for managing plantar plate injuries. During the first 2 weeks, the exercises are extremely gentle and the joints of the feet are moved through a very limited range of motion. The affected toe is exercised by building a small platform made of *Bunion Putty* (or any soft foam) and placing it beneath the involved toe (**A**). Before the silicone compound dries, it is placed beneath the involved toe allowing it to form into all the nooks and crannies of that toe. This stabilizes the toe while performing the exercise. The exercise consists of pushing the entire toe down into the silicone platform, timing these pulse-like movements to the beat of a metronome set at 55 bpm (**B**). 4 sets of 25 repetitions are performed daily, 5 times per week. After completing the final set, a standing exercise is performed by placing the tips of your toes in the uppermost crest of a ToePro, and forcefully pushing your toes downward to the beat of the metronome. Note that the heels do not rise above horizontal during this movement, as the exercise consists primarily of driving the toes down into the foam (**C**). 2 sets of 15 repetitions are performed with the knees straight, and 2 sets are performed with the knees bent. Lastly, to exercise peroneus longus, rotate the ToePro so the first metatarsal head is supported at the base of the crest and the big toe rests comfortably in the center of the crest (**D**). Next, lean sidewards into a wall and do 2 sets of 15 repetitions, driving your inner forefoot and big toe into the foam. As you get stronger, you can hold a weight in the hand opposite the wall to increase resistance. This exercise is great for offloading the second and third plantar plates, as a strong peroneus longus distributes pressure away from the central forefoot onto the first metatarsal head.

Last but not least, isolated contracture of the medial gastrocnemius must be addressed, as the premature heel lift associated with this condition drives the central forefoot into the ground perpetuating the plantar plate injury. Individuals with less than 5° dorsiflexion should consider using the hold/relax stretches illustrated in figure 12, which very effectively increase both ankle range of motion and tendon resiliency (11). Extremely tight individuals should also consider using focal muscle vibration over the medial gastrocnemius while performing straight leg calf stretches. Focal muscle has been proven to increase range of motion without negatively altering force output (12). The best outcomes occur when holding stretches for a minimum of 45 seconds and repeating these stretches at least 5 times per day (13). Gait changes should also be recommended, and people with plantar plate injuries should be encouraged to walk and run with shorter stride lengths until the injury has healed. They should also practice forcefully pushing down with their big toes during the propulsive phase of gait for at least 5 minutes daily, as this creates a motor engram that teaches the toe muscles to offload the central forefoot. Should conservative treatment fail, various surgical options exist, including the Weil osteotomy, and/or direct reconstruction of the plantar plate. Although these procedures have proven efficacy and good long-term outcomes, they are rarely necessary as the vast majority of people with plantar plate injuries respond to conservative care.

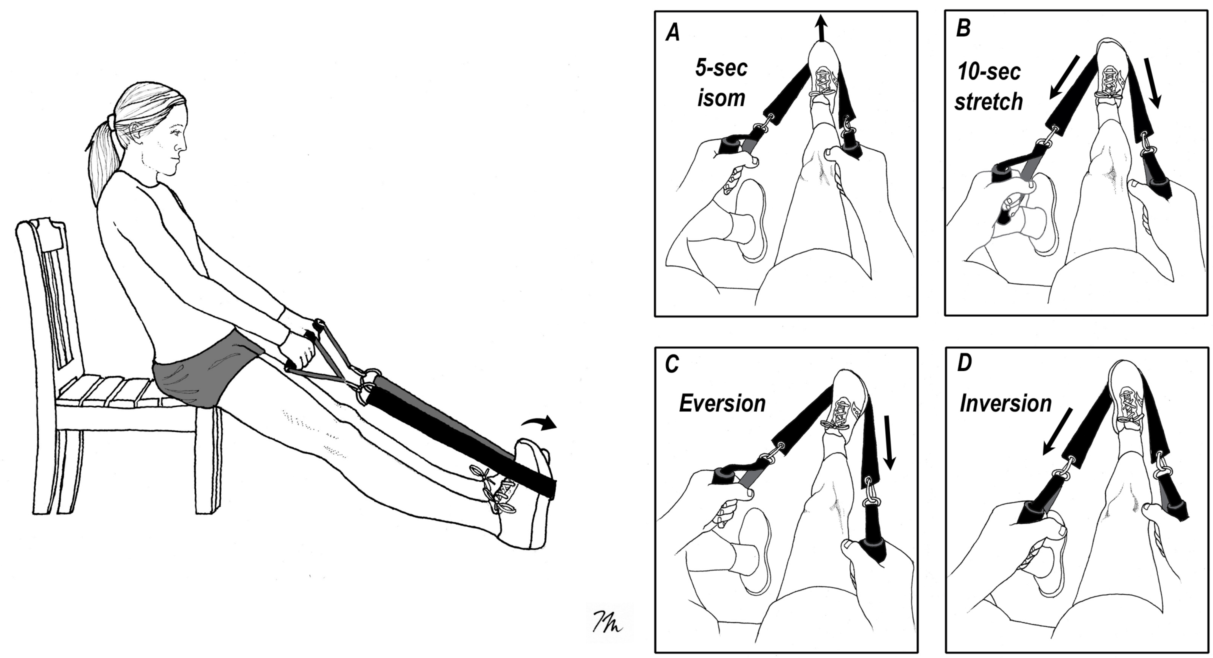


Fig. 12. Neutral position stretching to increase ankle range of motion. Place your ankle at a 90° angle to your leg and isometrically tense your calf by pushing into the strap with light resistance for 5 seconds (**A**). Follow the 5-second contraction with a 10-second stretch by pulling back with your hands (**B**). Repeat this 2 times and do your next 5-second isometric contraction with the foot slightly everted (**C**). Follow the contraction with a 10-second stretch keeping the foot everted (**arrow**). Lastly, perform a 5-second isometric contraction with the ankle inverted and finish by stretching in this position for an additional 10 seconds (**D**).

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