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**A PRACTICAL APPROACH TO PROBLEM-SOLVING MOVEMENT TASKS LIMITED BY AN ANKLE DORSIFLEXION RESTRICTION**

**ABSTRACT**

Limitations in ankle dorsiflexion range of motion have been shown to increase compensatory movements at both proximal and distal joint segments in the lower extremity. This article discusses methods to assess and correct deficiencies in ankle dorsiflexion range of motion. Previously, however, the removal of joint restrictions has not been shown to reduce compensatory strategies developed through such restrictions. Therefore, this article will also discuss important considerations for facilitating the relearning process and propose key principles for developing a corrective program.

**INTRODUCTION**

During high load activities, failure to control joint segments has the potential to result in excessive loading of both active and passive structures, with injury being a possible outcome (20). Poor movement quality during dynamic activities may be caused by reduced movement control from a stability perspective, whereby suboptimal muscle activation strategies lead to compensatory movements at joints being loaded, resulting in the poor transfer of forces across joint segments (22). Another cause for compensatory movement strategies is joint hypomobility (12, 35, 36), where joint restrictions reduce movement options for the performer, leading to a suboptimal approach to solving a movement challenge.

During dynamic tasks such as squatting (28), jumping (12) and running (46), ankle dorsiflexion is a natural strategy used by athletes in order to manipulate the location of the centre of mass and dissipate load in preparation for propulsion. These activities vary in their demands for ankle dorsiflexion range of motion (ROM), with approximately 10° required for walking, increasing to 30° for running (46).

A reduction in ankle dorsiflexion ROM has been identified as a risk factor for numerous injuries. In the lower leg, limited ankle ROM is a risk factor for the development of plantar fasciitis (29), tibial stress syndrome, ankle sprains and Achilles tendinopathy (48). More proximally, restrictions in ankle joint ROM have been related to the occurrence of hamstring strains (13), iliotibial band syndrome (38), anterior knee pain (39) and patella tendinopathy (1).

Although the exact mechanism through which a restriction in ankle dorsiflexion ROM increases the risk of lower extremity injuries is at present unclear, researchers have identified a number of dysfunctional movement patterns that are developed as a consequence of joint hypomobility. Limitations in ankle dorsiflexion ROM have been shown to result in greater peak vertical ground reaction forces, secondary to reduced peak knee flexion angles during landing tasks (12). This jarring strategy is likely adopted due to reduced ankle dorsiflexion ROM limiting the angular displacement of the proximal tibia, thereby inhibiting knee flexion from occurring (12). During movements such as squatting, reduced ankle dorsiflexion ROM also prevents knee flexion (34).

Another compensatory strategy that can be attributed to limitations in ankle dorsiflexion ROM during dynamic tasks is a dynamic knee valgus (35, 47). This strategy has the potential to allow an athlete to continue the angular displacement of the tibia by excessively pronating at the foot complex (27). As a compensation for ankle hypomobility, pronation at the foot unlocks the midtarsal complex, resulting in the talonavicular and calcaneocuboid joints becoming structurally less congruent (27). However, pronation at the foot complex is coupled with tibial internal rotation, facilitating a knee valgus (49). With knee valgus during athletic type activities placing excessive stress on passive structures, such as the anterior cruciate ligament (20), limitations in ankle dorsiflexion ROM may be a risk factor for this type of injury (35, 58).

It has previously been suggested that the hip musculature plays a crucial role in preventing malalignment of the lower extremity during weight-bearing activities, by preventing the hip internal rotation and adduction associated with a dynamic knee valgus (22). When considering the efficiency of these muscles in their ability to stabilize the lower extremity during weight bearing tasks, limitations in ankle dorsiflexion ROM have been shown to alter the co-contraction patterns for key hip musculature in people with suboptimal movement strategies (36). Therefore, a restriction in ankle dorsiflexion ROM has the potential capacity to determine the movement strategies at proximal joint segments, resulting in modified muscle activation strategies. In this case, interventions aimed at improving hip muscle activity during squatting and jumping tasks may prove futile until ankle dorsiflexion ROM is improved.

This article presents strategies and techniques that allow the strength and conditioning (S&C) professionals to identify limitations in ankle ROM and design tailored interventions in order to improve ankle mobility for their athletes. This is followed by a discussion on strategies that may be employed to improve movement patterns in the lower extremity where inefficient compensations exist due to ankle joint restrictions.

**ASSESSING ANKLE DORSIFLEXION RANGE OF MOTION**

During bodyweight squatting, reduced squat depth has been shown to strongly correlate with ankle dorsiflexion ROM (10, 28, 52). Therefore, athletes who are limited in their ability to achieve sufficient depth in the squat pattern should be identified as potentially possessing a limitation in ankle joint ROM. A strategy to confirm that limitations in ankle dorsiflexion ROM are the primary cause for reduced squat depth can be accomplished by manipulating task demands through changes in arm position. Rabin and Kozol (52) showed that athletes who possessed insufficient squat depth with the arms in an overhead position had reduced dorsiflexion ROM at the ankle. This study demonstrated that the overhead squat, scored in real-time, had greater sensitivity (1.00) for identifying individuals with ankle dorsiflexion restrictions when compared to the forward arm squat alternative (0.56-0.70) (52). Therefore, if limitations in squat depth are identified in the traditional bodyweight squat, with the arms in front of the body but the depth decreases when the arms are placed in the overhead position, then ankle dorsiflexion ROM is likely to be the limiting factor and further assessment is required (52).

Whilst investigating the hypothesis that ankle dorsiflexion restriction is contributing to reduced squat depth, isolated testing for ankle dorsiflexion ROM can be performed. Although both non-weight-bearing and weight-bearing methods can be employed, the relationship between the two methods is poor (r2=0.18) (63). It has, therefore, been suggested that non-weight-bearing methods underestimate the ankle joints ROM capacity (63). As many S&C professionals are interested in the ankle joint’s ability to dorsiflex in a loaded closed-chain environment, weight-bearing tests are recommended over their non-weight-bearing counterpart.

The weight-bearing lunge test (WBLT) provides practitioners with a tool to measure ankle dorsiflexion ROM with the knee flexed in a closed chain task (Figure 1) (2). Although the WBLT fails to assess gastrocnemius extensibility due to the knee being flexed (26), it does identify ankle dorsiflexion ROM in positions similar to that of squatting and jumping (10) and therefore, may be more representative of the demands for ankle motion required for these type of activities. The performance of this test can be measured using a number of different methods; tape measure to record the distance between the big toe or heel from the wall, a digital inclinometer placed at the tibial tuberosity, or a goniometer aligned with the floor and the shaft of the fibula (30). Konor et al. (30) showed ‘good’ reliability for the toe-to-wall distance (ICC=right 0.98; left 0.99), digital inclinometer (ICC=right 0.96; left 0.97) and goniometer (ICC=right 0.85; left 0.96) procedures. Standard error of measurement, representing the absolute measurement error, for each technique was 0.4-0.6 cm for the toe-to-wall distance, 1.3-1.4° and 1.8-2.9° for the digital inclinometer and goniometer technique, respectively (30). As the SEM for each technique investigated is relatively low, S&C professionals should be confident that changes in the WBLT score outside of this range following an appropriate intervention is not due to error in the measurement technique used (30). The findings are similar to other investigations establishing the clinometric properties of the WBLT (2, 26, 60).

\*INSERT FIGURE 1 HERE\*

Unfortunately, methods used to measure ankle dorsiflexion ROM in degrees usually require specialized equipment that may not be available to S&C professionals. Recently, Langarika-Rocafort et al. (32) investigated the reliability of a trigonometric technique that provided ankle dorsiflexion capacity in degrees using only a tape measure. This technique requires the athlete to perform the WBLT to just before the point where the heel lifts from the ground whilst the knee contacts the wall. Using the heel-to-wall and knee-to-ground distance, practitioners can calculate the ankle dorsiflexion angle through basic trigonometry (ankle dorsiflexion ROM = 90- arctangent(KG/HW)) (32). This method was shown to possess higher reliability (ICC=0.95 vs. 0.87) and a lower standard error of measurement (1.18° vs. 2.17°) when compared to measuring ankle dorsiflexion ROM with an inclinometer on the tibial shaft (32).

The commonly used technique of measuring toe-to-wall distance, whilst reliable, prevents comparison between participants due to variation in foot length (32). A simple solution for this issue is to measure the heel-wall distance, which does not account for variation in foot length and provides a reliable score (ICC = 0.95) that may represent ankle dorsiflexion capacity and used to compare participants in order to identify individuals with restrictions in motion (32). The limitation to this method, at present, is that little normative data exists, which would provide the S&C practitioner with the necessary information to conduct an accurate gap analysis. Table 1 presents normative values for each WBLT measurement technique.

\*INSERT TABLE 1 HERE\*

Regardless of the method used to measure ankle dorsiflexion ROM during the WBLT, S&C professionals must attempt to maintain consistency by employing the same technique within the similar conditions in order to obtain a reliable measure. This should account for the time of day, activities performed prior to assessment and inter-rater reliability if different investigators are being used to measure ankle dorsiflexion ROM during the WBLT. By doing so, practitioners should be able to detect genuine changes in ankle dorsiflexion ROM following intervention through implementing robust and repeatable procedures and analyzing the data with the appropriate analytical techniques (see reference 59).

**IMPROVING ANKLE DORSIFLEXION RANGE OF MOTION**

Methods to improve ankle dorsiflexion ROM can be divided into two main categories; myofascial or joint mobility restrictions (23). Myofascial restrictions involve limitations in the extensibility of the muscles that surround the ankle joint and their related fascial components. The ankle plantar flexors, being primarily the gastrocnemius and soleus, are the likely causes for myofascial restrictions (26).

Numerous techniques exist for increasing gastrocnemius and soleus extensibility. Active and passive stretching of the plantar flexors is the most commonly used technique (14, 15, 26, 53). For the soleus muscle, this can be accomplished with a dorsiflexed position at the ankle whilst keeping the knee relatively flexed in order to relieve tension on the gastrocnemius muscle (see Figure 2a) (5). The gastrocnemius may be preferentially stretched by using a similar technique but with the knee extended (see Figure 2b) (26). As dorsiflexion during the weight acceptance phase of a landing occurs concurrently with knee flexion (12), improving soleus flexibility is likely more valuable as the gastrocnemius is less capable of limiting ankle dorsiflexion ROM when the knee is flexed due to its attachment on the femoral condyles (45).

\*INSERT FIGURE 2 HERE\*

In order to increase the extensibility of the plantar flexor musculature acutely with static stretching, Nakamura et al. (42) showed that the total time stretching should be > 2 min. Following a four-week intervention using 2 min of plantar flexor static stretching performed 3 times per week, significant increases in ankle dorsiflexion ROM can be established (44). Regarding the stretching method employed, Nakamura et al. (43) showed that both static stretching and proprioceptive neuromuscular facilitation increased dorsiflexion ROM equally, as long as the time spent stretching lasted a total of 2 min. Therefore, S&C professionals have numerous options for prescribing flexibility training for the plantar flexors.

Another potential strategy for the S&C professional is to employ self-massage techniques using tools such as a roller massager. Self-massage has been shown to acutely increase (effect size = 0.26) weight-bearing lunge test scores measured to the same degree as a static stretching routine (effect size = 0.27), matched for time (19). However, muscle force output of the plantar flexors was reduced following static stretching compared to the self-massage technique (effect size = 1.23, mean difference = 8.2%) (19). Thus, to increase ankle dorsiflexion ROM prior to training or competition, self-massage may be an alternative option. Figure 3 shows the self-massage technique used by Halperin et al. (19). For this investigation, increases in ankle dorsiflexion ROM where found by employing a cadence of one-second to roll the length of the calf in a proximal-to-distal direction, with a single set lasting 30-seconds (19). Three sets were performed, with an intensity of 7 out of 10 using the rate of perceived pain scale (19).

\*INSERT FIGURE 3 HERE\*

Joint mobility restrictions may also limit ankle dorsiflexion ROM. Ankle dorsiflexion ROM increases following manual joint mobilisation in both previously injured (4, 9, 16) and healthy populations (18, 24). However, the mechanisms to explain why joint mobilization increases ankle ROM are unclear (31). Mulligan (41) suggested that the limited ability of the talus to posteriorly glide relative to the tibia and fibula reduces ankle dorsiflexion ROM, secondary to a disruption in joint arthrokinematics. This is supported by evidence that talar positional faults are common among people with chronic ankle instability (64), with studies investigating the impact of joint mobilizations showing increased posterior talar glide following treatment (62).

Although hands-on manual therapy is outside the remit of the S&C professional, self-mobilization is recommended for athletes with limited ankle dorsiflexion ROM (7). In support of this recommendation, Jeon et al. (25) showed that a self-stretching technique using a strap positioned to improve the posterior glide of the talus while concurrently stretching the plantar flexor musculature, significantly increased dorsiflexion ROM following a 3-week intervention. Although arthrokinematic changes following the intervention were not measured, differences in ROM during the WBLT were greater in the group performing self-stretching with a strap (effect size = 0.85, mean difference = 5.08°) when compared to a static stretching only group (effect size = 0.30, mean difference = 1.27°). Therefore, mobilization of the ankle joint can be achieved by using the self-mobilization technique demonstrated in Figure 4.

\*INSERT FIGURE 4 HERE\*

When determining which technique to employ, practitioners are advised to use a practical approach in order to select an appropriate intervention (23). By performing the WBLT, then an intervention, followed by the WBLT, S&C professionals will be able to determine whether a myofascial or joint mobility based intervention is most appropriate for increasing ankle dorsiflexion ROM. For example, when greater increases in ankle mobility are found following the application of myofascial techniques (i.e. stretching or self-massage), it is likely a restriction of the muscle-tendon unit. However, if greater success is found with mobilisation of the talus relative to the distal tibia and fibula, self-mobilizations are recommended.

This may be confirmed by gathering subjective information from the athlete. When performing the WBLT, if the athlete reports of ‘tightness’ in the posterior aspect of the lower leg, limited extensibility of the gastroc-soleus complex is likely. However, if the athlete describes a ‘pinching’ at the anterior aspect of the talocrural joint, anterior impingement may be occurring, indicating a requirement for self-mobilization (7). Practitioners can use the same test-retest approach to identify the ideal acute variables and frequency for application in order to establish the suitability of the intervention. From this perspective, S&C practitioners will be able to individualize their corrective programme for each athlete to restore ankle joint function.

**INTEGRATING ANKLE DORSIFLEXION STRATEGIES INTO DYNAMIC SKILLS**

When an athlete presents with limited ankle dorsiflexion ROM, it is likely that they will also present with distal and proximal compensatory movements in order to maintain function within a number of athletic activities (10, 34, 36, 47). To improve an athlete’s movement quality, the removal of any joint restriction does not seem to result in an immediate alteration of the athlete’s preferred movement strategy (24, 40). Therefore, interventions to remove ROM restrictions should be complemented with movement coaching that encourages the integration of dorsiflexion ROM into functional patterns, negating the need for compensatory strategies.

In some instances, an athlete may perform a movement pattern such as the squat, utilizing insignificant amounts of ankle dorsiflexion ROM with obvious compensatory strategies. This may lead the S&C professional to hypothesize an ankle dorsiflexion restriction exists and is the primary cause. However, on an isolated assessment such as the WBLT, enough ankle dorsiflexion ROM may be available for the athlete to complete the desired movement task. In this instance, a motor control dysfunction is likely present, that inhibits the athlete from utilizing their available ankle dorsiflexion ROM (23). For this athlete, an intervention aimed at increasing ankle ROM will likely provide negligible changes to their squat pattern, as a mobility restriction is not the primary driver for their compensatory strategies. In this scenario, the athlete should engage with a neuromuscular relearning process that will teach them to incorporate their available ROM into their strategies for athletic movement tasks (23).

Within dynamic systems theory, the athlete is regarded as a complex system, where numerous systems are constantly interacting to form a movement output (8). Through the interaction of all relevant systems within the existing constraints of the movement, the athlete self-organizes their coordination in order to fulfil a movement objective (8). The emergence of movement patterns occurs under constraints provided by the characteristics of the organism/athlete (e.g. force development capabilities), the task they are performing (e.g. jumping) and the environment they are operating within (e.g. Newton’s laws of motion). Figure 5 provides an example of relevant constraints that exist within a bilateral landing task.

\*INSERT FIGURE 5 HERE\*

As an organismic constraint, the emergence of a movement pattern will be partly determined by the athlete’s current physical status. Mobility restrictions, in the context of a limitation at the ankle complex, present as an organismic constraint that demands a compensatory strategy be developed during numerous athletic activities in order to fulfil the movement goal. Once the mobility constraint decays following the application of the appropriate intervention (i.e. stretching), the athlete is provided with an additional degree of freedom that they must learn to utilize as part of their movement strategies during closed chain lower extremity activities.

In developing an athlete’s movement proficiency, S&C professionals should adopt a multifaceted approach so to develop the necessary physical qualities along with providing the athlete with an environment that offers affordances and encourages opportunities for self-organization in relevant movement tasks. When appreciating the influence of organismic constraints on movement patterns, the development of strength qualities in the musculature of the lower extremity is vitally important in order to allow the athlete to transition into a new coordination pattern for dissipating forces during dynamic tasks such as landing from a jump. The S&C professional must therefore prioritize the athlete’s physical preparation, while concomitantly supporting the process of developing better movement strategies through appropriate manipulation of task and environmental constraints. This method of manipulating the organismic, task and/or environmental constraints to promote the development efficient movement patterns, underpins the constraints-led approach to motor learning.

In contrast to the proposals outlined by scientists advocating a constraints-led approach to motor learning which is underpinned by principles of ecological psychology and dynamical systems theory, traditional approaches to movement coaching involve the practitioner providing athletes with a high volume of technical instructions. However, such methods have been criticised for advocating a perfect technical model which fails to recognise an individual’s unique organismic constraints and how this might affect their coordination tendencies in finding solutions to movement based problems. Furthermore, learners receiving a high volume of technical instructions have poorer retention of skills over time, especially when performing under pressure (33, 37).

In the context of modifying suboptimal movement patterns, designing a learning environment that manipulates constraints, offers opportunities for self-organization on the part of the athlete, as they are encouraged to explore their perceptual-motor workspace, while both coach and athlete have less reliance on technical “rules”. The use of analogies from the S&C professional could provide a useful task constraint to guide the athlete, whilst allowing them freedom to explore and discover the most appropriate movement solution to satisfy this. Critically, this allows the athlete the freedom to interact with their environment while performing specific movement tasks that encourage the athlete to discover movement patterns that are effective in achieving the desired outcome (8). A basic example of this for teaching an athlete to incorporate ankle dorsiflexion ROM into their squat pattern is asking the athlete to “*sit down onto the centre of the box like they’re getting in and out of a chair*”. Initially, the box may be located a small distance from their feet (Figure 6A), requiring only a moderate amount of ankle dorsiflexion ROM. To progress the exercise and allow the athlete to search their available movement options whilst problem-solving the task, the box may be moved forwards so it is located directly behind their feet (Figure 6B). Now, ankle dorsiflexion is a necessity for success in the task.

\*INSERT FIGURE 6 HERE\*

The progression of exercises should be logically sequenced to support the athlete in modifying their movement behaviors towards strategies that preserve tissue health. Basic principles are centred on optimizing the mechanical loading of the lower extremity, as well as the athlete’s ability to achieve some levels of success in the movement task they are presented with. Velocity of movement, the forces the task requires, the level of predictability of the movement and the perceived risk are all variables that may be considered for progression in the corrective program (21).

In developing a sequential progression of exercises under varying constraints, the ultimate outcome should provide the S&C professional with the context to select exercises for each stage of the corrective program. For example, if an athlete presents with poor single-leg landing mechanics secondary to a dorsiflexion restriction, each phase of the program should include landing tasks that require some contribution of concurrent flexion at the hip, knee and ankle joints to decelerate the downward acceleration of their COM. This provides the program with the element of specificity required for the learning process to be optimized (51).

In the initial stages of the corrective program, co-contraction of the mobilized joint segment may potentially restrict motion as the athlete lacks the necessary skill to use their available ROM (57, 61). This has been demonstrated during squatting, with higher activation of the anterior and posterior ankle musculature being identified in participants with limited ankle dorsiflexion ROM (47). As such, excessive muscle co-contraction of the agonist and antagonist muscles has the potential to inhibit ankle joint motion by causing a bracing effect at the talocrural joint complex. Therefore, techniques should be employed that promote ankle dorsiflexion ROM in integrated patterns by reducing co-contraction around the ankle joint. Providing the athlete with whole body stability during closed chain lower extremity movements can decrease co-contraction of the ankle musculature (50). For an athlete with a suboptimal squat pattern, an example movement that may develop the squat pattern while increasing whole body stability would be the pole squat exercise. Here, the athlete lowers and raises their COM vertically, imitating the general joint positions observed during squatting, while maintaining four points of contact with their environment resulting in an increase in the base of support (i.e. both hands on the fixed pole and both feet with the ground). Progression would involve the gradual reduction in the athlete’s base of support, while maintaining a certain level of success to challenge the athlete to ensure motor learning is occurring. For landing tasks, this can be accomplished by moving from a double-leg to a single-leg landing.

Table 2 provides an example of exercise progressions for an athlete to integrate an ankle dorsiflexion strategy into their squat and single-leg landing pattern. This is accomplished by altering the demands of the tasks by manipulating the constraints associated with the pattern. For example, during the bilateral landing from the low box, minimal ankle dorsiflexion ROM would likely be needed as the dissipation of forces will be relatively low. The demands for ankle dorsiflexion ROM are increased via adding load (i.e. adding external load or moving to a single-leg task), increasing the time constraints to dissipate forces (i.e. landing from a higher box), moving the arms to the overhead position to increase ankle dorsiflexion demands, and varying the surface properties to alter the muscle co-contraction patterns whilst encouraging an ankle dorsiflexion strategy. This results in the athlete attempting to solve the movement problem presented to them under varying constraints, while preserving the health of their structural system. This encourages the athlete to self-organize within the task, leading to the emergence of new patterns that may be used to problem-solve movements in the athletic environment whilst incorporating an ankle dorsiflexion strategy.

\*INSERT TABLE 2 HERE\*

Although the exercises in Table 2 present a prescriptive approach to corrective programming, it is important to appreciate the individuality of each athlete when designing learning environments that facilitate the development of optimal movement patterns. Crucially, practitioners should tailor their approach to planning activities and the allocation of time spent on any modality that may improve the athlete’s movement, based on the individual that presents to them. This is done to allow the athlete the opportunity to experiment with different movement solutions and discover their way of satisfying the goals of the task under the constraints that are present. As such, S&C professionals may need to employ a relaxed approach to the prescription of acute exercise variables such as sets and repetitions. Instead, the practitioner should attempt to allow the process itself to determine such considerations and base the decisions on the success the athlete achieves in the session. For example, an athlete that is repeatedly successful after on a few attempts of a movement task may require less volume than an athlete who struggles to find an optimal movement solution.

In order facilitate the movement education process, the athlete should be provided with a rich and diverse learning experience (54). This can be achieved by offering the athlete variety in the movement patterns they are exposed to as part of their program. By doing so, the athlete’s movement library is expanded as they learn to solve numerous movement problems whilst incorporating ankle dorsiflexion into their strategy. This occurs as the athlete is encouraged to explore their available movement options in order to perform different variations of a task (55). This approach of adding variability to the learning process has been termed Differential Learning by Schöllhorn et al. (55), and aligns with Bernstein’s principle of ‘repetition without repetition’ (3).

At the foundational level of the process, this may start with constant adjustments in foot position as an athlete performs a squat, progressing to more creative movement tasks, such as squatting under hurdles of various heights with different angles of approach whilst moving across different surface types. Further progression may involve creative games that further remove the conscious element for controlling the movement, while increasing the exposure to movement variability through the manipulation of constraints (54). Such strategies are vital for allowing the athlete to develop adaptable and functional movement patterns that prepare them for the chaos of sport (54).

Compensatory movement strategies that have been developed secondary to restrictions in ankle dorsiflexion also require attention. Athletes must learn to subconsciously control these aberrant kinematic compensations, whilst favouring ankle dorsiflexion strategies that provide superior dissipation of forces during dynamic tasks (12). Using a constraints-based approach to promoting the emergence of behaviours through the process of self-organization, S&C professionals can employ Reactive Neuromuscular Training methods to drive an unconscious neuromuscular response that functions to decrease compensations (6). This technique purposely provides a perturbation that stimulates a neuromuscular response to prevent the deterioration of movement patterns (6). This technique results in the disruption of the athlete’s usual strategy comprising compensations, forcing the athlete to adapt to these perturbations and develop robust and stable movement patterns. With careful manipulation of the task or environment, a full ROM ankle dorsiflexion strategy can be encouraged to manage the movement problem. This controlled disruption of movement has been suggested as a fundamental tool for promoting the reorganization of the athlete’s movement patterns (54).

Practically, if an athlete presented with a dynamic knee valgus as a compensation for limited ankle dorsiflexion ROM during a squatting task, the coach could use mini bands to further increase the knee valgus moment (6). This technique would potentially provide the athlete’s central nervous stimulus with a strong stimulus for a stabilization response (6), resulting in the athlete resisting the pull of the band by activating the gluteal musculature to a higher degree in order to preserve the health of the movement system (11). Further perturbation of the athlete can be achieved with strategic and unexpected ‘nudges’ from the S&C professional as the athlete performs the squat. This may further inform the athlete as to the effectiveness of the movement pattern they have adopted and provide them with another opportunity for them to develop a more robust pattern. This example reduces the need for prescriptive instructions, but instead sets a clear goal while applying constraints that encourage the athlete to search for an effective strategy using sagittal plane ankle, knee and hip motion in closed chain activities. Using a trial and error approach, the development of different techniques to implicitly reduce compensations is limited only by the S&C professional’s imagination.

Finally, feedback should also be carefully considered when designing a learning experience for the athlete. As movement efficiency is reduced with internally focused cues (67), and learning occurs to a higher degree with externally focused cues (66), the S&C professional must be careful to provide appropriate feedback that supports the desired outcome. This should be considered alongside the frequency of feedback (17) and the amount of feedback (65) provided to the athlete, as well as other strategies that support the process such as observational learning (56). The interested S&C professional is advised to read Wulf et al. (68) for further information on these topics.

**CONCLUSION**

This article has presented tools for the S&C professional that will allow them to effectively assess ankle dorsiflexion ROM restrictions in their athletes. Furthermore, this article has discussed methods to improve ankle dorsiflexion through modifying the surrounding myofascial structures and improving joint mobility with stretching, self-massage and self-mobilization techniques. As sufficient ankle dorsiflexion ROM is achieved, it is vital that practitioners design corrective training programs that teach the athlete to incorporate their newly developed ROM. This can be accomplished with a constraints-based approach to motor learning. Here, it is suggested that the S&C professional provides a careful progression of exercises through manipulation of task, environmental and organismic constraints that offer opportunities for action and support the self-organization processes of the athlete.

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**Table 1.** Normative values within healthy populations for the WBLT using the various measurement techniques.

**Table 2.** Exercise progression for improving squatting and landing mechanics using a constraints based approach to varying the demands for ankle dorsiflexion ROM.

**Figure 1.** Weight-bearing lunge test. The athlete stands facing a wall, with the tested foot positioned closest to the wall. The second toe, centre of the calcaneus and centre of the patella are all aligned perpendicular to the wall and remain within this plane throughout the test. The athlete positions their non-testing leg behind them so to not obscure the result, with the hands placed on the wall ahead. The athlete lunges forward until the front knee contacts the wall. The heel must remain in contact with the floor throughout. Upon successful completion, the athlete repositions their test leg 1 centimetre further away from the wall. TW = toe-to-wall distance; HW = heel-to-wall distance; KG = knee-to-ground distance.

**Figure 2.** Example stretches for the (a) soleus and (b) gastrocnemius musculature.

**Figure 3.** Example of self-massage technique for increasing ankle dorsiflexion ROM.

**Figure 4.** Example of self-mobilization technique for increasing ankle dorsiflexion ROM. Note the band is placed inferior to the lateral and medial malleoli, on the anterior aspect of the talus to produce a posterior pulling-force.

**Figure 5.** Classification of the constraints that provide the foundation for the development of coordination patterns that an athlete presents with for any given movement (8). Example constraints examples for a bilateral landing are also shown.

**Figure 6.** Example of manipulating constraints to alter the demands for ankle dorsiflexion ROM; (a) the center of the box is positioned several inches posterior to the athlete’s base of support, resulting in a relatively small requirement for ankle dorsiflexion ROM during the squat; (b) by moving the box closer to athlete’s base of support, there is a greater demand for ankle dorsiflexion ROM in enabling the athlete to lower their center of mass to the center of the box.