Dorsiflexion (DF) in Elite Soccer Players:

Change of dynamic/static dorsiflexion range of motion over the course of a season and dorsiflexion's relationship with training load & top speed.

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Soccer is one of the most demanding sports in terms of time spent constantly moving, so demanding that during matches players spend less than 6% of their time stationary (Bradley, et al., 2009). During the 94% of time players aren't stationary, they spend it covering serious ground. It has been found that within the span of one match players cover an average of 6.2 to 6.5 miles. Out of those 6.5 miles players will utilize an explosive sprint up to 58 times, resulting in just under a half mile of pure maximal sprinting (Bradley, et al., 2009) (Burgess, Naughton, & Norton, 2006). Within that time spent sprinting, it can be assumed that a player will reach their maximum speed. A lot goes into reaching a maximum speed, especially actions at the ankle.

Sprinting and reaching a maximum speed are usually related back to the plantar flexors of the ankle due to the propulsion force they produce (Pandy, Lai, Schache, & Lin, 2021). However, another action that needs to be examined at the ankle is dorsiflexion. Dorsiflexion is defined as decreasing the angle between the shank and the foot, we see this during multiple phases of sprinting. Sprinting mechanics are some of the most complex mechanics, so how dorsiflexion optimizes performance will be analyzed. Dorsiflexion helps to control the positioning of the foot before making ground contact. Mainly, it helps athletes to land on the balls of their feet instead of their toes, in turn that allows the athlete to land closer to their center of mass. Landing closer to the center of mass means that the foot can land closer to under the hip, and this allows the hip and foot to pass through the sprint cycle simultaneously. In other words, dorsiflexion is important because it limits ground contact time by allowing the foot to quickly transition from foot strike to the toe off phase (Martine-Fuentes & van den Tillaar, 2022). The stretch shortening cycle explains exactly how that quick transition takes place. This concept states that force attained during a concentric contraction is enhanced following an eccentric contraction (Fukutani et al., 2020). During sprinting we see what is known as a heel collapse after initial ground contact. The

toes hit the ground first and we see the heel rapidly drop all the way or close to the ground then snap back up to go into the propulsion phase. This happens because it is the body's way of creating the stretch shortening cycle in the shank. The heel collapse stretches the achilles tendon, going into dorsiflexion, stretching the gastrocnemius and soleus with it to create an eccentric contraction before going into the concentric contraction to produce more force. This stretch shortening cycle can be made more efficient by actively dorsiflexing before ground contact. If the athlete has the ability to dorsiflex before ground contact, the heel collapse can be minimized because the achilles is already somewhat stretched and in the eccentric phase. This is called landing in a "loaded" position. This reduces the time that the foot has to take to work through the eccentric phase to the amortization phase and then the concentric phase. By reducing the stretch shortening cycle we can reduce ground contact time. With this knowledge of dorsiflexion and the function of it, athletes in a sport like soccer that involves constant running need to know if range of motion is important for dorsiflexion. In general, soccer players are at a very inclined risk for lower body injuries. Specifically, they are at risk for ankle and foot injuries more than anything else (Valderrabano, Barg, Paul, Pagenstert, & Wiewiorski, 2014). Due to the pulling nature of the action that dorsiflexion causes on certain musculature, limited dorsiflexion range of motion has been linked to increased injury risk with conditions like achilles tendinopathy (Scattone Silva, Smitheman, Smith, & Silbernagel, 2022). It has also been shown that large amounts of high-speed work may increase achilles injury risk (Lorimer & Hume., 2016). We see a lot of high-speed work in the sport of soccer. When anything is linked to an increase in chance of injury, it begs the question about the effects that it may also have on performance. Dorsiflexion and changes over the course of a season has been analyzed, but there was no insight to what could have influenced the change or how the change could have affected each individual player

(Monero-Perez et al., 2020). The gaps between injury prevention measurements and performance risk need to be bridged.

Based off of a recent meta-analyses conducted in September 2021, it could be assumed that in general, increasing range of motion can lead to increased physical performance (Konrad, Najamura, Bernsteiner, & Tilp , 2021). It could also be deduced that increasing range of motion creates more freedom to move, so if the dynamical system theory holds true then we can assume that increasing range of motion provides more paths to improving performance. However, the existing research lacks with directly relating range of motion at a joint to a specific measurement like top speed when sprinting. There have been studies done on how dorsiflexion affects sprinting and the relationship with decreasing time of dorsiflexion to the point of toe off to increase sprint speed (Martine-Fuentes & van den Tillaar, 2022) (Bradley, et al., 2009). The issue is connecting the dorsiflexion range of motion normative values to the effect it has on performance to see if there is a relationship between the two. If a player is going through a season showing signs of decreased dorsiflexion range of motion, but is still performing at an acceptable level, is trying to increase his range of motion to a normative value necessary? This creates many questions about range of motion normative values and how much they mean to performance. This also leads us to the question of why do these range of motion values change? Is it external factors, training, mental factors?

Due to the existing partnership between Georgia Southern University and South Georgia Tormenta FC, the athletes on the USL 1 team will be examined for this study to further our knowledge on this topic using the already existing testing procedures and the GPS monitoring system. All of which will be discussed later on.

The purpose of this study is to investigate how dorsiflexion ROM changes throughout a season in elite soccer players, and to determine any existing relationships between dorsiflexion range of motion and performance variables such as top speed and training load.

Methods

Participants

A total of 18 professional United States League 1 soccer players participated in this correlational study. All eighteen players are from the same club, Tormenta Football Club. The participants position distribution was made up of two goalies, four attackers, four defenders, and six mid-fielders. Eight of the eighteen players showed a sign of limb dominance or restricted range of motion, landing them on a red flag list for future injury, but this does not exclude them from the study. Players were excluded from the study if they met any of the following criteria: (a) came into the pre-season testing injured, (b) major injury sustained during the season, (c) left the club for any reason and was not able to complete pre/mid/post testing. Any information from all testing was relayed to the Tormenta sport medicine/performance staff. No intervention was measured or performed by the researchers, this study was strictly observational to identify any existing correlation between top speed, training load and changes in dorsiflexion range of motion over the course of a season. All of the players were briefed by the testing staff before testing was conducted.

Procedures

Pre-season, mid-season, and post-season testing for active and static dorsiflexion range of motion was conducted in the Georgia Southern University biomechanics and motor control laboratories. All top speed measurements were completed on the field by administering the RAST test before practice began on that day. These measurements were collected on separate

days. All data was collected by Georgia Southern University Exercise Science graduate students and faculty. To identify trends and correlations over the course of a season measures were taken at three separate times throughout the season: pre-season, mid-season, and post-season. The active range of motion measurement consisted of a single hop exercise, which has a risk for a learning curve. To eliminate this risk, the athletes were given a chance to practice their single leg hop before measurements were taken. Before the laboratory testing, the research staff joined the athletes in a conference room to introduce themselves and brief the athletes on the testing. The athletes were instructed to do anything that they need to do to make them feel comfortable to undergo testing. There were no instructions from the researchers telling the players to perform a specific warm up. The athletes were instructed to wait in the conference room before they were called to the first station, where they would be assessed one at a time starting with their height measurement. The players completed a battery of injury risk tests, but the ones that are being analyzed are the two-dorsiflexion range of motion tests. The athletes single leg jumps were analyzed in the Georgia Southern biomechanics lab to identify active range of motion. Before the single leg jump trails commenced the motion capture and THEIA 3D system was calibrated with a wand wave procedure to allow the cameras to identify where they were in space. The origin was also set using the wand to allow the camera to identify the axes of movement. After the single leg jumps are performed the athletes had their body composition analyzed. Then their static dorsiflexion range of motion was taken in the biomechanics lab. There was no specific cool-down instruction from the research staff after testing was completed. Laboratory testing was completed in a singular day. The field testing to assess top speed was done two days later before practice, but after the athletes completed a dynamic warm-up that was determined by their coaches.

Instrumentation/Measurements

Active ankle dorsiflexion range of motion. Unilateral dorsiflexion active range of motion was measured by using joint angles, obtained by use of Theia3D Motion Capture. Due to the practicality and accuracy of markerless motion capture, it is an incredibly promising method for analyzing sport performance (Lahkar et al., 2022). Our active range of motion results were obtained through having the athletes perform single leg jumps on both legs. We quantified the active range of motion by assessing the joint angles at the talocrural joint, measuring the angle between the foot/ankle and shank. Athletes were in a standing position and were told to go up on to one leg. The leg that was not being tested was told to be lifted off the ground. The athletes were told to have their hands on their hips and perform a single leg jump to the best of their availability. Each athlete performed a single leg jump three times on each leg. This measurement was taken the exact same way for the three points throughout the whole season.

Static ankle dorsiflexion range of motion. The athlete's static dorsiflexion range of motion was obtained through the lunge test. Each leg was checked once for static dorsiflexion range of motion. The athlete was told to stand in a staggered lunge stance that was comfortable for them. Then they were told to position their foot being measured close to the wall and lunge until their knee hit the wall. After the athlete got comfortable with the lunging motion, they were told to move the foot being measured further away from the wall. The athlete was then told to lunge till their knee hit the wall while still being able to maintain heel to ground contact of the leg being measured. The athlete could not hold on to the wall and was told that the back leg that wasn't being measured could be positioned however is comfortable. Once the athlete determined that they could not increase the distance any more between the leg being measured and the wall without their heel coming up, the researcher checked form. This was to make sure that when the

athlete's knee hit the wall that their heel was in contact with the ground. After form was verified, the research team measured the distance from the athlete's big toe to the wall in centimeters. This measurement was taken the exact same way for the three points throughout the whole season.

*Top speed***.** The RAST test is conducted on a day that is separate from range of motion measurements. The RAST procedure is reliable and valid for measuring running anaerobic power and short distance performance (Zagatto et al., 2009). It occurs before a training session and a warmup is given at the coaching staffs discretion. The research team are not coaches, so we do not tell the athletes how to warmup. Two graduate students measured the athletes top speed through the RAST test. Equipment needed was STATSport GPS devices, 50 meters of sprinting space, one administrator times the duration of each sprint, one administrator times the 10 second recovery periods, weighing scale, stopwatches, and marking cones. Before the test is administered each athletes, body mass is measured. The athletes perform a warmup before testing that is determined by their coaches. On the "go" signal both test administrators press the start button on their stopwatch and the participant must sprint at maximal effort to the end of the 35-meter distance. Once the athlete crosses the 35m line, the second test administrator must shout "clear", at which point they stop the clock and record the sprint duration. The first test administrator begins the countdown of the ten second recovery. During the recovery period, the athlete should get ready to perform another 35-meter maximal sprint back to where they started. This procedure is repeated for a total of six sprints. The test administrators record the duration of all six sprints individually. Top speed is being examined by the data we get from the STATSport GPS technology in miles per hour and the time it took to sprint the 35 meters. This measurement was taken the exact same way for the three points throughout the whole season.

Training load. Training load is being measured by STATSport GPS units that are given to each players. Distribution, collection, and data processing is handled by the research team before and after every practice and match. For away matches the sport performance staff is aware of distribution and collection procedures, then the research team handles data processing when the club returns from an away match. Training load is being quantified by total distance covered and number of sprints reaching > 5.5 m/s for at least 2 seconds. Before every testing session (pre,mid,post), the weekly average for total distance covered and number of sprints is calculated for each player based on statistics from every training and match session leading up to the testing.

Statistical Analysis

All analyses were performed using SPSS version 25. Descriptive statistics like mean and standard deviation were calculated for all measures for each individual limb. Ankle dorsiflexion range of motion scores were categorized as normal or restricted according to normative values for athletes (Young & Baggett, 1993). The alpha level was set at 0.05. To determine if previous literature held true, a one-way ANOVA with repeating measures was used to determine the change in range of motion values over the course of the season. Pearson's correlation (r) coefficients were calculated to determine the relationship between dynamic range of motion and top speed values, static range of motion and top speed values, dynamic range of motion and training load values, static range of motion and training load values. Overall, four correlations were examined to determine relationships. A z-test will be used to determine if the correlations between values change over the course of a season.

References

Baggett, B. D., & Young, G. (1993). *Ankle joint dorsiflexion. Establishment of a normal range.* Journal of the American Podiatric Medical Association, 83(5), 251–254. https://doi.org/10.7547/87507315-83-5-251

Bradley, P., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). *High intensity running in English FA Premier League soccer matches.* Journal of Sports Sciences, 27(2), 159–168.

Burgess, D. J., Naughton, G., & Norton, K. I. (2006, January 1). *Profile of movement demands of national football players in Australia.* JOURNAL OF SCIENCE AND MEDICINE IN SPORT, 9(4), 334–341.

Fukutani, A., Isaka, T., & Herzog, W. (2020). *Evidence for Muscle Cell-Based Mechanisms of Enhanced Performance in Stretch-Shortening Cycle in Skeletal Muscle.* Frontiers in Physiology, 11. https://www.frontiersin.org/articles/10.3389/fphys.2020.609553/full

Konrad, A., Nakamura, M., Bernsteiner, D., & Tilp, M. (2021). *The Accumulated Effects of Foam Rolling Combined with Stretching on Range of Motion and Physical Performance:A Systematic Review and Meta-Analysis.* Journal of Sports Science and Medicine, 20(3), 535. https://doi.org/10.52082/jssm.2021.535

Lahkar, Bhrigu K., et al. *Accuracy of a Markerless Motion Capture System in Estimating Upper Extremity Kinematics during Boxing*. Frontiers, Frontiers, 30 June 2022, https://www.frontiersin.org/articles/10.3389/fspor.2022.939980/full.

LaStayo, P. C., Woolf, J. M., Lewek, M. D., Snyder-Mackler, L., Reich, T., & Lindstedt, S. L. (2003). *Eccentric muscle contractions: their contribution to injury, prevention,*

rehabilitation, and sport. The Journal of orthopaedic and sports physical therapy, 33(10), 557–571. https://doi.org/10.2519/jospt.2003.33.10.557

Lorimer, A. V., & Hume, P. A. (2016). *Stiffness as a Risk Factor for Achilles Tendon Injury in Running Athletes.* Sports medicine (Auckland, N.Z.), 46(12), 1921–1938. *https://doi.org/10.1007/s40279-016-0526-9*

Martín-Fuentes I, van den Tillaar R. *Relationship between Step-by-Step Foot Kinematics and Sprint Performance.* International Journal of Environmental Research and Public Health. 2022; 19(11):6786. https://doi.org/10.3390/ijerph19116786

Moreno-Pérez, V., Soler, A., Ansa, A., López-Samanes, Á., Madruga-Parera, M., Beato, M., & Romero-Rodríguez, D. (2020). *Acute and chronic effects of competition on ankle dorsiflexion ROM in professional football players*. European Journal of Sport Science, 20(1), 51–60.

Pandy, M. G., Lai, A. K. M., Schache, A. G., & Lin, Y. (2021). *How muscles maximize performance in accelerated sprinting.* Scandinavian Journal of Medicine & Science in Sports, 31(10), 1882–1896. https://doi.org/10.1111/sms.14021

Scattone Silva, R., Smitheman, H. P., Smith, A. K., & Silbernagel, K. G. (2022). *Are static foot posture and ankle dorsiflexion range of motion associated with Achilles tendinopathy*? A cross-sectional study. Brazilian Journal of Physical Therapy, 26(6). *https://doi.org/10.1016/j.bjpt.2022.100466*

Valderrabano, V., Barg, A., Paul, J., Pagenstert, G., & Wiewiorski, M. (2014). *Foot and Ankle Injuries in Professional Soccer Players.* Sport-Orthopädie - Sport-Traumatologie, 30(2), 98–105. https://doi.org/10.1016/j.orthtr.2014.04.002

Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). *Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances.* Journal of strength and conditioning research, 23(6), 1820–1827. *https://doi.org/10.1519/JSC.0b013e3181b3df32*

Appendix A

A) Research Questions/Hypothesis:

- Does active and static dorsiflexion range of motion change over the course of a season?
- Will one form of dorsiflexion range of motion show a stronger correlation to top speed and training load than the other (static versus active)?
- Will the correlations between ROM values and training load/top speed change over course of season?

B) Hypotheses:

- A decrease in dorsiflexion range of motion will be observed over the course of the season, previous literature will hold true.
- Both ROM measurements will show similar correlations to performance values.
- A significant negative relationship will be observed between training load and dorsiflexion ROM measurements.
- A significant positive relationship will be observed between top speed and dorsiflexion ROM measurements.

C) Limitations:

- Convenience sampling will be used, so selection bias is a risk.
- Injuries occur over the course of a season; this could be a history issue that is a threat to the internal validity and could cause the sample size to drop.

- Due to groups being formed by certain scores, statistical regression is a possible issue threatening internal validity.
- Reactive effects of testing could be a threat to external validity. Since we provide the sport science team with the information from testing, the players will be alerted and will possibly work to improve the deficiency in range of motion.

D) Delimitations:

- Elite soccer players will be examined, so the results may not be generalizable to all soccer players.
- The RAST test will be utilized to determine an absolute top speed that may not be achievable in-game due to the start/stop nature of soccer. The top speed measurement will be very controlled.
- Only two performance variables are being examined (training load & top speed)

E) Assumptions:

- We assume that all players will go through the single leg jump and RAST test with their best effort.
- We assume that all players are healthy going into pre-season testing unless told otherwise by sport medicine staff.
- We assume that all measurements observed are recorded the same.
- We assume that all players are wearing their STATSport GPS vests when given to them.

F) Definitions:

- The RAST test is a rapid anaerobic sprint test designed to measure anaerobic power, capacity, and to allow the players to achieve a top speed.

- Active dorsiflexion ROM is measured by joint angles when performing a single leg jump.
- Static dorsiflexion ROM is measured by the lunge test and recorded in centimeters.
- Elite soccer players are considered USL 1 players.
- Training load will be quantified by miles run per practice and game as determined by STATSport GPS systems.
- The course of a season consists of pre-season, mid-season, post-season.