Original Research

Kinematics analysis of ankle dorsiflexion when using the modified orthosis in order to increase stability in the moment of heel strike with the ground

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ABSTRACT

In this study, an investigation was done in order to increase stability of ankle and reduce injuries resulting twist while using aid orthosis and effort in providing superior samples. Therefore this study aims to investigate the effect of ankle hinged Stirrup brace on the Sagittal position of ankle joint in healthy individuals.

Eighteen healthy subjects participated in this quasi-experimental study (8 males, 10 females) aged 19 to 30 years. Individuals were selected by non-random sampling and accessible sampling type based on inclusion criteria. Dorsiflexion angle at the moment of heel contact with the ground while walking in the 3 different steps of test with just shoes, shoes with articulated Stirrup brace, shoes with modified articulated Stirrup brace (stretch strep) was recorded by using (VICON Motion Systems) motion analysis system. For comparison of the supposed positions also paired t test was used. Articulated ankle brace have no significant effect on the ankle joint sagittal plane position. In addition, the modified brace cause a significant change in the position of the ankle joint sagittal plane and increase the angle of the ankle joint in the desire direction. Adding a stretch strap to the main plantar brace according to the picture presented in the research methodology as an involuntary factor creates movement restrictions in the sagittal plane to increase dorsiflexion angle that the change would lead to increased dorsiflexion ankle angle in order to increase consistency at the moment of heel contact with the ground in healthy individuals.

Keywords: Recurrent ankle sprains, Articulated Stirrup brace, Biomechanics, Angle of dorsiflexion, Increase stability

Introduction

An ankle injury is one of the most common lower extremity injuries that in the term of frequency after the knee injuries are in the second (Worrell et al., 1994). Ankle sprain as one of the most common injury to the area is said to a situation be in which as a result of individual's balance disorder, weight-bearing ankle sprains and may cause damage to the ankle ligaments (Eechaute et al., 2007). Accordingly, frequent ankle sprain constitute 10% to 30% of musculoskeletal injuries and ankle sprains and its outer side comprise approximately 85% of sport injuries (Worrell et al., 1994; Eechaute et al., 2007).

Given the extent of this damage in normal and athletic life and costs imposed on the United States (Osborne and Rizzo, 2003) and Individuals' disability whether in industry and whether sports team members, extensive studies have been conducted on a variety of foot and ankle supporters that a large part of them is orthotics mechanical properties and their ability to limit the range of motion of the ankle joint is set (Ragust at al., 2006; Werb and Knight, 2010; Masharawi et al., 2003; Anderson et al., 1995).

In fact, in patients with recurrent ankle sprains dorsiflexion limited range and error in repositioning ankle is seen (Yang et al., 2002; Youdas et al., 2009). In addition to this domain, restriction angle of foot dorsiflexion momentum causes many lower extremity injuries (like ankle sprain, CAI, Achilles injuries, ACL and bone ligament Patellar) (Wahlsteadt et al., 2014; Parsley et al., 2013; Backman et al., 2011), as well the moment of heel strike with the ground (Heel-Strike) is one of the most distinctive and most important feature of healthy subjects' walking that is crucial and important during the normal gait cycle, also affect most in the development of pathological conditions (Sheffler et al., 2008; Bulley et al., 2014). In addition, fail to create maximum dorsiflexion causes reducing stability of the ankle joint in the closed chain (Drewes et al., 2009). Thus increasing the angle of dorsiflexion of the ankle at the time of the foot heel collision with the ground, reducing the repetition of a lateral ankle sprain, otherwise not only increases the repeated occurrence of sprain, but also increases the severity of the sprain (Willems et al.,, 2005; Delahunt and Moran, 2009; Distefano et al., 2008; Verhagen et al., 2001). Therefore, increasing dorsiflexion of ankle at the moment of collision with ground, the center of body mass has more displacement downward and reduce the force from the ground to the body and making right positioning of the ankle before, during and immediately after the heel strikes the ground, it is necessary to prevent lateral ankle sprain (Spaulding et al., 2008).

In addition to this inappropriate position of the effect place and to implement ground reaction force at the moment of impact with the ground heel, rather than center of rotation of the ankle joint, especially when using different orthoses (e.g. differences in appearance, in conformity with the essential form feet, height insoles orthosis) is especially important so that the absence of attention to the above cases could affect the precise location of effect and changing in ground reaction force applied to the insole and thereby increase the torque arm and increase effective power component in torque application to the instability of the ankle joint and in this case, coordination of foot with used orthoses lead to the correct posture and optimization of the reaction force around the axis of rotation leads to increased levels of accuracy in kinetics and kinematics of the knee compared to normal situation (Eddison et al., 2013; Jagadamma et al., 2014).

Many studies examined kinetics and kinematics of ankle and the effects of different treatment methods in people with spraining outer side of the of ankle and the different variables which measured (Surve at al., 1994; Beynnon et al., 2003; Wiley and Nigg, 1996; Brooks et al., 2006; Willems et al., 1994). So in order to prevent the recurrence of ankle sprain the preventive taping, Bracing and shoes that are specifically designed and preventive exercises are used (Thacker at al., 1999). The impact of preventive taping is through reduced range of motion plantar flexion and inversion (Inversion) of ankle, but over time its preventive effect fells down (Verhagen et al., 2001, Verhagen et al., 2000),Meanwhile preventive effect of brace will not reduce with time pass (Osborne and Rizzo, 2003; Worrell et al., 1994; Willems et al., 1994; Thacker et al., 1999; Verhagen et al., 2000). Semi-rigid orthoses or articulated treatments are common today, a combination of semi-rigid plastic bars and straps and support the lower part of the tibia and fibula and ankle joint (Werd and Knight, 2010).

Also in Some studies stabilizer impact of orthesis, their long-term impact on the recurrence of an ankle sprain and their impact on the performance of people with recurrent ankle sprain was examined (Brooks et al., 2006; Wiley and Nigg, 1996; Beynnon et al., 2002; Surve et al, 1994), But few studies is done on the effects of ankle support on biomechanics of ankle joint on Sagittal plane during normal activities like walking and jogging (Nishikawa et al., 2002). Focus of studies that examined the ability of ankle supportive on limiting the of ankle motion further have the inversion motion (motion in the frontal plane) was frontal (Masharawi et al., 2002; Anderson et al., 1995). Of course many also stated that correcting walking pattern in limiting the range of motion in phase plantar Swing (immediately before impact with the ground heel) (Ramdharry et al., 2012; Geboers et al., 2002). In addition, studies that have examined the motion in sagittal plane have verified the effect of other treatments including physiotherapy techniques such as mobilization with the ankle range of motion in the sagittal plane (range of dorsiflexion) The results showed improvement in range of dorsiflexion motion on this page (Youdas et al., 2009; Hoch and Mckean, 2010). According to various studies have shown that semi-rigid orthoses impact in reducing the probability of further ankle twist (Brooks et al., 2006; Wiley and Nigg, 1996; Callaghan et al., 1997), On the other hand, several studies have reported also lack of control of ankle plantar flexion when using semi-rigid orthoses heel lace-up Ankle brace at the moment of collision with the ground which is part of the twist mechanism, (Spaulding et al., 2003; Werd and Knight, 2010). Hence, possibly change in the structure of the orthosis (add straps tap orthotics) can help to solve this problem and thus increase the angle of dorsiflexion and control the movement of the ankle. Therefore, due to lack of sufficient documentation in controlling plantar motion in the sagittal plane we are aimed to examine the effect of articulated Stirrup brace on the Sagittal position of ankle joint in healthy individuals so that context will be provided for the use of this new orthosis in the world.

Material and Methods
Participants

This study employed a quasi-experimental and interventional design without a control group. Samples were consists of 18 healthy students from the University of Social Welfare and Rehabilitation Sciences. Subjects were non-randomly selected and their demographic information were height 172±12 cm, age 27±8 years old and weight 68±9 kg. Inclusion criteria for the study were included; none of subjects had a history of surgery, fracture or dislocation in the lower extremities and spine, no acute ankle twist history in the past 6 months, no gait detectable abnormalities when viewed by an expert, having no peripheral nerve Neuropathic disorder that affect the walking pattern, initial incorrect structural conditions like rigid ankle supination, the high internal longitudinal arch of the foot, varus High Tibial, non-pathological rotation talus and the ankle ligament laxity. The subjects before entering the test were under clinical examination, including the Anterior Drawer Test and Talar Tilt Test based on researcher's method in other articles and studies (Drews et al., 2009; Willems et al., 2000; Vincenzio et al., 2006).

Surface design

In this study, measuring the changes in ankle, ankle angles in the sagittal while walking has been considered. Shahriari and et al for measuring used the VICON motion analysis system with a sampling frequency of 100 Hz that the raw data obtained from their study, have been prepared and used in this article. The test was included with just shoes, Shoes with articulated Stirrup brace, shoes with modified articulated Stirrup brace (stretch strep). Determining the order of test conditions randomly was done via lottery by selecting choice by the subject. Each test was repeated 3 times. For each individual two orthosis has been prepared with appropriate size. One of these two orthoses, semi-rigid articulated stirrup brace and was the other previous orthosis plus straps confounding plantar flexion (contributing to dorsiflexion) (37) (Fig. 1).

Figure 1. A(left): hinged stirrup brace (unghanged), B: modified articulated Stirrup brace (anterior view), C: modified articulated Stirrup brace (medial view), D: modified articulated Stirrup brace (Schematic view).

Test protocol

In this study in order to start measurement, the subjects were asked to dress appropriately (use of sports shorts and socks) and shoes that have already been prepared for this purpose and walk for 10 minutes to get used to it. For each subject six 14-mm markers were used. Markers were placed on important anatomical lower extremity landmarks which include femur lateral epicondyle, tibial tubercle, first and fifth metatarsal heads, lateral and medial malleolus. Markers related to femur lateral epicondyle and tibial tubercle were placed directly on the patient's skin but the markers of first and fifth metatarsal heads and heel were attached to the patient's shoe. In cases of test that was done by orthosis lateral and medial malleolus markers were placed on the ankle-foot orthosis (37) (Fig. 2). After the subject announced his readiness to start the test, the test began. Before the start of each person was asked in all stages (without brace, with semi-rigid articulated Stirrup brace, with modified brace) at the same speed (with their normal walking pace), walk and at each step of testing complete the walk cycle.

Figure 2. The exact location markers on the body position of the subjects.

Then Subjects were asked to perform the test with shoes and without wearing orthosis. Data were recorded by the analysis devices and were recorded in a file with the specifications and test conditions. Subjects were asked to wear the orthosis into the shoe and to walk with the orthosis for 10 minutes to get used to it, and later the same stage before while wearing the orthosis to walk and data were recorded in the same procedure. The third phase tests began with an interval of 10 minutes. At this stage the subject worn the modified orthosis and he was asked to perform the same procedures and data were recorded similarly. After recording details of the testing stages, information obtained from each stage of each individual was collected in a file (37).

Data analysis

In order to process the information, data obtained from each subject in each three cases to calculate the dorsiflexion angle of the ankle joint in sagittal plane were calculated by Microsoft Excel software. After removing the defects data, dorsiflexion angle of the ankle joint axis through the talus bone at the moment of contact on the ground using geometric methods such as relationships and equations and laws of the inner line and page space vectors in space were calculated.

Statistical analysis

Descriptive statistics of variables and variables to assess compliance with the normal theoretical distribution of the scattering characteristic tendency (mean, standard deviation) and test KS One - Sample Kolmogorov-Smirnov Test was used. Paired - Sample T Test was used to assess the pure effects of orthoses and the initial orthosis modification on the position of the ankle joint in sagittal plane.

Results

T test results are shown in Figure 1, information indicate the average angle of the ankle in the sagittal plan (plantar flexion angle) when the heel strikes the ground in the SBS (shoes with modified brace) (99.38±3.28) less than SB (shoes with braces) and SO (Shoe).While the average in situation of SB (101.01±3.38) is less than the situation of SO (102.79±4.34).

T test results are shown in Figure 1. According to this diagram, there is a significant difference between the situations SO and SBS (p=0.001) and SBS and SB (p=0.024) and only no significant difference was found between SO and SB (p=0.069).

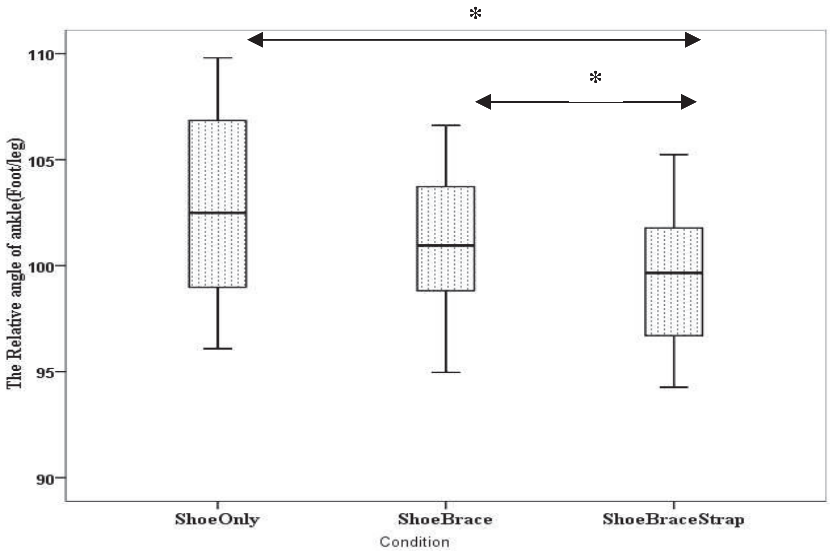

Figure 3. Comparing mean values relative angle of ankle joint (Foot/Leg) in sagittal plane in assumed situation (Only Shoe, Shoe with Brace, Shoe with Brace and strap).
* Significant difference

Discussion & Conclusion

This study aimed to investigate the effect of ankle articulated Stirrup brace on the Sagittal position of ankle joint in healthy individuals. The results showed that use of the articulated Stirrup brace, does not have a significant effect on the position of the ankle joint on sagittal plane, however, the use of modified orthosis caused a significant change on the sagittal position of the ankle joint angle and increases dorsiflexion. Many studies have been conducted on various types of semi-rigid articulated Stirrup brace (without change) and the its effects undifferent positions and directions of the ankle that almost all showed the lack of the motion controls of ankle joint on sagittal plane as no significant effect was report about used orthoses on the sagittal position of the ankle joint in normal gait phase In other words, in order to increase stability dorsiflexion angle does not say that this view is entirely consistent with study (Spaulding et al., 2003; Jacqueline and Katrin, 2015; Eils et al., 2002; Werd and Knight, 2010; Monaghan et al., 2006). However, DiStefano et al (2008) study on healthy individuals demonstrated that the use of the orthosis ASO ankle brace decreased the maximum angle of dorsiflexion and motion range of dorsi-plantar flexion (Distefano et al., 2008) and on the other hand Gudibana and Wang (2005) have proofed the 48% decrease of dorsi-plantar flexion range of motion that is not consistent with the results of this study. Distefano and his colleagues examined the effect of ankle-foot orthosis on the ankle joint sagittal position (angle of dorsiflexion) in landing after jumping and jerky movements, dorsiflexion angle during lateral and forward motions, while in the present study have been reported dorsiflexion angle when the heel with the ground to walk normal phase (Gait phase).

Also Eils et al. (2002) have expressed the reason for these differences in orthosis design that in his study investigated the effect of 10 types of semi-rigid articulated Stirrup brace in sudden supination in the sagittal position of ankle which in this case is perfectly in line and consistent with the present study (Eils et al.,

2002). It seems that the cause of difference results from different types bracing and differences in the method of study and differences in methods of data collection, which in this study data from healthy subjects while walking recorded.
In majority of studies mentioned the lack of control of the ankle joint by normal orthoses (unchanged) in the sagittal in healthy individuals have expressed but Ploeger et al (2014) showed the impact of conventional orthosis (unchanged) in patients with cerebral palsy, especially those with muscle weakness of the front leg examined in normal gait and results indicated physical recovery of dorsiflexion angle restriction of the target lesion compared to situation without orthosis (shoe sole) (Ploeger et al., 2014). In general, according to the results of this study and Ploeger, regardless of the type of orthosis can be used in any of the studies stated. Conventional braces cannot compensate and control existing short comings (such as tear and elongation of the ligaments and ligaments of the ankle joint area, neuromuscular disorders) in the joint as a result of various factors created in the sagittal and it seems that the modified orthosis could have a positive effect on the maintenance and improvement of the wrist in the desired position in order to increase stability (in other words dorsiflexion angle) at the moment of impact with the heel strike. So most likely, according to the results of this study and using the results of other studies mentioned above, the possibility of development outcomes (modified orthosis effectiveness in improving dorsiflexion angle in order to increase stability) in other groups, for example people with wrist twist and generally have people with CAI.

Most studies have major effects of orthosis (without changes) on the position of the ankle joint and several researchers have studied conditions (Wiley and Nigg, 1996; Werd and Knight, 2010; Eils et al., 2002) but did not make any major changes to the orthosis. In this regard, Yvette et al. (2015) with the creation of physical changes in the orthosis ASO (increasing the height of insoles orthosis) examined the impact of the intervention on the angular kinematics and SVA (Shank-to-Vertical-Angle) ankle joint in healthy individuals gait phase. The results showed a significant increase in the angle of the SVA and subsequently increasing the dorsiflexion angle of the joint that this intervention and was consistent with the results of this study (Yvette L. Kerkum et al., 2015). Thus, increasing the height of the heel insoles inheritance as inclined to results of this study in order to increasing the angle of heel dorsiflexion in the moment of impact with the ground and ultimately increase the stability of the ankle joint, reduced risk of injury at the moment of twist. It is worth noting that the effect of adding an passive agent to the orthosis on ankle joint in creation of restriction in the motion range of joint and helping to improve the structure state and being in a close to normal and enhance the stability has been largely positive and significant. In addition, this involuntary external factors play important role in helping the involved muscles in maintaining the stable situation creating expected range of motion and stability as a result of intervention actions and as many lead to changes in biomechanical characteristics of the ankle joint (Derek et al., 2015). For this reason, in this article we have tried to apply a passive agent for more stability measure its impact on the position of the ankle joint while researchers have tried to make changes (add stretch straps in crossed leg brace from the floor to brace in Figure 1. as a passive factor in the proper direction (Drews et al., 2009), a state of involuntary dorsiflexion in the main brace to achieve better condition and keep it tends to be more stable. So that the angle between the foot and leg by stretch straps when heel strikes the ground in order to increase stability (the angle dorsiflexion). Because, increasing the ankle dorsiflexion angle when heel strikes with land, leading in further displacement towards the center of gravity low and thus reduce the force from the ground in the body (Wright et al., 2005). On the other hand, this change (increase dorsiflexion angle) in the area of situation ankle joint to a neutral position, which provides greater stability to the joint (because ankle in a neutral position with more dorsiflexion, Tibia and Fibula larger part of the talus covered and increase the stability) (Delahunt et al., 2009).

Therefore, passive factor (stretch straps) applied by the researcher was able to cause increase dorsiflexion angle and decrease the stress on the ligaments angle in the anterior talofibular ligament that is the most prone leg ligament lesion twist frequent and it is hoped this modified orthosis could have a significant impact on the containment and control of the lesion in susceptible to damage individuals (healthy individuals) and injured individuals, and in the future with changes such as of the wrapping, straps elastic coefficient orthoses used in more favorable outcomes achieved.

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References

4. L. Lidgren. *The bone and joint decade 2000-2010*. Bulletin of the World Health Organization. 2003; **81**(9):629-629.
5. Parsley A, Chinn L, Lee SY et al. Effect of 3 different ankle braces on functional performance and ankle range of motion. Athletic Training Sport Health Care 2013; **5**(2):69–75.
6. Eechaute C, Vaes P, Van Aerschot L, Asman S, Duquet W., *The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: a systematic review*. BMC musculoskeletal disorders. 2007; **8**(1):6.
7. M. Osborne and J. Rizzo. *Prevention and treatment of ankle sprain in athletes*. Sports Medicine. 2003; **33**(15): p. 1145-1150.
8. Derek J. Haight, Elizabeth Russell Esposito, Jason M. Wilken. *Biomechanics of Uphill Walking Using Custom Ankle-foot Orthoses of Three Different Stiffnesses*. Gait & Posture, 2015; **41**(3):750-756.
9. Worrell, T., L. Booher, and K. Hench, *Closed kinetic chain assessment following inversion ankle sprain*. Journal of Sport Rehabilitation, 1994; **3**(3):197-203.
10. Drewes LK, McKeon PO, Kerrigan DC, Hertel J..*Dorsiflexion deficit during jogging with chronic ankle instability*. Journal of Science and Medicine in Sport, 2009; **12**(6):685-687.
11. Ploeger Hilde E., Bus Sicco A. Ankle-foot orthoses that restrict dorsiflexion improve walking in polio survivors with calf muscle weakness. Gait & Posture. 2014; **40**(3):391–398.
12. Willems, T., et al., Relationship between gait biomechanics and inversion sprains: a prospective study of risk factors. Gait & posture, 2005; **21**(4):379-387.
13. Wright, I., et al., The influence of foot positioning on ankle sprains. Journal of Biomechanics, 2000; **33**(5):513-519.
14. Eddison N, Chockalingam N. The effect of tuning ankle foot orthoses-footwear combination on the gait parameters of children with cerebral palsy. Prosthetics and Orthotics International, 2013; **37**(2):95–107.
15. C. Yang, BV. Impairments in dorsiflexion and joint re-positioning in acute, sub-acute and recurrent ankle sprain: A preliminary report Journal of Science and Medicine in Sport. 2002; **5**(4): p. 17.
16. Youdas, J., et al., Changes in active ankle dorsiflexion range of motion after acute inversion ankle sprain. Journal of sport rehabilitation. 2009; **18**(3):358-374.
17. Jagadamma KC, Coutts FJ, Mercer TH, Herman J, Yirrell J, Forbes L, et al. Optimising the effects of rigid ankle foot orthoses on the gait of children with cerebral palsy (CP)—an exploratory trial. Disability and Rehabilitation: Assistive Technology, 2014; **10**(6):445-451.
18. Delahunt, E., J. O'DRISCOLL, and K. Moran, Effects of taping and exercise on ankle joint movement in subjects with chronic ankle instability: a preliminary investigation. Archives of physical medicine and rehabilitation, 2009; **90**(8):1418-1422.
19. DiStefano, L., et al., Lower extremity kinematics and ground reaction forces after prophylactic lace-up ankle bracing. Journal of Athletic Training, 2008; **43**(3):234-241.
20. Backman LJ, Danielson P. Low range of ankle dorsiflexion predisposes for patel-lar tendinopathy in junior elite basketball players. American Journal of Sports Medicine, 2011; **39**(12):2626–2633.
21. Spaulding, S., L. Livingston, and H. Hartsell, The influence of external orthotic support on the adaptive gait characteristics of individuals with chronically unstable ankles. Gait & posture, 2003; 17 (2):152-158.

22. Thacker, S., et al., The prevention of ankle sprains in sports. The American Journal of Sports Medicine, 1999; **27**(6):753-760.
23. Verhagen, E.A.L.M., A.J. van der Beek, and W. van Mechelen, The effect of tape, braces and shoes on ankle range of motion. Sports Medicine, 2001; **31**(9):667-677.
24. Verhagen, E., W. van Mechelen, and W. de Vente. The effect of preventive measures on the incidence of ankle sprains. Clinical Journal of Sport Medicine. 2000; **10**(4):291-296.
25. Brooks, P., The burden of musculoskeletal disease-a global perspective. Clinical rheumatology, 2006; **25**(6):778-781.
26. Yvette L. Kerkum, Han Houdijk, Merel-Anne Brehm. The Shank-to-Vertical-Angle as a parameter to evaluate tuning of Ankle-Foot Orthoses. Gait & Posture. 2015; **42**(3):269-274.
27. Wiley, J. and B. Nigg, The effect of an ankle orthosis on ankle range of motion and performance. The Journal of orthopaedic and sports physical therapy, 1996; **23**(6):362-369.
28. Masharawi, Y., et al., The effect of braces on restricting weight-bearing ankle inversion in elite netballers. Physical Therapy in Sport, 2003; **4**(1):24-33.
29. Jacqueline Romkes, Katrin Schweizer. Immediate effects of unilateral restricted ankle motion on gait kinematics in healthy subjects. Gait & Posture. 2015; **41**(3):835-835.
30. Geboers JR, Drost MR, Spaans F, Kuipers H, Seelen HA. Immediate and longterm effects of ankle-orthosis on muscle activity during walking: a randomized study of patients with unilateral foot drop. Archives of Physical Medicine and Rehabilitation, 2002; **83**(2):240-245.
31. Beynnon, B., D. Murphy, and D. Alosa, Predictive factors for lateral ankle sprains: a literature review. Journal of Athletic Training, 2002; **37**(4):376-380.
32. Surve, I., et al., A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. The American Journal of Sports Medicine, 1994; 22(5):601-606.
33. Anderson, D., D. Sanderson, and E. Hennig, The role of external nonrigid ankle bracing in limiting ankle inversion. Clinical Journal of Sport Medicine, 1995; **5**(1):18-24.
34. Nishikawa, T., et al., Effects of prophylactic ankle supports on pronation during gait. International orthopaedics, 2002; **26**(6):381-385.
35. Hoch, M. and P. McKeon, The effectiveness of mobilization with movement at improving dorsiflexion after ankle sprain. Journal of sport rehabilitation, 2010; **19**(2):226-232.
36. Bulley C, Mercer TH, Hooper JE, Cowan P, Scott S, Van der Linden ML. Experiences of functional electrical stimulation (FES) and ankle foot orthoses (AFOs) for foot-drop in people with multiple sclerosis. Disability and Rehabilitation: Assistive Technology, 2014 [Epub ahead of print].
37. Eils, E., et al., Comprehensive testing of 10 different ankle braces: Evaluation of passive and rapidly induced stability in subjects with chronic ankle instability. Clinical Biomechanics. 2002; **17**(7):526-535.
38. Monaghan, K., E. Delahunt, and B. Caulfield, Ankle function during gait in patients with chronic ankle instability compared to controls. Clinical Biomechanics, 2006; **21**(2):168-174.
39. Wahlsteadt C, Rasmussen-Barr E. Anterior cruciate ligament injury and ankle dorsiflexion. Knee Surgery, Sports Traumatology, Arthroscopy, 2014; **23**(11):3202-3207.
40. Vicenzino, B., et al., Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. Pamela Teys, 2006; **36**(7):464–471.
41. Sheffler LR, Hennessey MT, Knutson JS, Naples GG, Chae J. Functional effect of an ankle foot orthosis on gait in multiple sclerosis: a pilot study. American Journal of Physical Medicine & Rehabilitation, 2008; **87**(1):26–32.
42. Crosbie, J., T. Green, and K. Refshauge, Effects of reduced ankle dorsiflexion following lateral ligament sprain on temporal and spatial gait parameters. Gait & posture, 1999; **9**(3):167-172.

Callaghan, MJ, Role of ankle taping and bracing in the athlete. British Journal of Sports Medicine, 1997; **31**(2):102-108.

43. Ramdharry GM, Day BL, Reilly MM, Marsden JF. Foot drop splints improve proximal as well as distal leg control during gait in Charcot-Marie-Tooth disease. Muscle Nerve 2012; **46**(4):512–9.

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