

Effects of Lace-up and Aircast Ankle Braces on Dynamic Postural Control in Functional Fatigue Condition: A Study on Volleyball Players with Ankle Instability

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ABSTRACT

Purpose: To determine the more effective ankle brace (lace-up or Aircast ankle brace) at providing dynamic postural control in volleyball players with unstable ankle under functional fatigue conditions.

Methods: Subjects of this study participated in 3 separate testing sessions and did not use or used a different brace at each session i.e. no brace (NB), lace-up ankle brace (AB), and Aircast ankle brace (AA). Through each testing sessions the functional fatigue protocol was performed and dynamic postural control test was performed by Biodex Balance System (single leg stability testing in difficulty level 4) after induced functional fatigue. They were 15 volleyball players with at least 3 years playing record in the national and or Kerman Province leagues at youth and teenagers levels (mean age 19.46 ± 1.50 years, mean height 182.53 ± 5.28 cm, mean mass 67.70 ± 5.91 kg, VO_{2max} 52.05 ± 2.97 mL/kg/min) and stratified sampling method was used. All two by two comparisons were performed by using 1-way repeated measures analysis to investigate the effects of different braces. Data analysis was done by SPSS 16 and significance level was $P \leq 0.05$.

Results: According to the results, both types of ankle brace could improve dynamic postural control under functional fatigue condition. Although lace-up ankle brace was more efficient than Aircast ankle brace, the difference was not statistically significant.

Conclusion: In athletes with unstable ankle, a brace can prevent ankle sprain via improving dynamic postural control in fatigue condition.

1. Introduction

Ankle sprain is a frequent injury in sports and daily activities with the highest incidence in young and physically active individuals [1]. This injury is very common in volleyball because in jump-landing, the ground reaction force is great. Based on previous studies, 45.6% of the volleyball injuries occur in ankle and ankle sprain

is the most common injury reported in lower extremity accounting for 99.3% of all ankle injuries [2]. High prevalence of ankle sprain in volleyball requires more preventive measures in this sport.

The most frequent ankle injury mechanism in jumping sports is related to landing phase accounting for 58% of basketball and 63% of volleyball injuries [3]. Several factors such as muscular fatigue may affect landing pat-

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tern and ankle control at landing. Fatigue has negative effects on muscular spindles and during physical activity it affects neuromuscular control and might reduce the body's ability to maintain stability [4]. Muscular fatigue resulting from physical activity occurs in different parts of the neuromuscular control system such as central nervous system, neural control of muscle, and the muscle itself. Fatigue decreases muscle performance and increases the likelihood of injury, so that 76% of reported injuries occur in the second half of the games.

The range of these injuries varies from grade I external ankle sprain to complete rupture of the anterior cruciate ligament [5]. Ankle inversion sprain is very common in sports and daily activities and often endangering young and active individuals. Ankle ligament injury in jumping sports, especially ball sports, is very prevalent and in comparison to other sport injuries causes more absence from athletic activities [6]. This injury disturbs athletic performance, wastes time and economic benefits of both athletes and sport clubs. Because of the high cost and long-lasting treatment, prevention of ankle sprain has become the most important issue of the last decade. For example, the total amount of medical and limited duty task costs due to ankle sprain in parachutists who did not wear brace has been estimated as \$1299996 [7].

One of the successful interventions for decreasing the incidence rate and severity of ankle sprain is using external ankle supports [8]. Taping and bracing are two common methods used by athletes for preventing ankle sprain during training and competitions. According to previous studies, prophylactic ankle bracing can prevent 30 ankle sprains in every 1000 athletes at risk [9]. Studies have shown several advantages for bracing in comparison to taping. For example, at the end of a season bracing cost was 3 times less than taping and with regard to time, bracing took less time for both the athlete and sports medicine technician [10].

According to previous studies, long/short-term use of bracing not only assist athletic performance, but also improves it [9]. Wikstrom et al. have determined the rate of dynamic postural control in 28 participants with unstable ankle (13 males with mean age of 21.5 ± 1.2 years and 15 females with mean age of 20.5 ± 1.1 years) using either semi-rigid or soft (lace-up) ankle braces. They found that in individuals with functionally unstable ankle, bracing did not improve dynamic postural control [11]. Shaw et al. in their research entitled "effect of ankle bracing and fatigue on time to stabilization among collegiate volleyball athletes" have studied the effect of lace-up and semi-rigid braces on postural con-

trol among 10 female volleyball players with the mean age of 19.5 ± 1.27 years and normal ankle. Their results showed that in fatigue condition both types of braces have a positive effect on postural control, but lace-up bracing is more efficient [12]. Similar to the mentioned study, Hadadi et al. in their study about the effect of soft and semi-rigid orthoses on postural control have concluded that while these orthoses improve postural control in subjects with functional unstable ankle, they have no effect in healthy subjects [13]. In Phillip et al. study on individuals with chronic unilateral ankle instability, lace-up brace had no significant effect on postural control [14].

Given the variety of results and lack of any study about the effect of bracing on postural control in fatigue condition among subjects with unstable ankle, the present study was designed to investigate the effect of two braces (lace-up and Aircast) on postural control under fatigue condition in volleyball players with unstable ankle.

2. Materials & Methods

Participants

We used stratified sampling method for this study. Of 146 volleyball players in Kerman Province, 41 players with unstable ankle, aged 18-23 years with at least 3 years record of playing in volleyball leagues were selected. After analyzing the distributed Cumberland Ankle Instability Tools (CAIT) questionnaires (Validity 0.84 and reliability 0.83) [15] and physiotherapist confirmation, 15 players were randomly selected as study subjects (mean age 19.46 ± 1.50 years, mean height 182.53 ± 5.28 cm, weight 67.70 ± 5.91 kg, and mean VO_2 max 52.05 ± 2.97 mL/kg/min).

Subjects' selection was done in two steps. In the first step, an information record form, including demographic features and medical history related to diseases or injuries during the last month prior to the study and CAIT questionnaire were distributed among participants. Based on the obtained information, subjects with the history of operation or injury in the ankle, knee, femur and pelvis sites or ankle fracture during the last 6 months, those with visual, auditory or neurological deficits, and those with head trauma resulting in medical interventions were excluded. Then, CAIT questionnaires were investigated. This questionnaire includes 9 questions assessing the severity of ankle instability with a 0-30 score range for each leg in which 27-30 shows stable ankle, while 0-27 represents ankle instability. Accord-

ing to this scoring system, lower scores indicate more instability [15]. In this stage, in order to have more homogeneous subjects, those with ankle instability in their dominant leg and CAIT score of 13-22 were selected.

In the second step, of this group, those volleyball players whose ankle instability was confirmed by a physiotherapist were selected. In order to be ensured of the instability in ankle and determine the instability side, Medial Talar tilt test, Lateral Talar tilt test, and Anterior drawer test (Figure 1) were performed by the physiotherapist [16]. Finally, of 41 remaining subjects, 15 were randomly selected as the study subjects. All selected subjects had inversion ankle instability and based on Fujii table cited in Leumann et al. study [17], the grade of instability was I in 7 and II in 8 participants. After explaining the exact purpose and method of the research for participants and obtaining their informed consent for participation, all 15 volleyball players volunteered to participate in this study.

Measurements

The instruments and tests used in this study were as follows: information record form, CAIT questionnaire with reliability of 0.84 and validity of 0.83 [15], functional fatigue protocol [12], lower extremity length measuring test [12, 18], dominant leg determining test [18], plantar flexor strength test [17], Cooper test with reliability of 0.897 for measuring VO_2 max, maximum jump height test [12], baseline time [12], Biodex Balance System (Balance system SD, Biodex Manufacturing), digital Sergeant jumping device (Masaru D Yagami - War Casualty Summary), lace-up and Aircast ankle braces (Figure 2), and metronome for performing tests.

All tests were performed in sports hall and running track. Some tests such as Cooper test and plantar flexor strength test were used to select a more homogeneous subject group and some others tests such as Sergeant jump, lower limb length, and dominant leg were used as prerequisites of volleyball functional fatigue test.

Fatigue protocol

Each participant was referred to the research laboratory on 4 separate sessions. At the initial session, an assessment of each participant's maximal vertical jump height (Vertmax) was done. First, the standing height of the participant was measured by having him under a digital Sergeant jumping device (Yagami) and reach up to touch the highest point possible while maintaining both feet flat on the ground. Second, participant per-

formed a 2-foot maximal vertical jump reaching to the highest point possible on the Vertec. Each participant was given 3 jump trials, and we recorded the highest jump achieved. The Vertmax was determined by subtracting the standing-reach height from the maximum jump height.

We measured and recorded the length of each participant's testing limb from the anterior superior iliac spine to the distal portion of the medial malleolus. This length was used to determine the reach distance of the lunging task that was part of the functional fatigue protocol. Finally, the functional fatigue protocol was explained and demonstrated to the participants during the initial session. Each athlete was allowed to practice the protocol once to establish a baseline time and perform the protocol a second time while being timed. Five minutes of rest were provided between these 2 trials. The timed trial was used for the other 3 testing sessions to establish the point of fatigue. The functional fatigue protocol comprised 3 stations: Modified Southeast Missouri (SEMO) agility drill (Figure 3.A), stationary lunges (Figure 3.B), and quick jumps (Figure 3.C).

Modified Southeast Missouri Agility Drill: The SEMO agility drill is a series of forward sprints, diagonal backpedaling, and side shuffling. We used a modification form of SEMO that was completed in a rectangle of 3.6x5.7 m (Figure 3.A). At the completion of this station, participants immediately began the stationary lunges station.

Stationary lunges: Activities at this station occurred at the finishing position of the SEMO agility drill. Using an alternating leg pattern, the participant lunged forward with each leg 5 times to a distance equal to the recorded leg length. Pieces of tape on the floor served as the point of origin and the target reaching distance. With a metronome to establish the rate of performance, the participant performed lunges at a rate of 1 lunge per 2 seconds. A lunge cycle was defined as reaching to the target, achieving approximately 90 of hip and knee flexion in the lunging leg while maintaining an upright trunk, and returning the reaching leg to the point of origin. At the completion of the lunges, the participant immediately began the quick jumps station [12].

Quick Jumps: Quick jumps were accomplished near a wall and consisted of 10 quick, 2-foot jumps with both arms above the head reaching for a mark on the wall equal to 50% of the previously measured Vertmax. The participants continued to run through each station until the time to finish the stations increased by 50%

compared with their baseline timed runs. Athletes were given standardized verbal encouragement throughout the protocol. As soon as fatigue was achieved, participants immediately moved to the testing area and began the posttest stand on Biodex Balance System within 5 seconds.

The applied protocol in this study was functional fatigue protocol, including several repeated cycles until achieving fatigue. Each cycle has 3 consecutive stations (SEMO agility drill, 10 lunge stationeries, and 10 vertical jumps). For each subject, the lower extremity length was considered as the distance between two legs in lunge movement. The obtained maximal height jump using sergeant jumping device was used to calculate 50% of maximal jump (part of fatigue protocol). SEMO agility drill (Fig 3.A) includes forward sprints, diagonal backpedaling, and side shuffling. In the present study, modified SEMO agility drill was performed in a rectangle of 3.6×5.7 m. Immediately after SEMO agility drill, lunge movement was performed 5 times by each leg. Finally, there was vertical jump station that started immediately at the completion of lunge movement and includes 10 fast jumps equal to 50% of the subject's maximal jump height. After performing 3 consecutive stations, one cycle was completed and the subject was immediately returned to the starting point to begin the new cycle and repeated cycles until achieving fatigue [12].

Fatigue protocol was performed in 3 conditions (without ankle brace, with lace-up ankle brace, and with Aircast ankle brace) after general warm up (10 minutes slow running and lower extremity stretching exercises) and specific warm up (5 minutes movement patterns like volleyball) at different times. Following fatigue protocol, postural control test was performed by using Biodex device.

Dynamic postural control evaluation: For measuring postural control, athlete single-leg stability testing by Biodex Balance System was used. In this device, the rigidity of platform can be set from difficult level of 1 (the most instability or dynamic state) to level 12 (the most rigid state or static state). In the present study, in order to determine dynamic postural control of athletes

with unstable ankle, the system was set at difficulty level of 4. Each test included three 20-second trials with 10 seconds intervals as rest. Following 3 trials, the device was calculated the stability index [19]. In order to make subjects familiar with the test performance, they were allowed to practice it once before the test. During the study procedure, the fatigued subject was placed on the device in 3 conditions (no brace, wearing lace-up ankle brace, and wearing Aircast ankle brace).

Statistical analysis

In order to investigate the effects of different braces in fatigue condition (F), all two by two comparisons were performed in 3 conditions (no brace [N], lace-up ankle brace [B1], and Aircast ankle brace [B2]) for overall postural control index (O) using 1-way repeated measures analysis to find the significant differences. Prior to performing two by two comparisons, it was necessary to detect significant differences between means by within-subject effects test. In order to test within-subject effects, variances homogeneity and Mauchly Test of Sphericity were used (Table 1). Data analysis was done by SPSS 16 (download from <http://en.softonic.com>) and significance level was $P \leq 0.05$.

3. Results

Two by two comparisons were performed to detect significant differences between means of overall postural control indexes in 3 different conditions (Table 2). The results of 1-way repeated measure analysis (Table 2) show the following points in fatigue condition:

Mean scores of dynamic postural control indexes using Aircast ankle bracing (1.58) and no bracing (1.83) conditions showed significant difference. The decrease (from 1.83 to 1.58) of overall stability index was significant ($P < 0.001$).

Mean scores of dynamic postural control in lace-up ankle bracing (1.53) and no bracing (1.83) conditions showed significant difference. The decrease (from 1.83 to 1.53) of overall stability index was significant ($P < 0.001$).

Table 1. Within-subject effects test.

		Type III sums of squares	df	Mean square	F	Sig.
F-O	Sphericity assumed	0.702	2	0.351	16.477	0.000*
	Greenhouse-geisser	0.702	1.889	0.372	16.477	0.000*

* $\alpha = 0.05$.

Table 2. Paired samples test between mean overall postural control index in three different conditions.

Pairwise comparisons		Mean difference	Std.error	Sig.	95% Confidence interval for difference	
					Lower bound	Upper bound
N-F-O	B1-F-O	0.308	0.050	0.000*	0.199	0.417
N-F-O	B2-F-O	0.254	0.062	0.001*	0.120	0.388
B1-F-O	B2-F-O	-0.054	0.060	0.383	-0.183	0.076

*Based on Sidak ($\alpha=0.017$).

PHYSICAL TREATMENTS

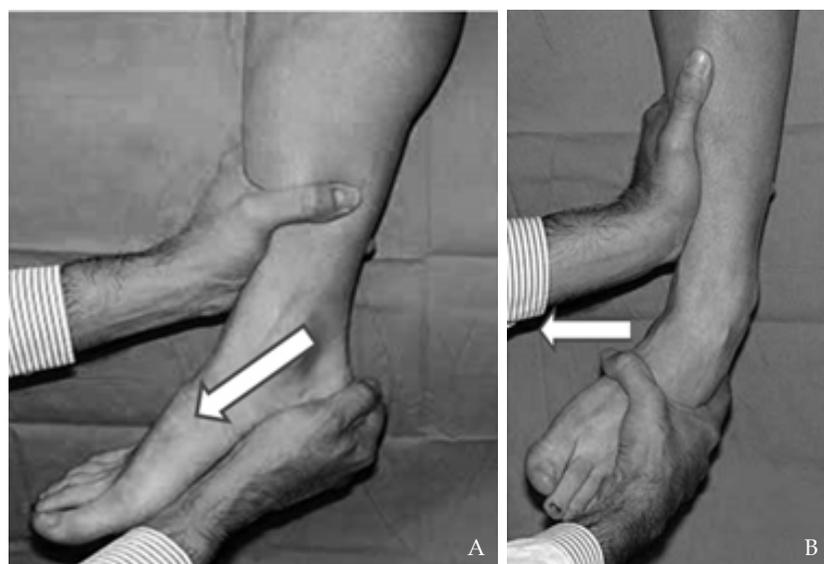
Mean scores of dynamic postural control in Aircast ankle bracing (1.58) and lace up ankle bracing (1.53) conditions showed no significant difference ($P=0.383$). Therefore, there is no significant difference between Aircast and Lace-up ankle bracing and both can improve dynamic postural control under fatigue condition.

The results of the present study agree with the results of Shaw et al. who had reported improvement of postural control by applying lace-up and Active ankle bracing during fatigue condition, but differ with the results of Wikstrom et al. [11] and Phillip et al. [14]. It seems that the difference is related to the effect of fatigue, because the two latter studies, contrary to the present study, had not been performed under fatigue condition.

The peroneus longus muscle is the first defense mechanism against ankle inversion movement. It seems that the reaction time and response magnitude of this muscle

play important roles in preventing inversion forces at the ankle and helping postural control [12]. Fatigue decreases the activity of peroneus longus muscle and neuromuscular conductance velocity [20]. On the other hand, fatigue by decreasing muscular activity through inhibiting motoneuron activity, threatens muscle's functional stability [21]. Bracing can prevent the injury via restriction of the movement domain and its effect on proprioceptive receptors [9]. Studies have shown that bracing increases peroneal motoneuron excitability [21]. Accordingly, brace application increases muscular response through its excitatory effect on skin's mechanoreceptors which results in dynamic postural control improvement.

In fatigue condition muscle spindles and afferent pathways to the central nervous system are desensitized and this condition inversely affects dynamic postural control and consequently increases the possibility of injury



PHYSICAL TREATMENTS

Figure 1. Anterior drawer test (A) evaluates the anterior talofibular ligament. The patient needs to be relaxed, seated with the knee flexed and the ankle plantar flexed around 10 to 20 degrees. One of the examiner's hand stabilizes the tibia and, with the other hand, the foot is pulled forwards. Talar tilt test (B) evaluates the calcaneofibular ligament. With the ankle plantigrade, the hindfoot is tilted one way then the other to assess for asymmetric movement [16].



Figure 2. Lace-up ankle brace (A), Aircast ankle brace (B). **PHYSICAL TREATMENTS**

[22]. In normal condition the excitation signal to muscle contraction is very rapid and an adequate number of motor units are recruited. After initiation of muscle contraction, less motor units are needed for maintaining contraction; however, in fatigue condition the excitation is slow and less motor units are recruited resulting in less muscle contraction. Because brace application helps motor unit recruitment, ankle bracing might be able in recruiting mechanoreceptors that can use motor units even in fatigue condition, which results in improved dynamic postural control.

Lace-up brace has been designed in a way that it can restrict all 4 movements of ankle, but Aircast brace can restrict just inversion and eversion movements and allows plantar and dorsal flexion movements. Because all ankle sprains have a common underlying reason, it is expected that lace-up brace acts better than Aircast brace.

The results of the present study are in agreement with this point. Higher efficiency of lace-up bracing might be due to more afferent messages sent to the central nervous system by skin mechanoreceptors, as lace-up brace compared to Aircast brace covers a greater area and consequently might stimulate more mechanoreceptors resulting in increased afferent messages and amplitude of the peroneus longus reflex. Aircast brace cannot affect mechanoreceptors of skin as much as lace-up brace can (due to the smaller covered area) and for this reason it is less efficient than lace-up brace. Cordova et al. in their study on the amplitude of peroneus longus muscle during brace application, showed that in short-term application (once), the excitatory force of muscle reflex in lace-up bracing is higher compared to semi-rigid bracing, but in long term (8 weeks) excitatory force of muscular reflex is higher in case of Aircast bracing while lace-up bracing has no significant improving effect [23].



Figure 3. The functional fatigue protocol comprised 3 stations. A: Modified Southeast Missouri (SEMO) agility drill [12], B: Stationary lunges, C: Quick jumps. First modified SEMO agility drill was performed, immediately after that lunge movement was performed 5 times by each leg. Finally, there was vertical jump station that included 10 fast jumps equal to 50% of the subject's maximal jump height. After performing 3 consecutive stations, one cycle was completed and the subject immediately returned to the starting point to begin the new cycle and repeated cycles until achieving fatigue [12]. **PHYSICAL TREATMENTS**

Likewise, the results of the present study showed that in short-term application, lace-up brace has better result than Aircast brace with regard to stability.

Almost all ankle sprains in volleyball occur because of two players hitting and approximately half of the sprains occur when the defense player lands on the leg of the opponent's attacker (the attacker is ready for spike and sets his or her jump too short or close to the net). Moreover, one quarter of all sprains occur when the defense player lands on the leg of his/her teammate at multi-person defense. Therefore, middle defense and outer attacker are at higher risk of ankle sprain and the most major mechanism of ankle sprain in volleyball is of the hitting type. Based on the mechanism of ankle injury in volleyball, it is recommended that players with grades 1 and 2 ankle instability in the case of the likelihood of hitting with other players (based on their position in game) apply lace-up or Aircast ankle brace in order to improve postural control and prevent the injury. Because according to the related literature and results of the present study, these two types of braces provide ankle joint stability, applying these braces improves postural control. Therefore, athletes with unstable ankle can improve their dynamic postural control during fatigue by applying a brace and consequently prevent the potential injury resulting from impaired postural control.

4. Discussion

Postural control is one of the key issues in daily and athletic activities [24] and has been identified as an important factor in many athletic skills. Postural control impairment is associated with some injuries, especially acute ankle sprains [25]. Individuals with chronic ankle instability have significantly less postural control compared to healthy individuals [26]. Postural control and performance are not two separate issues and postural control is the origin of all voluntary motor skills [27]. Although postural control deficit in athletes is often not observable, even a minor alteration causes impaired performance [28]. Ankle ligament injury accounts for 44.1% of all volleyball injuries [29]. High prevalence of ankle sprain in volleyball requires more preventive measures in volleyball. The results of the present study showed that in functional fatigue condition, application of both types of ankle braces in athletes with unstable ankle causes significant improvement in dynamic postural control. Therefore, these braces can prevent ankle sprain by the mechanism of improving postural control.

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