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Research article

Evaluating The Effect of Elastic Ankle Support On Running Foot Strike Patterns: A Comparison of Chronic Ankle Instability Patients with Healthy Controls

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ABSTRACT

Background: Elastic ankle supports can effectively prevent recurrent ankle sprains but little is known about how habitual running characteristics such as foot strike patterns are influenced. The objective was to examine the effect of elastic ankle support on foot strike patterns of individuals with Chronic Ankle Instability (CAI) in comparison to healthy controls.

Methods: Three-minute running trials at 2.[illegible] m/s of 20 individuals with CAI and 20 healthy controls were recorded with a 3D motion capture system and video cameras. Foot strike patterns were classified as non-rear foot strikes and rear foot strikes according to the foot part that initiated ground contact. Measurement conditions (with vs. without ankle support) were applied in random, counterbalanced order. A regression analysis via binomial Multilevel-Logit-Model was applied to examine the effect of ankle support on foot strike patterns for both groups.

Results: Ankle support was a significant predictor for rear foot striking prevalence for both groups (p<0.001). The significant group by ankle support interaction effect (p<0.001) indicated that the prevalence of rear foot striking increased significantly for the control group but decreased for the CAI group.

Conclusion: Foot strike patterns of individuals with CAI and healthy controls were influenced by an elastic ankle support. Mechanical stability provided by the ankle support might be responsible for changes in foot strike patterns.

Keywords: Bandage; Ankle sprain; Ankle brace; Orthosis; Prevention

INTRODUCTION

Consistently over the last years, high incidence rates of ankle sprains have been reported in the general population and among highly active individuals [1,2]. Up to 70% of individuals who sustain an acute ankle sprain continue to suffer from symptoms like pain, inflammation, and weakness known as Chronic Ankle Instability (CAI) [1,3,4]. Additionally, to these complaints, individuals with CAI exhibit altered walking and running ankle kinematics compared to healthy counterparts [5-8]. In an overview of systematic reviews, six reviews with 46 individual reports were unanimous in their consensus that braces and taping are effective in the treatment of acute ankle sprains for self-reported function and recurrence [9]. Possible mechanisms that might be responsible for the preventive effects of ankle supports have been studied in recent years. Depending on the type of support, mechanical stability is provided [10-12]. Several studies showed that wearing an ankle support influences running ankle kinematics [7,12,13]. Especially in the sagittal plane, a brace can reduce ankle angle range of motion during

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running, lead the ankle joint in a more neutral position during the initial swing phase, and therefore possibly prepare the ankle to be in a more stable position at the subsequent touchdown [7,14]. In the frontal plane, results are less consistent and dependent on the biomechanical foot model used [15].

Sagittal plane ankle angle at touchdown depends highly on whether the individual strikes with the heel, mid foot, or forefoot [16]. It is, therefore, reasonable to assume that wearing an ankle brace might also influence foot strike patterns. The prevalence of rearfoot or non-rearfoot strikes is influenced by several factors such as footwear, habituation, surface conditions, or running speed [17-21] but nothing is known regarding the effects of external joint support (braces, orthoses, taping) which is often used during sports activities in order to prevent the ankle from giving way. One hypothesis that can be made is that the mechanical stability provided by the brace possibly supports the lower leg and foot muscles and ligaments and therefore stabilizes foot strike patterns. Especially foot strikes of individuals with CAI who might suffer from weakness or instability could be more influenced by the ankle brace compared to those of healthy counterparts who have sufficient musculoskeletal capabilities in the ankle joint complex [22]. Therefore, this study aimed to examine the effects of elastic ankle support on foot strike patterns during running in individuals with CAI and healthy controls. Results could help to better understand the influence of external ankle joint stabilization on running patterns, as a part of the return to sport process in individuals with CAI.

MATERIALS AND METHODS

Subjects

Twenty young adults with CAI and 20 healthy controls who volunteered for study participation were recruited from the local university campus. The definition, inclusion, and exclusion criteria for CAI individuals were based on the position statement of Gribble, et al., [23]. For inclusion in the CAI group, the initial ankle sprain must have occurred at least 12 months and the most recent sprain must have occurred more than 3 months before the study enrolment. The ankle sprain had to be associated with inflammatory symptoms (pain, swelling, and bruising) and led to an interruption of desired physical activity for at least one day. Additionally, episodes of "giving way" and/or "feeling of instability" had to be reported for the injured ankle. The severity of the CAI was tested with the "Cumberland Ankle Instability Tool" (CAIT) [24]. As described by Gribble, et al., [23], cut-off points for the CAIT were scores of ≤ 24. For CAI subjects who suffered ankle sprains on both ankles, the ankle with the weaker CAIT score was chosen as the testing limb.

The same questionnaire was also used for the recruitment of healthy controls. Scores above the previously mentioned cut-off values were necessary to participate as a control subject. In the case of equal CAIT scores for both ankles, the preferred leg for single-leg landing was chosen as the test limb. Exclusion criteria for both groups included a history of previous surgeries to the musculoskeletal structures, a fracture in either lower extremity requiring realignment, and acute injuries to the musculoskeletal structures of other joints of the lower extremity in the previous 3 months. Every participant received a study information sheet. Before the beginning of the measurements, participants signed written informed consent. Ethical approval has been obtained by the local ethics committee (Protocol number: FSV 18/09).

Testing procedure

At first, anthropometric measurements of height, weight, and ankle circumference at the malleoli were taken. The size of the ankle support (Tricodur TaloMotion life, BSN medical, Hamburg, Germany) ranging from small (17 cm) to double extra-large (29 cm) was chosen according to the ankle circumference. Two viscoelastic pelottes inside the fabric of the elastic ankle support provided compression and stabilization of the ankle [7,25]. Footstrikes were recorded with a 3D motion capture system (Qualisys, Göteborg, Sweden). Ten infrared cameras and two high-resolution (1080p) video cameras were directed at an instrumented treadmill (Bertec Corporation, Columbus U.S.A.). Measurement conditions (with vs. without ankle support) were applied in random, counterbalanced order with a 5-minute recovery period between both running trials.

To build a lower body model, 26 passive reflective markers were attached to specific anatomic landmarks (anterior and posterior superior iliac spine, lateral side of the greater trochanter, femur lateral and medial epicondyle, proximal tip of the head of the fibula, most anterior border of the tibial tuberosity, lateral prominence of the lateral malleolus, medial prominence of the medial malleolus, distal aspect of the Achilles tendon insertion on the calcaneus, dorsal margin of the first, second and fifth metatarsal head) of the lower extremity according to Leardini, et al., [26]. A one-segment foot model was applied since the participants were running in their habitual running shoes and cutting holes for marker placement was not performed. An L-frame and a calibration wand (length 601.3 mm) were used to establish the origin of the coordinate system and the recording volume, respectively. Static calibration was executed during the still standing of the participant. After familiarization with the two belted treadmill surface participants walked at a comfortable walking speed for about one minute. Thereafter the treadmill speed was gradually increased until the running speed of (2.78 m/s) was reached. Each running trial lasted 180 s.

Data acquisition and statistical analysis

Foot strike patterns were analyzed with Qualisys Track Manager (version 4.3.0.0 Qualisys, Göteborg, Sweden). Since a pure forefoot strike is less common among runners [17,27] and is not always easy to distinguish from a mid-foot strike, both strike types were classified as a non-rearfoot strike [16]. Some of the participants changed their strike patterns multiple times per trial. Therefore, each foot strike of the tested foot was individually classified by analyzing the foot position at touchdown with the lower body model of Qualisys Track Manager and video material and opted against computing an algorithm that automatically classifies the strike patterns according to the marker position, ankle angle or force plate data. Foot strikes in which the heel of the foot contacted the ground first were classified as rearfoot strikes. When simultaneous landing of forefoot and rearfoot was apparent or the forefoot contacted the ground first the foot strike was classified as a non-rearfoot strike [16]. One trained member of the research team classified the foot strikes and in cases where foot strikes were uncertain, a second trained team member classified the foot strike and a consensus was established. With a recording frequency of 200 Hz foot strikes could be analysed at 0.005 s intervals. Statistical analyses were performed with JASP (JASP Team 2020, version 0.14.1) and R (R Core Team, 2020; version 4.1.3). Means and standard deviations are reported in the descriptive data. Group differences were analysed with a Student's t-test. In case equal variance was violated Welch test was applied. The effects of group (CAI vs. controls) and test condition (with and without ankle support) on the probability of rearfoot striking were analyzed with a multilevel logit model (random intercepts, multiple foot strikes nested within subjects).

RESULTS

Table 1 shows descriptive data of individuals with CAI and healthy controls. The CAI group included 12 females and 8 males (Age: 23.3 ± 3.3 years, Height: 173.3 ± 8.9 cm, Mass: 68.4 ± 11.6 kg, BMI: 22.7 ± 3.0 kg/m2). The control group consisted of 5 females and 15 males (Age: 25.5 ± 3.4 years, Height: 176.3 ± 7.7 cm, Mass: 73.8 ± 9.6 kg, BMI: 23.7 ± 2.3 kg/m2. The CAIT score was 16.4 ± 3.7 for the CAI group and 28.8 ± 1.8 for the control group. Students t-test presented significant differences in age (p=0.04) and sex distribution (p=0.025). Welch-test displayed significant differences in CAIT scores (p= <0.001) (Table 1).

	CAI group (n=20)	Control group (n=20)	P
Age (years)	23.3 ± 3.3	25.5 ± 3.4	0.04
Sex (m, f)	8 m, 12 f	15 m, 5 f	0.025
Height (cm)	173.3 ± 8.9	176.3 ± 7.7	0.263
Mass (kg)	68.4 ± 11.6	73.8 ± 9.6	0.12
BMI (kg/m2)	22.7 ± 3.0	23.7 ± 2.3	0.25
CAIT score	16.4 ± 3.7	28.8 ± 1.8	<0.001

Table 1: Characteristics of individuals with CAI and healthy controls (mean ± SD). Between-group differences are presented with p-values.

The number of analyzed foot strikes was nearly identical at both running conditions (245 ± 12 strikes with and 245 ± 12 strikes without ankle support) and in both groups (245 ± 13 strikes in CAI and controls). Out of the 20 CAI patients, n=16 showed exclusively rearfoot strikes and n=4 exclusively forefoot strikes during the three-minute running trail without the external ankle support. Two rearfoot striking CAI patients changed foot strike patterns while wearing the external joint support towards a more mixed forefoot and rearfoot use. Out of the 20 healthy controls, n=14 were exclusively rearfoot strikers and n=6 showed mixed running patterns without the ankle support. Six healthy controls changed foot strike patterns while wearing the external joint support. Three of them increased and three subjects reduced the amount of rearfoot strikes (Table 2).

	Estimate	Std. error	t Value	Pr (>|z|)
(Intercept)	15.175	2.22	6.836	<0.001
CAI group	4.678	2.814	1.662	0.097
Condition with ankle support	0.417	0.093	4.502	<0.001
CAI group* with ankle support	-5.846	0.888	-6.583	<0.001

Table 2: Results of the multilevel-logit regression. Test group, running condition and their interaction were chosen as the predicting variables and probability of rearfoot strikes as the depending variable.

Table 2 shows the results of the multilevel-logit model. The prevalence of rearfoot striking was higher in the CAI group compared to the control group but the effect was not significant (p=0.097). Secondly, the prevalence of rearfoot striking was higher when subjects were running with ankle support (p<0.001). The group by ankle support interaction for foot strikes was also significant (<0.001) indicating that the prevalence of rearfoot striking increased significantly for the control group but decreased for the CAI group.

DISCUSSION

The goal of the study was to examine the influence of an elastic ankle support on foot strike patterns in individuals with CAI and healthy counterparts. Our results show that wearing an ankle support overall increased the probability of rearfoot striking. The interaction effect between both predictors (group and ankle support condition) was significant indicating that the probability of rearfoot striking increased significantly for the control group but decreased for the CAI group. To our knowledge, this is the first study that examined the effect of ankle support on foot strike patterns. Previous reports for running demonstrated the effect of ankle support on ankle kinematics in healthy controls and specifically in the sagittal plane in individuals with CAI . We hypothesized this effect may be, at least partially, a result of a change in foot strike patterns. Although our primary hypothesis was partially confirmed by our results the mechanisms for this phenomenon are not fully understood. Ankle kinematics are commonly presented as angles throughout the gait cycle while foot strike patterns have a different data pattern. Previous examinations are inconsistent at which part of the gait cycle individuals with CAI differ in sagittal ankle angles from healthy controls. This leads to uncertainty about which of these phases is crucial for the effect of the joint support . Tamura, et al., and Stotz, et al., both showed decreased sagittal ankle angles at the toe-off phase when the ankle is at maximal plantar flexion during running. However, in theory, ankle sprains occur during the touchdown when ground reaction forces get applied on the unstable ankle . In this phase, both authors reported no significant differences. Previous results about the effect of ankle support on ankle kinematics in CAI and healthy populations cannot be directly compared with our results for foot strike patterns. For instance, out of the six control group subjects who changed their foot strike patterns when wearing elastic ankle support, three subjects increased, and three subjects reduced the amount of rearfoot strikes. The associated increments and decrements in sagittal ankle angles might balance each other and therefore no changes in ankle angles of the six subjects would be detectable. Nevertheless, we assume that changes in foot strike patterns just like the changes in ankle kinematics are the result of reduced mechanical instability through a range of motion restriction provided by the ankle support .

Although CAI subjects are known to exhibit proprioceptive deficits compared to healthy controls a review from Raymond, et al., concluded that using an ankle brace or ankle tape has no effect on joint position sense and movement detection in participants with recurrent ankle sprain or functional ankle instability. Thus, while ankle bracing is generally effective in preventing recurrent ankle injuries in CAI patients it can be concluded that other mechanisms than alterations of peripheral proprioception mechanisms cause this effect. In this context, it has been reported in a review by Bain, et al., that individuals with more than one lateral ankle sprain have increased levels of injury-related fear and decreased psychological health compared to healthy controls. While ankle support did not improve performance in the star excursion balance test or the hopping test it provided multiple psychological benefits like significantly improved participants' perceptions of confidence, stability, and reassurance and also decreased anxiety for injury or re injury . Further research using e.g., placebo tapes is needed to examine whether psychological factors of ankle support can influence foot strike patterns.

Due to the preventive effect of ankle support on recurrent sprains, we also expected that foot strikes of subjects with CAI could be more influenced by the ankle brace compared to those of healthy counterparts. However, this was not confirmed by the results of the present study. More subjects in the control group (n=6) changed foot strike patterns during the ankle support conditions than the CAI groups (n=2). Previous studies already reported a high adaptability of foot strike patterns to changing external and internal conditions such as fatigue, running speed, or footwear conditions . The increase in non-rearfoot strikes when running barefoot or with minimalist shoes has often been attributed to the lack of cushioning and shoe weight as well as a higher flexibility of the foot . The elastic ankle support we used for the current study did not change ankle range of motion John t al. and the shoes were the same in both running conditions. Thus, we can only speculate regarding the underlying mechanisms responsible for the higher prevalence of rearfoot strikes when using ankle support. One reason might be a change in ankle stiffness and knee stiffness that has already been observed during acute changes in footwear conditions Sinclair et al. Another possibility is the unfamiliarity with the elastic ankle support leading to more careful movement patterns with voluntary or involuntary adaptations of foot strike behavior . Whether the ankle support can help to maintain the running technique and strike pattern compared to the pre-sprain conditions remains speculative. Since it can provide additional mechanical stability to the ankle joint complex and is also effective in the prevention of recurrence sprains it can be recommended for use in sports practice along with other effective injury prevention measures .

A few limitations need to be addressed in the context our results. Running trials were relatively short and therefore our study cannot provide further information on how the ankle support influences strike patterns in long-distance running or fatigued states. We assume that the effect may be even stronger because runners tend to switch their foot strikes with increased distance and it has been shown that changes in ankle kinematics persist through 25-30 min of exercise . The running speed was set at a fixed speed for all trials. It has been shown that running speed influences foot strikes and forefoot strikes are more prevalent with higher speeds . Therefore, it is unknown how faster or slower running speeds would interact with the ankle support. We did not analyze the effect of the elastic ankle support on the contralateral leg. In some CAI subjects, one ankle was affected, and others had ankle sprains in both ankles. Therefore, analyses of heterogeneous ankles seemed inadequate. Lastly, the difference in age and sex distribution between groups might have influenced our results. Although they are not specific predictors for foot strike patterns they generally influence components like muscles, tendons and bones around the ankle joint .

CONCLUSION

Foot strike patterns of individuals with CAI and healthy controls were influenced by an elastic ankle support. Further, an interaction effect was apparent indicating a group-specific effect of the ankle support. The mechanical stability provided by the ankle support might be responsible for the changes in foot strike patterns. Although further research is necessary on whether the effect of the ankle support on running patterns is related to the preventive effect against recurrence sprains the usage of an ankle support is recommended during the rehabilitation process. Also, further research with longer running durations or other running speeds is necessary to further examine the effect of ankle supports on running patterns.

AUTHOR CONTRIBUTION

Astrid Zech, Andreas Stotz, Anna Lina Rahlf and Danial Hamacher planned and designed the study. Andreas Stotz, Cornelius John, Julian Gmachowski, and Ralf Schwenksbier performed data collection. Andreas Stotz wrote the manuscript. Daniel Hamacher and Andreas Stotz performed statistical analysis and data interpretation. Astrid Zech, Karsten Hollander, Anna Lina Rahlf and Daniel Hamacher revised and edited the manuscript.

RETRACTED

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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