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The effectiveness of rearfoot medial wedge intervention on balance for athletes with chronic ankle instability

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Abstract

Background: Athletes with chronic ankle instability (CAI) often develop complications such as pain, instability, and reduced postural control and balance stability, all of which affect athletic performance. This study investigated the effects of a 4° medal wedge intervention on static and dynamic balance in athletes with CAI.

Methods: The participants were 24 healthy and 25 CAI athletes. Participants received a 4° medial wedge applied at the rear foot insole and completed the experiment measurements before and after the wedge intervention. The main outcome measures included the area and path length of the center of pressure when participants performed single-leg standing balance in the closed eye condition and the dynamic balance scores of a multiple single-leg hop stabilization test.

Results: The single-leg standing balance significantly improved in CAI ($P=.027$) and control groups ($P=.005$) after the medial wedge intervention. The dynamic balance scores significantly decreased from 53.00 ± 25.22 to 41.24 ± 21 48 ($P=.015$) in CAI group after medial wedge intervention.

Conclusion: Wearing a 4° medial wedge applied at the rear foot insole improved static and dynamic balance immediately in athletes with CAI. We suggest that clinicians may provide the foot insole to improve balance deficit in athletes having CAI.

Abbreviations: CAI = chronic ankle instability, CAIT = Cumberland ankle instability tool, COP = center of pressure.

Keywords: chronic ankle instability, insole, orthotics, posture control

1. Introduction

Lateral ankle sprain is a common injury in sports.[1,2] Previous studies have shown that 15% to 45% of athletes sustain lateral ankle sprains and that over 70% of athletes with a history of ankle sprains sustain repeated injuries in the future. Of those with repeated injuries, 75% develop chronic ankle instability (CAI).[2–4]

Common symptoms of CAI are a buckling sensation in the ankle and ankle instability and pain when engaging in functional activities.[4] In a previous study, researchers found that anterior talar positional fault was more prevalent in CAI limbs than in non-CAI limbs and that CAI may cause structural changes in the bone alignment of the subtalar joint and ankle joint.[5] These changes could alter the neuromuscular control of the ankle and the foot pressure of athletes during weight-bearing activities, increasing the likelihood of post-traumatic ankle osteoarthritis.[5,6] Athletes with CAI often develop other complications such as pain, instability, a buckling sensation of the ankle, reduced proprioceptive function, and reduced postural control and balance stability, all of which affect athletic performance.[4,7]

In a previous study, researchers found that the postural sway of athletes with CAI increased.[8] Wikstrom et al[5] invited 16 healthy subjects, 16 subjects with 1-time ankle sprain (copers), and 16 subjects with CAI to participate in an activity in which they were instructed to stand on 1 leg on a force plate with their eyes open. Comparison results showed that mediolateral and anteroposterior sway velocity was greater in the CAI subjects than in the copers and healthy controls, validating that ankle instability affected postural control and balance stability.[5] CAI affects both static and dynamic balance. Wikstrom et al[6] invited 24 controls, 24 copers, and 24 subjects with ankle instability to participate in an activity in which they were instructed to perform a single-leg hop stabilization maneuver. Comparison results indicated poorer anteroposterior stability in the subjects with ankle instability than in the copers and controls. Nyska et al[9] invited 12 subjects with recurrent ankle sprains and 12 healthy subjects to participate in an activity in which they were instructed to walk at their own pace. Comparison results showed that a lateral shift in body weight during the stance phase was often exhibited in the subjects with recurrent ankle sprains. Morrison

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et al[10] examined the plantar pressure of 15 healthy subjects, 15 subjects with 1-time ankle sprains, and 15 subjects with CAI during a walking exercise and also found that the subjects in the CAI group exhibited an outward shift in foot pressure distribution. The findings of the aforementioned studies show that CAI affects the static and dynamic balance of athletes and causes athletes to shift the center of foot pressure distribution outward. Therefore, improving the balance of athletes with CAI is a major challenge for clinical practitioners and vendors specializing in preventing sports injuries.

Foot orthoses can be broadly categorized into 2 types: braces and insoles. They have been validated in previous studies to be an effective means to treat patella-femoral pain syndrome, plantar fasciitis, foot pain, and other lower-limb injuries.[11,12] Braces are a type of external support to prevent ankle sprains, and insoles help correct patients' foot structures to relieve pain and discomfort. Insoles are easy to make, and they can be used in conjunction with different wedges to correct improper foot postures. Insoles vary depending on their function. A wedge, 1 part of an insole, can be placed on the inside or outside of the foot to meet patients' requirements. Wedges have become integral components of foot orthoses. At present, however, the therapeutic effects of insoles for CAI remain unclear.[13–15] Chang et al[13] tested different medial heel wedge interventions on eight students with CAI and found that the inner-heel medial wedge with an elevation of 4° achieved the most favorable results in improving the subjects' balance with their eyes closed. Hertel et al[14] developed interventions using 5 different insoles. However, none of the interventions effectively improved the balance of subjects with ankle sprains. Hamlyn et al[15] examined the improvement in postural control and balance stability of 40 patients with ankle sprains after insole intervention. Results showed that insoles effectively increased postural stability when participants had their eyes closed. However, the aforementioned studies failed to address whether custom-fitted insoles or wedges improved the balance stability of subjects with ankle instability. From the aforementioned studies, no conclusion can be drawn concerning the level of improvement that medial wedges provide for subjects with CAI. Therefore, this study aimed to elucidate the benefits of inner-heel medial wedge intervention on the static and dynamic balance of athletes with CAI.

2. Materials and methods

2.1. Participants

The participants were a CAI group comprising 25 athletes with CAI and a control group comprising 24 healthy athletes, all of them were recruited from collegiate athlete team members (Table 1). The inclusion criteria for the CIA group were that the subjects must

(1) have a history of at least 1 lateral ankle sprain incident in which immobilization was required or load-bearing was prohibited,[7]
(2) have experienced ankle pain, instability, and buckling in the 12 months before intervention,
(3) have received a Cumberland ankle instability tool (CAIT; Appendix 1, http://links.lww.com/MD/D65) score of 27 or lower,[16]
(4) have no incident of brain or acute lower-limb injury or history of ankle joint fracture in the 3 months before intervention, and
(5) have experienced at least 1 incident of recurrent ankle sprain between 3 and 6 months before the intervention.

Intervention commenced once this study was approved by the Medical University Hospital Institutional Review Board.

2.2. Test instruments and procedures

All tests were performed twice. Tests were conducted before the medial wedge intervention (hereafter referred to as "the intervention") and immediately after the intervention. All subjects were instructed to wear the same athletic shoes (ASICS GEL-STRIKE 3 T1G3N-0191) throughout the intervention period.

2.3. Static balance measurement

We primarily tested the subjects' static and dynamic balance. The Zebris FDM distribution measurement system (FDM-TB, Zebris, Germany) was used to evaluate static balance. This evaluation tool is a high-quality capacitance sensor that can assess the subjects' dynamic gait, static center of pressure (COP) area of the foot, displacement path, and pressure distribution. In this study, the COP displacement area and displacement path length of the subjects while standing still on 1 leg were adopted as the indicators for static balance. During the tests, the subjects were instructed to stand on 1 leg on the Zebris FDM system while keeping the other leg raised at a 90° angle, hands on hips, and eyes closed. A set of headphones was also provided to the subjects for vestibular interference. The subjects were instructed to hold their positions for 10 seconds. Tests were conducted before the intervention and immediately after the intervention. Three sets of data were collected per test, and the average results were recorded. Records included COP displacement area and length of displacement path. A smaller COP area represented better static balance stability, and a shorter length of the displacement path represented better neuromuscular control in the lower limbs.

2.4. Dynamic balance tests

A multiple single-leg hop stabilization test was adopted to evaluate dynamic balance.[17] White tape was used to create 11 squares of 2.5*2.5 cm on the floor. The subjects were instructed to hop on 1 leg to different points marked by the squares, depending on their height, while holding the other leg raised backward, facing forward, and keeping their hands on their hips. They were required to step on the mark for 5 seconds. Two researchers were positioned in front of the mark to observe the subjects' body and foot positions on landing. Errors were categorized into landing and balance errors. Landing errors consisted of not landing on-point, stumbling, foot not forward-facing, ankle varus and valgus angles greater than 10°, and hands leaving hips. Balance errors consisted of landing on the non-test leg, contact between test leg and non-test leg, movement of non-test leg forward, backward, or sideways, and hands leaving waist. The 2 researchers summed the scores for the landing and balance errors and calculated the averages. The average landing error score was then multiplied by 10, and the balance error score was multiplied by 3. The 2 products were then summed to obtain the total score for dynamic balance error. A higher score represented poorer balance.

2.5. The intervention of medial wedge

Medial wedges with an elevation of 4° were used in this study. They were adhered to the inner heel section of the subjects' insoles

(Fig. 1). The elevation and position of the wedges were determined by a pre-test trial could improve the balance for collegiate students with CAI.[13] All subjects were ignorant of the function of the medial wedge and blinded to the intervention.

2.6. Statistical analyses

Statistical analyses were performed in SPSS 18.0 for Windows (SPSS Inc, Chicago, IL). The independent variables were the 2 subject groups (control and CAI groups) and 2 times of intervention (before intervention and after intervention). The demographics of the 2 subject groups were compared by independent samples *t* test. Then the differences between the static and dynamic balance of the 2 groups were analyzed and compared by repeated measures 2-way analysis of variance. All data are presented as mean and standard deviation values. The significance level was $\alpha = 0.05$.

3. Results

The homogeneity of the subjects' demographics was examined by independent samples *t* test. The age, height, weight, and daily athletic shoe-wearing time did not differ significantly between the 2 groups. Only the CAIT scores were significantly lower in the CAI group than in the control group ($P < .001$). The demographics of the 2 groups are tabulated in Table 1.

The statistical analysis showed no interactions in the static balance and dynamic balance between the 2 groups or between pre-test and post-test. Significant differences between the pre-test and post-test were exhibited only within each group ($P < .05$; Tables 2 and 3).

4. Discussion

The major finding of this study was that in the short-term, the static COP displacement path and dynamic balance of the subjects in both the CAI and control groups improved after the medial wedge intervention, suggesting that a medial wedge with an elevation of 4° immediately provides significant improvement in the balance of CAI athletes.

Lateral ankle sprains and subsequent CAI developments often lead to poor alignment of static or dynamic foot posture. Van Bergeyk et al[18] used computerized tomography to compare the heel alignments of control subjects and subjects with CAI and found increased varus alignment in the calcaneus of the CAI subjects under non-weight-bearing conditions. In weight-bearing conditions, the CAI subjects would compensate for calcaneus valgus, which increases the likelihood of lateral ankle sprain-induced structural subtalar joint hypermobility.[19] Mattacola et al[20] invited subjects with heel misalignment to participate in an intervention with a prefabricated, full-length insole. The subjects were instructed to wear a foot orthosis for 6 weeks. One-

Figure 1. Medial wedge with an elevation of 4° glued to insole of the athletic shoes.

Table 1

Participant demographics.

Participates	CAI group (mean ± SD)	Control group (mean ± SD)	$F_{(2,\ 47)}$	*P*
N	25	24		
Age, yr	19.80 ± 1.38	20.17 ± 1.93	3.684	.45
Height, cm	172.64 ± 7.53	172.29 ± 9.42	1.003	.89
Weight, kg	69.08 ± 11.39	69.38 ± 13.76	1.119	.94
CAIT score	21.36 ± 3.90	29.29 ± 0.86	16.704	<.001
Shoe-wearing duration, h/d	4.24 ± 1.90	3.88 ± 1.90	0.721	.40
Testing side (R/L)	15/10	20/4	$\chi^2 = 3.267$	.071
Gender (M/F)	23/2	18/6	$\chi^2 = 2.590$	.138

CAI = chronic ankle instability, CAIT = Cumberland ankle instability, SD = standard deviation.

Table 2

The results of balance parameters in the CAI and control groups.

	CAI group (N = 25)			Control group (N = 24)		
	Pre-test (mean ± SD)	Post-test (mean ± SD)	*P*	Pre-test (mean ± SD)	Post-test (mean ± SD)	*P*
Static balance						
Area, mm^2	605.54 ± 250.53	581.92 ± 248.14	.687	589.97 ± 264.94	558.75 ± 241.04	.421
Path length, mm	823.15 ± 232.64	720.53 ± 160.28	.027*	785.38 ± 313.67	697.51 ± 240.72	.005*
Dynamic balance	53.00 ± 25.22	41.24 ± 21.48	.015*	42.83 ± 20.78	39.88 ± 19.51	.452

CAI = chronic ankle instability, SD = standard deviation.
* $P < .05$.

Table 3

The repeated measures 2-way ANOVA results of the balance parameters between CAI and control group.

	Within-subject (pre-post)			Between-subject (group)			Interaction (group × pre-post)			
	F	*P* value	Partial Eta Squared	*F*	*P* value	Partial Eta Squared	*F*	*P* value	Partial Eta Squared	Power
Static balance										
Area, mm^2	0.616	.436	0.013	0.095	.759	0.002	0.012	.914	0.000	0.051
Path length, mm	13.262	.001*	0.220	0.225	.637	0.005	0.079	.779	0.002	0.059
Dynamic balance	6.097	.017*	0.115	1.100	.300	0.023	2.180	.146	0.044	0.304

ANOVA = analysis of variance, CAI = chronic ankle instability, SD = standard deviation.
* $P < .05$.

leg and 2-leg standing balance tests were performed before the intervention, immediately after the intervention, and 2, 4, and 6 weeks after the intervention. Results indicated that the foot orthosis improved subjects' heel misalignment while enhancing their balance capabilities. In this study, we referenced these results and applied the wedges to the subjects' heels. However, whether to place the wedge on the inside or outside of the heel and the elevation of the wedge was unclear. Chang et al[13] tested medial and lateral wedges having elevations of 0°, 2°, 4°, and 6° on 8 subjects with CAI while they performed eyes-closed and eyes-open, single-leg-standing balance activities. Results showed that the medial wedge with an elevation of 4° was the most effective in minimizing the subjects' sway area. Therefore, we selected medial wedges with an elevation of 4° as the foot orthosis in the treatment intervention.

The results of this study showed that after the wedge was applied to the athletic shoes, the static COP displacement paths of the subjects in the CAI group visibly improved, suggesting that the neuromuscular control in their ankles improved, possibly because the heel wedge increased the contact area between the bottom of the foot and the orthotics. Tactile stimulation and proprioceptive feedback under the foot increased concurrently with the contact area, thereby improving static balance.[21–23] Hamlyn et al[15] examined the improvement in the eyes-closed, single-leg-standing postural stability of 40 subjects with ankle sprains after an intervention with a fabricated, full-length insole. Results showed that insoles effectively increased the postural stability when participants had their eyes closed. However, the validation period was only 2 weeks. The primary difference between the study of Hamlyn et al and this study was that in Hamlyn's study, a fabricated, full-length insole was adopted, whereas we used only heel wedges. Nonetheless, the outcomes of the subjects in the control group showed that the intervention developed in this study effectively improved their static and dynamic balance.[15] Ganesan et al[24] applied lateral and medial wedges to 20 healthy subjects to examine the effects of wedges on their postural sway. The researchers found that wedges also improved standing postural control and asserted that wedges could change the joint alignment and adjust the compensatory muscle contraction of healthy people, thereby improving their balance. In this study, we found that the effects were similar in the control group. Alternatively, the tests were conducted with the subjects wearing athletic shoes. Athletic shoes have comfortable soles, which could be a contributing factor in the improved balance.[25]

Dynamic balance refers to the ability to maintain postural stability when transitioning from a static state to a mobile state. Dynamic balance is typically functional and is required to perform movements. Favorable dynamic balance necessitates muscle strength, proprioceptive functions, and neuromuscular control.[26] Different tests have been developed to measure the dynamic balance of athletes with CAI,[27,28] including instrumented measures and clinical evaluations. The Star Excursion Balance Test and multiple single-leg hop stabilization test are the methods most widely employed by clinical practitioners and researchers to evaluate the effects of lateral ankle sprains on the dynamic balance of CAI patients.[26,29] Both methods are relatively easy to perform, and neither requires complex instruments or equipment. They are also highly credible and reliable. In this study, we chose the multiple single-leg hop stabilization test because the movement and jumping activities in the test are associated with the actions that athletes have to perform on a day-to-day basis. These activities include jumping left, right, forward, and backward, and researchers are required to observe the postural stability of athletes as they land.[26,27,29] Therefore, the multiple single-leg hop stabilization test was employed in this study.

A previous study found that athletes with lateral ankle sprains are more likely to exhibit outward COP displacement in the contact phase of gait while walking or running, which increases the risk of recurrent lateral ankle sprains and dynamic balance deficit.[10] In this study, we found that a 4° prefabricated medial wedge can improve the dynamic balance of athletes with CAI. Lee et al[30] examined the changes in the proprioceptive function, dynamic balance, and functional balance of 41 patients with CAI after custom-fitted foot orthotics and rehabilitation exercise for 4 weeks. Results showed that the effects of foot orthotics were no less than those of the rehabilitation exercises. However, the benefit of foot orthotics was that they could be applied immediately to improve balance. Therefore, they would be less time- and cost-intensive than long-term rehabilitation exercises.

This study has the following limitations:

(1) in clinical practice, medial wedges are usually adhered to the insoles before being placed into athletic shoes. However, the properties and materials of athletic shoes may affect the test results. To control bias, we provided the same make and model of the shoes to all subjects.
(2) Subjects with CAI may have prior foot deformations or problems.

The intervention carried out in this study entailed adhering a medial wedge to the heel section of the insole. Therefore, problems concerning the forefoot or midfoot were excluded from this study. Future researchers can consider comparing the effects that full-length insoles and rearfoot medial wedges have on subjects with CAI, and also comparing the long-term wedge intervention effects.

5. Conclusion

The major finding of this study is that applying a medial wedge with an elevation of 4° to foot orthoses can immediately improve the static and dynamic balance of athletes with CAI. We suggest that clinical practitioners can introduce foot orthoses during early treatment to enhance sensory input to the foot and improve balance.

Author contributions

The conception and design of the study (Chang H-Y, Chang Y-C, Wang C-H), or acquisition of data (Chang H-Y, Chang Y-C), or analysis and interpretation of data (Chang H-Y, Chang Y-C, Cheng S-C, Wang C-H);

Drafting the article or revising it critically for important intellectual content (Chang H-Y, Chang Y-C, Cheng S-C, Wang C-H);

Final approval of the version to be submitted (Chang H-Y, Chang Y-C, Cheng S-C, Wang C-H).

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