©Journal of Sports Science and Medicine (2016) **15,** 352-357
http://www.jssm.org

Research article

Effect of Semi-Rigid and Soft Ankle Braces on Static and Dynamic Postural Stability in Young Male Adults

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Abstract

Ankle braces have been suggested to protect ankle joints from a sprain by restricting inversion and improving proprioception. However, the difference in effects between a semi-rigid brace and a soft brace regarding dynamic postural control after landing is not known. The aim of the present study was to compare the effect of soft (SB) and semi-rigid (SRB) ankle braces on static and dynamic postural stability in healthy young men. Altogether, 21 male adults (mean age 24.0 ± 1.5 years) were assessed for one leg while wearing non-brace (NB), SB or SRB. Balance in single-limb stance on a single-force platform with open eyes and closed eyes were assessed for the non-dominant leg under SB, SRB, and NB conditions. Locus length/second (mm/s) and the enveloped area (mm·s^{-2}) surrounded by the circumference of the wave pattern during postural sway were calculated. For assessing dynamic postural stability, the participant jumped and landed on one leg on a force platform, and the Dynamic Postural Stability Index (DPSI) and the maximum vertical ground reaction force (vGRFmax) were measured. The data were compared among the three conditions with repeated-measures analysis of variance. The correlations between locus length/second, enveloped area, DPSI values (DPSI, Anterior-Posterior Stability Index, Medial-Lateral Stability Index, and Vertical Stability Index), and vGRFmax were then calculated. The results indicated that locus length/second and enveloped area with open eyes and closed eyes were not significantly different for each condition. However, a significant lower in the DPSI and Vertical Stability Index were observed with the SRB in comparison to the SB and NB. A significant improvement in vGRFmax was also observed with the SRB in comparison to NB. SRB demonstrated a positive effect on dynamic postural stability after landing on a single leg and may improve balance by increasing dynamic postural stability.

Key words: Ankle brace, static postural balance, dynamic postural balance, Dynamic Postural Stability Index.

Introduction

Ankle sprain occurs commonly among athletes in sports (Hootman et al., 2007; Mack et al., 1982; van den Bekerom et al., 2012). An ankle sprain accounts for 14.8% of all injuries in collegiate sports, and the athletes who participate in activities that involves jumping and landing, such as basketball and volleyball, have a higher chance of ankle sprain (Hootman et al., 2007). Pain, decreased range of motion, and functional instability occur as a result of ankle sprains (Ivins et al., 2006). Yeung et al. (1994) reported that 30.2% of patients experience pain. Ankle sprains recur at a high rate (56–74%) (McKay et al., 2001), and repeated ankle sprain leads to chronic ankle instability. Because chronic ankle instability incurs enormous economic and social costs, preventing lateral ankle sprain recurrence is important.

Ankle braces are used as one of the preventive measures against ankle sprains. The benefit of the ankle brace includes: 1) decreasing anterior tibial shear force; 2) decreasing range of motion in ankle and subtalar joints; 3) improving ankle proprioception facilitated by mechanoreceptors; and 4) maintaining dynamic balance ability (Hardy et al., 2008). An ideal ankle brace should protect the ankle from lateral ligament injury without restraining its normal movement.

There are various ankle braces, including soft braces, semi-rigid braces, and rigid braces. The braces are prescribed widely to prevent sports injuries during athletic practice or competitions and treat them if they do sustain an injury. Sitler et al. (1994) reported that use of a semi-rigid brace (SRB) could significantly reduce the frequency of ankle injuries. Clinically, SRBs are believed to help athletes with functional ankle instability by improving neuromuscular control and mechanical stability. The ability of ankle braces to prevent ankle sprain, however, is still debatable (McGuine et al., 2012).

Although a number of studies have investigated the effect of ankle braces on postural control, evidence on the effects of ankle braces on postural control is still inconclusive. Guskiewicz and Perrin (1996) and Baier and Hopf (1998) reported the positive effects of ankle braces on postural control. To the best of our knowledge, however, there have been no comparisons of the effects of soft braces (SB) and SRBs on static or dynamic postural control after landing.

Dynamic postural control can be assessed using the Dynamic Postural Stability Index (DPSI) (Wikstrom et al., 2006). The DPSI assesses balance while the subject transits from a dynamic to static state in single-leg hop stabilization maneuver. Thus it is a functional measurement of neuromuscular control (Wikstrom et al., 2006).

The effects of the SB, SRB, and no brace (NB) on static and dynamic balance could have implications for athletes, trainers, and rehabilitation staff. The difference in the effects of SRB and SB on static and dynamic postural control after landing is not known. The purpose of this study was to compare the effects of SBs and SRBs on static and dynamic postural control. We hypothesized that there are no difference between interventions in static

Received: 13 November 2015 / Accepted: 25 April 2016 / Published (online): 23 May 2016

postural sway and dynamic postural stability.

Methods

Participants

A total of 21 healthy, young, recreationally active men [age 24.0 ± 3.6 years (mean ± SD); height 1.74 ± 0.06 m; body weight 63.1 ± 14.4 kg] voluntarily participated in this study. “Recreationally active” was defined as having participated in at least one exercise session per week during the preceding 2 months but no involvement in structured exercise training during this period (Costa et al., 2009). Exclusion criteria of this study were: 1) current ligamentous defects; 2) history of a grade II or higher sprain; 3) history of ligament or joint reconstruction or repair; 4) trauma (including fracture, myositis ossificans, burns); or 5) dysfunction of the vestibular system affecting balance. All the participants never used any of the braces used in this study. The power for each analysis of variance (ANOVA) was not less than 0.65 for an effect size more than 0.8 (Cohen et al., 1998). The Ethics Committee of the Graduate School of Health Sciences, Hiroshima University approved the study protocol (ID number, 1411).

Intervention

Subjects were assigned to three randomly ordered experimental conditions (NB, SB, SRB). Their order experimental conditions were counterbalanced across subjects. The participants performed under three brace conditions (SB, SRB, NB) in various orders on three separate days, with an intersession interval of at least 24 h and no more than 48 h between tests. Braces were fitted to each subject by a single investigator in order to minimize within-subject and between-subject variations.

Ankle brace

Zamst ankle braces (Nippon Sigmax Devices, Inc., Tokyo, Japan) were used in this study. The SB (Zamst FA-1) was a nylon supporter and was designed with two layers of support for weak and swollen ankles while allowing dorsiflexion/plantar flexion (Figure 1). An inner wrap adjusts with a hook-and-loop closure to provide compression and control of the ankle and heel area. The SRB (Zamst A1) was a nylon supporter and included L-strap and Y-strap stabilizers. It is designed to resist inversion loads while allowing dorsiflexion/plantar flexion and stabilize the ankle joint (Figure 2). Braces were fitted to each subject by a single investigator in order to minimize within-subject and between-subject variations.

Test protocol

To compare the effect of each condition, we measured both static postural sway and dynamic postural stability under SB, SRB, and NB conditions. Static postural sway was performed during single-leg standing on a single-force platform (UM-BAR; Unimec Corporation, Tokyo, Japan). Participants were asked to maintain an upright posture and place both arms on the hip for 30 seconds with their eyes open (EO) and then closed (EC). During the EO test, the participant looked forward at a wall approximately 3.0 m from the edge of the force platform. The unsupported leg was kept at approximately 30° of hip flexion and 60° of knee flexion. If the unsupported leg touched the weight-bearing foot or force platform, the trial was discarded and repeated. Statokinesigrams were obtained showing the entire range of postural sway from the central position on a chart.

Dynamic postural stability was evaluated using a single-leg jump landing in the anterior direction. This approach was chosen because it demonstrated good intersession reliability: intraclass correlation ICC (3,k) was 0.86 (Wikstrom et al., 2006). Subjects positioned 40% of their body height away from the edge of the force plate, and a 30-cm hurdle was placed at the midpoint between the starting position and the force plate.

Figure 1. Soft brace (ZAMST FA-1; SIGMAX Devices, Inc., Japan). Soft brace was a nylon supporter and was designed with two layers of support for weak and swollen ankles while allowing dorsiflexion/plantar flexion.

Figure 2. Semi-rigid brace (ZAMST A-1; SIGMAX Devices, Inc., Japan). Semi-rigid brace was a nylon supporter and included L-strap and Y-strap stabilizers

The participants were instructed to perform the following actions: jump in the anterior direction using a two-footed jump over the hurdle, land on the force plate on the non-dominant limb only, stabilize as quickly as possible, place their hands on their hips once they were stabilized, and remain still for 10 second while looking forward. Upper extremity movement was unrestricted during the jump but restricted after stabilization. They were allowed three practice trials for each condition to become familiar with the single-leg jump, with 1 min of rest after testing.

The jump-landing task was performed on the non-dominant leg for unilateral assessment. The non-dominant limb was the limb that was not used to kick a ball. Niu et al. (2011) suggested that the non-dominant leg might work more effectively in postural stabilization. Therefore, the non-dominant limb was used as the landing leg.

The measurement under each condition was conducted on different days to prevent fatigue and to avoid the subject becoming familiar with the task. The trial was discarded and done over if the subject failed to jump or came into contact with the hurdle, fell upon landing, or the non-dominant limb came in contact with the dominant leg or the ground outside the force plate. All subjects were able to complete the task. Three successful trials were performed under each condition (NB, SB, SRB),. The average duration of each laboratory trial was 52.0 ± 3.0 minutes.

Data collection

The locus length/second (mm/s) and enveloped area (mm^2) surrounded by the circumference of the wave pattern during postural sway in static postural control. Signals of static postural sway were amplified and sampled at 200 Hz via an analog-to-digital converter. The DPSI and maximum vertical ground reaction force (vGRFmax) were measured after each protocol using a force plate (AccuGait; AMTI, Hiratsuka, Kanagawa, Japan). The ground reaction force (GRF) data to calculate the DPSI in dynamic postural stability were also collected at the sampling frequency of 200 Hz. The global reference system of the laboratory was established so the anteroposterior axis was in the y-axis direction, the mediolateral axis was the x-axis, and the vertical axis was the z-axis.

The GRF data were filtered using a zero-lag, fourth-order, low-pass Butterworth filter with a frequency cutoff of 20 Hz.From these filtered data DPSI was calculated using a Microsoft Excel macro. The dependent variable was the DPSI, as shown in Table 1.

The DPSI is a composite of the anteroposterior, mediolateral, and vertical GRFs. It provides stability indices for anteroposterior (APSI), mediolateral (MLSI), and vertical (VSI) directions. The DPSI was calculated using the GRFs generated in 3 s immediately following initial contact, which was identified as the instant when the vertical GRF exceeded 5% of the body weight. The force plate data were normalized to the body weight. This study also used raw data signals to calculate the vGRF-max, which was calculated by dividing the peak force (N) with the participant's body weight. The mean of three successful trials for each condition was utilized for further analysis (Wikstrom et al., 2006).

Statistical analysis

A repeated-measures 1 (time) × 3 (NB, SB, SRB) ANOVA model was used for comparisons of locus length/second, enveloped area, and each DPSI value (DPSI, MLSI, APSI, VSI) and vGRFmax for each condition. When appropriate, follow-up analyses were performed using Bonferroni post-hoc tests. An alpha level of 0.05 was the criterion for rejection of the null hypothesis for all statistical tests. Effect sizes were calculated using the Cohen d statistic. Statistical analysis was conducted using SPSS for Windows, version 20.0 (IBM Japan Co., Tokyo, Japan).

Results

In the measures of static postural sway, the locus lengths/second and enveloped areas with OE (open eye) and CE (closed eye) were no significant differences among the three brace conditions.

The DPSI (APSI, MLSI, VSI) and vGRFmax for the three conditions are shown in Table 2. The DPSI values of each index in the measure of dynamic postural stability are shown in Table 2. DPSI for the SRB condition was significantly lower than that for the NB condition and the SB condition. There was no significant difference between the NB and SB conditions. The VSI with the SRB was significantly lower than that with the NBand the SB. The vGRF with the SRB was significantly lower than that with the NBcondition. There was no significant difference between the NB and SB conditions. DPSI, APSI, MLSI, VSI, and vGRFmax did not differ significantly among the three conditions.

Table 1. Equations for calculation of APSI, MLSI, VSI and DPSI.

Variable	Equation
APSI	$\sqrt{\frac{\Sigma(0-\text{GRFx})^2}{\text{Number of data point}}} \div \text{Body Weight}$
MLSI	$\sqrt{\frac{\Sigma(0-\text{GRFy})^2}{\text{Number of data point}}} \div \text{Body Weight}$
VSI	$\sqrt{\frac{\Sigma(0-\text{GRFz})^2}{\text{Number of data point}}} \div \text{Body Weight}$
DPS	$\sqrt{\frac{\Sigma(0-\text{GRFx})^2+\Sigma(0-\text{GRFy})^2+\Sigma(\text{Body Weight}-\text{GRFz})^2}{\text{Number of data point}}} \div \text{Body Weight}$

DPSI : Dynamic Postural Stability Index ; APSI : Anterior-posterior stability index; MLSI: Medial-lateral stability index; VSI: Vertical stability index ; GRF : Ground Reaction Force

Table 2. Values for Dynamic Postural Stability Index, directional components, and vGRFmax according to ankle brace condition. Data are means (±SD).

Variable	Condition			P-value	Effect Size	Observed Power
	NB	SB	SRB			
Dynamic Postural Stability Index (DPSI)	.32 (.01)	.32 (.01)	.31 (.01)	.014	.38	.78
Anterior-posterior stability index (APSI)	.14 (.01)	.13 (.01)	.13 (.02)	.315	.12	.23
Medial-lateral stability index (MLSI)	.03 (.01)	.03 (.00)	.03 (.01)	.508	.07	.15
Vertical stability index (VSI)	.29 (.02)	.29 (.03)	.28 (.03)	.005	.44	.88
vGRF max (%BW)	1.90 (.23)	1.90 (.24)	1.84 (.25)	.037	.31	.66

NB, Non Brace; SB, Soft supoort Brace; SRB, Semi-rigid support Brace; vGRF max, maximum vertical grand reaction force; %BW, % body weight. *Effect size was calculated using the formula $f = d^* \sqrt{1/2k}$, where $d = (mmax - mmin) / \sigma$ and k = the number of treatments. Observed power was generated by SPSS software.

Discussion

The aim of this study was to compare the effects of the SB, SRB, and NB interventions on static and dynamic postural stability in healthy young men. The primary finding of the study was that the DPSI and VSI were significantly lower with the SRB than with the SB or NB, although the APSI and MLSI remained unchanged. Therefore, our primary hypothesis was not reasonably supported. Sell et al. (2013) suggested that higher stability indices and DPSI scores reflect worse dynamic postural stability. The SRB had the most significant effect on dynamic posture control after landing. In addition, vGRFmax was significantly lower with the SRB than with NB. This result suggests that SRB may contribute to reducing stress on the musculoskeletal system during dynamic activity by decreasing energy absorption in the vertical direction following ground contact.

The DPSI is a composite of anteroposterior, mediolateral, and vertical GRFs. Wikstrom et al. (2006) found that SRBs contribute to dynamic balance. A significant decrease in VSI might explain the reduction in DPSI compared with those found with the SB and NB conditions. Thus, SRB may influence the stability of postural control after landing. However there were no differences for MLSI and APSI. Previous study suggested that MLSI was higher and APSI was lower in lateral side jump-landing task than forward jump-landing task for healthy subjects (Brown et al., 2010). Therefore there may be the influence for dynamic postural stability with ankle brace by the jump direction in the value of MLSI and APSI. Additionally, We confirmed jump-landing for the non-dominant leg. Niu et al. (2011) suggested that the non-dominant leg may work more effectively in postural stabilization. Although, we used a non-dominant leg, it is necessary to consider the difference between non-dominant and dominant leg in the future.

To the best of our knowledge, this is the first study to show that the SRB improved dynamic postural control, compared with the results with the SB and NB. DPSI values did not differ significantly between the SB and NB conditions. Bennell and Goldie (1994) reported similar results regarding dynamic postural control in healthy individuals. We did not investigate the change in the range of motion of the ankle or muscle activation for each condition. These measurements will be made in a future study.

In this study, locus length/second and enveloped area under OE and CE conditions showed no significant difference among the three conditions. The SB and SRB seemed to have no effect on static postural control during one-leg standing. Various mechanisms, such as improvement in proprioception or exteroception and mechanical support, have been proposed to explain how SBs and SRBs may improve postural control. We could not rule out any of these mechanisms in this study. Hadadi et al. (2011) reported that postural sway on single-leg standing increased progressively from the NB condition, to the SB condition, to the SRB condition, suggesting an adverse effect of the SRB when compared with that of the SB on static postural control in healthy individuals. Only the immediate response of the posture with the use of ankle braces was assessed in this study. Evaluation of balance performance in the single-leg stance on a force plate may not reflect actual activities in daily life and sports. The bracing effects should therefore be tested in more realistic conditions and environments. Namely, the effects of different positions and motions with brace intervention on dynamic posture stability must be examined in a future study. Defects in dynamic posture stability after landing are related to an increased burden on knee joints and the presence of sports injuries and trauma to the lower extremities (Sell et al., 2013). The results of the present study may contribute to clarifying the effects of different brace interventions.

Some limitations in the study need to be considered. First, the subjects were untrained and not experienced with the landing technique. Second, we analyzed only healthy men. An increased number of subjects of both sexes will allow analysis by sex. And the patient with injured chronic ankle instability will analysis and compare the healthy subjects. Third, this study investigated the immediate effect of the braces. The long-term effects of the braces must be addressed in a future study. Further studies are necessary to investigate under other activities, including side jumping and cutting maneuvers. Moreover, the effect of ankle braces on muscular activities and strength should also be explored.

Conclusion

We demonstrated that the SRB had significantly lower DPSI, VSI, and vGRFmax values after landing than were seen with the SB or NB. This result indicated that the SRB had positive effects on dynamic postural stability in healthy young men. Use of SRB is thus more likely to improve the ability to maintain dynamic balance than the SB or NB. Athletic trainers and athletes are advised to consider the effect of each ankle brace in regard to preventing ankle sprains because each ankle brace may have a positive but different effect on dynamic postural stability after landing on a single leg.

Acknowledgements

None of the authors has any conflicts of interest associated with this study. The author had no financial affiliations and/or involvement with any commercial organization.

References

Baier, M. and Hopf, T. (1998) Ankle orthoses effect on single-limb standing balance in athletes with functional ankle instability. *Archives of Physical Medicine and Rehabilitation* **79**, 939-944.

Bennell, K.L. and Goldie, P.A. (1994) The differential effects of external ankle support on postural control. *Journal of orthopaedic and sports physical therapy* **20**, 287-295.

Brown, C.N., Bowser, B., and Orellana, A. (2010) Dynamic postural stability in females with chronic ankle instability. *Medicine and Science in Sports & Exercise* **42,** 2258-2263.

Cohen, J. (1998) *Statistical power analysis for the behavioral science. Statistical power analysis for the behavioral sciences rev*. Lawrence Erlbaum Associates, Inc.

Costa, P.B., Graves, B.S., Whitehurst, M. and Jacobs, P.L. (2009) The acute effects of different durations of static stretching on dynamic balance performance. *Journal of Strength and Conditioning Research* **23**, 141-147.

Guskiewicz, K.M. and Perrin, D.H. (1996) Effect of orthotics on postural sway following inversion ankle sprain. *The Journal of Orthopaedic and Sports Physical Therapy* **23**, 326-331.

Hadadi, M., Mazaheri, M., Mousavi, M.E., Maroufi, N., Bahramizadeh, M. and Fardipour, S. (2011) Effects of soft and semi-rigid ankle orthoses on postural sway in people with and without functional ankle instability. *Journal of Science and Medicine in Sport* **14**, 370-375.

Hardy L., Huxel K., Brucker J. and Nesser T. (2008) Prophylactic ankle braces and star excursion balance measures in healthy volunteers. *Journal of Athletic Training* **43,** 347-351.

Hootman, J.M., Randall, D. and Agel, J. (2007) Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of Athletic Training* **42**, 311-319.

Ivins, D. (2006) Acute ankle sprain: an update. *American Family Physician* **74**, 1714-1720.

Lynch, S.A. (2002) Assessment of the injured ankle in the athlete. *Journal of Athletic Training* **37,** 406-412.

Mack, R.P. (1982) Ankle injuries in athletics. *Clin Sports Med* **1**, 71-84.

McGuine, T.A., Hetzel, S., Wilson, J., and Brooks, A. (2012) The effect of lace-up ankle braces on injury rates in high school football players. *American Journal of Sports Medicine* **40,** 49-57.

McKay, G.D., Goldie, P.A., Payne, W.R. and Oakes, B.W. (2001) Ankle injuries in basketball: injury rate and risk factors. *British Journal of Sports Medicine* **35**, 103-108.

Niu, W., Wang, Y., He, Y., Fan, Y. and Zhao, Q. (2011) Kinematics, kinetics, and electromyogram of ankle during drop landing: a comparison between dominant and non-dominant limb. *Human Movement Science* **30**, 614-623.

Sell, T.C., Pederson, J.J., Abt, J.P., Nagai, T., Deluzio, J., Wirt, M.D. and Lephart, S.M. (2013) The addition of body armor diminishes dynamic postural stability in military soldiers. *Military Medical Research* **178**, 76-81.

Sitler, M., Ryan, J., Wheeler, B., McBride, J., Arciero, R., Anderson, J. and Horodyski, M. (1994) The efficacy of a semirigid ankle stabilizer to reduce acute ankle injuries in basketball: A randomized clinical study at West Point. *American Journal of Sports Medicine* **22**, 454-461.

van den Bekerom, M.P., Struijs, P.A., Blankevoort, L., Welling, L., Van Dijk, C.N. and Kerkhoffs, G.M. (2012) What is the evidence for rest, ice, compression, and elevation therapy in the treatment of ankle sprains in adults?. *Journal of Athletic Training* **47**, 435-443.

Wikstrom, E.A., Arrigenna, M.A., Tillman, M.D. and Borsa, P.A. (2006) Dynamic postural stability in subjects with braced, functionally unstable ankles. *Journal of Athletic Training* **41**, 245-250.

Yeung, M.S., Chan, K.M., So, C.H. and Yuan, W.Y. (1994) An epidemiological survey on ankle sprain. *British Journal of Sports Medicine* **28**, 112-116.

Key points

- This study examined the effect of ankle braces on healthy young individuals during dynamic postural stability using the DPSI.
- The semi-rigid brace improved dynamic postural stability compared with the soft brace and no brace.

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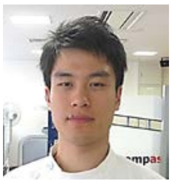

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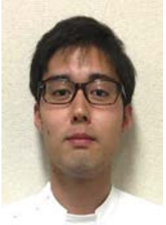

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