Effect of 3 Different Ankle Braces on Functional Performance and Ankle Range of Motion

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ABSTRACT

The Seattle Ankle Orthosis (SAO) is a prophylactic ankle brace designed to restrict ankle motion, with straps extending from a cuff around the distal leg to the lateral aspect of the shoe midsole. To date, no laboratory or clinical research about the SAO has been performed. Our purpose was to assess range of motion (ROM) and functional performance measures in 4 brace conditions: SAO, lace-up brace, semirigid brace, and no brace. Twenty-four healthy, young adults participated in this crossover study. Ankle ROM in all 4 directions was significantly restricted by all braces, compared with no brace; however, the SAO restricted inversion ROM significantly more than the other 2 braces. Vertical jump height was significantly reduced in all brace conditions, compared with no brace. No differences in agility or static balance measures between conditions were noted. The SAO had comparable effects on ROM and functional performance to lace-up and semirigid braces.

Prophylactic ankle bracing has been reported to reduce ankle injury.[1-3] Athletic trainers recommend that athletes use ankle braces more and ankle taping less because of the ease of application, effectiveness, and cost.[4] Olmsted at al[4] performed a cost–benefit analysis and reported that over a course of a season, ankle taping was approximately 3 times more expensive than ankle braces and that braces may be superior in injury prevention. However, athletes are more concerned with performance than cost and thus may be less likely to wear an ankle brace if the device results in deleterious consequences in performance.

Typically, there are 2 different classifications of ankle braces that have been researched: semirigid and lace up. These ankle braces fit into athletes' shoes and are designed to restrict range of motion (ROM). Excessive inversion is the typical mechanism of injury for a lateral ankle sprain; thus, braces are intended to primarily restrict this motion. In a landmark meta-analysis conducted in 2000, Cordova et al[5] evaluated the published literature on the effectiveness of various ankle supports on ankle joint ROM. Overall, they found that semirigid ankle braces significantly reduced inversion ROM, compared with lace-up braces. Ubell et al[6] evaluated semirigid and lace-up braces, compared with an unbraced condition, on forced inversion following a jump landing. Overall, they found that both types of braces prevented inversion, compared with the unbraced condition; however, only the semirigid brace significantly reduced inversion, compared with no brace.[6] Eversion ROM was also more restricted in semirigid braces, compared with lace-up braces.[5] Semirigid braces are not designed to restrict plantar flexion or dorsiflexion; however, lace-up braces were found to significantly restrict both motions.[5] Overall, Cordova et al[5] concluded that semirigid braces provide the greatest mechanical support to prevent ankle sprains; however, functional performance was not evaluated.

In a follow-up meta-analysis, Cordova et al[7] evaluated the same kinds of ankle braces on traditional

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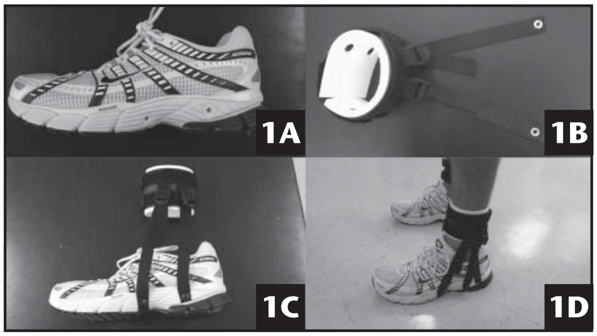

Figure 1. The Seattle Ankle Orthosis (SAO; R&D Medical, Lake Forest, California) brace. (A) The Nike Air Pegasus+ with the brace anchors. (B) The SAO brace, unattached to the shoe. (C) The SAO and the shoe. (D) The SAO brace, attached to the shoe.

functional performance measures. On calculating effect sizes, it was concluded that semirigid and lace-up braces had trivial to small effects on sprint speed, agility, and vertical jump performance. For all 3 outcome measures, semirigid and lace-up braces had small point estimates (–0.22 to 0.05), representing insubstantial to small effects. The effect size confidence intervals all crossed zero, indicating that the braces may be detrimental or beneficial to performance.

A new prototype brace, the Seattle Ankle Orthosis (SAO; R&D Medical, Lake Forest, California), was developed to restrict foot motion yet not hinder performance (Figure 1). The brace consists of a proximal plastic collar that is secured around the shank just proximal to the malleoli. Attached to the plastic collar are 2 nylon straps that are secured to the lateral aspect of the shoe's sole—one in line with the lateral malleoli, and the second in the lateral cuboid region proximal to the styloid process of the fifth metatarsal. The design of the SAO theoretically prevents inversion and plantar flexion at initial contact between the shoe and the ground. By increasing the eversion moment arm through its more lateral attachment on the shoe, inversion ROM is likely to be more restricted and the risk of ankle sprains may be decreased more than with traditional braces. Currently, there is no published research on a brace with this design. However, there is a need to determine whether this novel design restricts inversion and plantar flexion or alters functional performance. Therefore, the purpose of the current study was to determine how the SAO compares with commonly used braces (a lace up and a semirigid) and a no-brace condition on ROM and during functional testing. Our outcome measures were an agility run, maximal vertical jump height, static balance, and ROM. Our hypothesis is that the SAO will limit inversion ROM, compared with the control condition and the other brace types but will not have a detrimental effect on vertical jump, agility, or balance.

METHOD

This cross-over laboratory study evaluated one independent variable with 4 levels (SAO, lace up, semirigid, no brace) on nonweight-bearing ROM (dorsiflexion [DF], plantar flexion [PF], inversion [IV], eversion [EV]) and various functional outcomes (agility run, maximal vertical jump height, balance).

Participants

Twenty-four healthy, physically active, male participants (height = 180.9±6.4 cm; mass = 80.2±8.0 kg; age, 20.9±2.7 years) with no previous history of musculoskeletal injury to the knees or ankles were included in the study. This study protocol was approved by the institutional review boards at the University of Virginia and Virginia Military Institution, and all participants provided written informed consent prior to data collection. All research was conducted at these 2 institutions.

Testing Procedures

Each participant was tested on the same day in 4 conditions: the SAO, an ASO lace-up ankle brace (Medical Specialties Inc, Charlotte, North Carolina), an Aircast Airsport semirigid ankle brace (DJO LLC, Vista, California), and an unbraced control condition (Figure 2). The ASO and Aircast Airsport were chosen as representatives of braces commonly worn by athletes. Participants were fitted for each brace in accordance with the manufacturer's guidelines. Nike Air Pegasus+ shoes (Nike Inc, Beaverton, Oregon) were worn for each condition. For the SAO condition, the brace was screwed in and out of anchors previously inserted into the midsole of the shoe. For testing, participants wore the braces bilaterally and were instructed to retighten each brace between each test.

The order of conditions was counterbalanced via a Latin square. The order of outcome measurements was consistent across all participants: vertical jump, static balance using a modified Balance Error Scoring System (BESS), agility run using the southeast Missouri (SEMO) configuration, and nonweight-bearing active ROM: PF, DF, IV, and EV. The order of testing was

Figure 2. Ankle braces used in this study. (A) The Seattle Ankle Orthosis (R&D Medical, Lake Forest, California); (B) ASO lace up (Medical Specialties Inc, Charlotte, North Carolina); (C) Aircast Airsport semirigid (DJO LLC, Vista, California).

chosen to reduce the chance of fatigue throughout the testing session. One investigator (A.P.) measured and recorded all outcomes of interest. For all conditions and outcome measures, participants were encouraged to perform each task to the best of their ability.

The maximal vertical jump was performed using a Vertec jump training system (Vertec Sports Imports, Hilliard, Ohio). Participants started from a standing position and were allowed to use a countermovement but were not allowed to step into the jump.[8] This was performed 3 times with a 30-second rest between each trial. Vertical jump was determined by the maximum jump height minus standing reach height. The intratester reliability for the vertical jump measure was calculated from the 3 trials in the control condition (intraclass correlation coefficient $[ICC]_{3,1} = 0.97$).

For the modified BESS test,[9] each participant stood on 1 leg for 20 seconds with his or her hands on the iliac crests and the eyes closed. Participants were instructed to remain as motionless as possible. During each trial, the researcher recorded errors for any of the following: (1) opening eyes; (2) lifting the forefoot or the heel; (3) stepping or stumbling; (4) removing the hands from the iliac crests; (5) moving the hip more than 30° of flexion or abduction; and (6) being out of test position for more than 5 seconds. This was performed bilaterally 4 times; first on the stable gym floor (firm) followed by an unstable (foam) Airex Pad (Perform Better, Craston, Rhode Island), with each trial alternating between each leg. The errors were summed for a total for each limb on the floor and unstable surface for each brace condition. The intratester reliability for the BESS test measures were calculated from the 3 trials in the control condition ($ICC_{3,1} = 0.70$ for firm and 0.56 for foam).

The SEMO agility run uses running-forward sprinting, diagonal back pedaling, and lateral shuffling within a regulation basketball key.[10] Each participant was allowed to become familiar with the course prior to the time trials. For testing, a researcher (A.P.) with a hand-held stopwatch started the time when the participant left the starting position and stopped the time when the participant's foot crossed the line at the end. Three complete trials were obtained. Participants were given up to 1 minute of rest between trials. The intratester reliability for the agility measure was calculated from the 3 trials in the control condition ($ICC_{3,1} = 0.76$).

A standard goniometer was used to measure range of motion for PF, DF, IV, and EV in each condition. For PF and DF, participants were positioned sitting with their knees bent to 90° so the lower leg was hanging off the table.[11] Inversion and EV were measured with the participant in the prone position with the feet off the table, measuring from the rearfoot.[12] Each measurement was obtained 3 times. The intratester reliability for the range of motion measures was calculated from the 3 trials in the control condition ($ICC_{3,1} > 0.96$ for each of the 4 directions).

Statistical Analysis

Each test was performed 3 times, and the mean of the 3 trials was used for data analysis. To assess the effect of brace condition on the 8 dependent variables, a one-way multivariate analysis of variance (MANOVA), with repeated measures on brace condition, was the initial statistical test performed. In the event of significant main effect for brace with the MANOVA, the results of individual one within factor ANOVA with repeated

TABLE

Means±Standard Deviations (95% Confidence Intervals) for All Outcome Measures in Each Brace Condition (n = 24)

		BRACE		
OUTCOME MEASURE	CONTROL	SAO	LACE UP	SEMIRIGID
Dorsiflexion ROM (°)	13.0±4.9 (10.9, 15.1)	11.4±4.4[a] (9.5, 13.2)	10.0±4.5[a,b] (8.1, 11.9)	10.9±4.5[a] (9.0, 12.8)
Plantar flexion ROM (°)	48.3±8.0 (44.9, 51.6)	41.8±6.2[a] (39.1, 44.4)	38.5±7.0[a,b] (35.5, 41.4)	39.3±6.1[a] (36.8, 41.9)
Inversion ROM (°)	19.4±5.5 (17.1, 21.7)	8.4±3.7[a,c,d] (6.9, 10.0)	14.0±3.2[a] (12.6, 15.3)	12.1±4.1[a] (10.4, 13.8)
Eversion ROM (°)	16.6±5.2 (14.4, 18.8)	14.2±4.4[a] (12.3, 16.0)	12.6±4.6[a,b] (10.7, 14.5)	10.6±3.5[a-c] (9.2, 12.1)
Vertical jump (cm)	53.0±6.6 (50.2, 55.8)	51.1±5.3[a] (48.9, 53.3)	51.6±6.1[a] (49.1, 54.2)	51.6±6.1[a] (49.1, 54.2)
Agility (sec)	10.1±0.9 (9.7, 10.5)	10.1±0.9 (9.7, 10.5)	10.0±0.8 (9.7, 10.4)	10.2±0.9 (9.8, 10.6)
BESS, firm (errors)	9.3±3.3 (8.0, 10.7)	9.3±2.9 (8.1, 10.6)	9.6±3.1 (8.2, 10.9)	10.2±2.9 (9.0, 11.4)
BESS, foam (errors)	18.7±2.7 (17.5, 19.8)	19.0±2.4 (18.0, 20.0)	19.5±2.9 (18.3, 20.7)	18.8±2.5 (17.8, 19.9)

Abbreviations: SAO, Seattle Ankle Orthosis (R&D Medical, Lake Forest, California); ROM, range of motion; BESS, Balance Error Scoring System.
[a] Significantly less than the control condition ($P < .05$).
[b] Significantly less than the SAO brace ($P < .05$).
[c] Significantly less than the lace-up brace ($P < .05$).
[d] Significantly less than the semirigid brace ($P < .05$).

measures were examined for each dependent variable. For those dependent variables that had a significant main effect for bracing with the ANOVA, pairwise comparisons using Fisher's least significant difference were computed to identify significant differences between specific brace conditions. Alpha was set a priori at $P \leqslant .05$.

RESULTS

Means and standard deviations for all outcome measures in each brace condition are shown in the Table. The MANOVA revealed a significant main effect for brace condition ($P < .01$). For vertical jump, there was a significant ANOVA main effect for brace condition ($P < .01$). All 3 brace conditions significantly reduced vertical jump height, compared with the unbraced control condition, with the mean differences ranging from 1.3 to 1.8 cm ($P < .04$). Post hoc tests revealed no significant differences in the vertical jump height among the 3 braces ($P > .21$). No significant ANOVA main effect for agility ($P = .70$) or BESS performance on either the firm ($P = .60$) or foam ($P = .25$) surfaces was noted.

Significant ANOVA main effects for brace condition for all 4 ROM measures (DF, PF, IV, EV) were seen. All 3 braces significantly reduced ROM, compared with the control condition, in DF ($P < .04$), PF ($P < .01$), IV ($P < .01$), and EV ($P < .01$). Compared with the lace-up brace, the SAO allowed significantly more DF ($P = .05$), PF ($P < .01$), and EV ($P < .01$) but significantly less IV ($P < .01$). Similarly, the SAO allowed significantly more PF ($P = .05$) and EV ($P < .01$), as well as significantly less IV ($P < .01$), compared with the semirigid brace. However, there was no statistical difference between the SAO and the semirigid brace in DF ROM ($P = .71$).

DISCUSSION

Our primary finding was that all 3 braces (SAO, lace up, and semirigid) resulted in decreased ankle ROM, compared with the control condition. As hypothesized, the SAO restricted IV ROM more than the lace-up and semirigid braces. We also found that all 3 braces were associated with diminished vertical jump performance. Agility and static balance were not affected by any of the ankle braces.

The primary design of ankle prophylactic braces is to restrict frontal plane motion. Although all 3 braces significantly reduced IV ROM, compared with the unbraced condition, the SAO restricted IV significantly more, compared with the other 2 braces. In relation to the SAO, the mean differences were 10.9°, 5.4°, and 7.3° of IV restriction for no brace, the lace-up brace, and the semirigid brace, respectively. In addition, the effect sizes between the SAO and other braces were d = 2.35, 1.62, and 0.95 for the control, lace-up, and semirigid braces, respectively. According to Cohen,[13] all 3 effect sizes are considered large, indicating there were conclusive and clinically meaningful reductions in IV ROM associated with the SAO in comparison to all 3 other conditions. Similarly, the lace-up (d = 1.20) and semirigid (d = 1.50) braces also substantially reduced IV ROM, compared with the control condition. The results of a comprehensive meta-analysis[5] demonstrated mean differences of 14.9° and 20.2° of IV ROM reductions for lace-up and semirigid ankle braces, respectively, in comparison to no brace conditions. In the current study, we did not find reductions in IV ROM as dramatic as those demonstrated in the meta-analysis; however, our results agree with the restricted IV motion associated with the application of ankle braces. Although injury prevention effects were not evaluated in the current study, by best preventing IV ROM, the SAO may be able to better prevent lateral ankle sprains, compared with semirigid or lace-up braces. Clinical injury prevention studies are necessary to test this hypothesis.

In our study, EV, PF, and DF ROM were also reduced with the application of each of the 3 ankle braces. EV was restricted most by the semirigid brace (mean difference compared with control = 6.0°), followed by the lace up (mean difference = 4.0°) and the SAO (mean difference = 2.4°). Cordova et al,[5] in their meta-analysis, found larger EV ROM restrictions while evaluating semirigid (mean difference = 14.4°) and lace-up (mean difference = 19.8°) braces. Regarding PF and DF ROM, our study found that all 3 braces significantly restricted motion, compared with the unbraced condition. Mean differences, compared with the no brace condition, varied slightly for the SAO (DF = 1.6°, PF = 6.5°), lace-up (DF = 3.0°, PF = 9.8°), and semirigid (DF = 2.1°, PF = 9.0°) braces. Our results differ from those of Cordova et al,[5] who found significant restrictions in PF and DF ROM with only lace-up braces (pooled mean differences = 3.2° for DF and 9.3° for PF), but not with the semirigid braces (pooled mean differences = 0.9° for DF and 3.3° for PF). We believe that the differences in results may be due to our testing ROM in shoes, whereas the most previous studies have assessed ROM without shoes. In our study, all participants wore standardized shoes for all testing; this was deemed necessary because the application of the SAO requires a shoe. Putting the semirigid and lace-up braces in shoes may alter ROM measures.

The previous literature has concluded that traditional lace-up and semirigid braces have minimal or no effect on vertical jump.[7,14] However, in our study, we found that the application of the lace up, semirigid, and SAO all statistically reduced vertical jump height. The mean difference in vertical jump height, compared with the no-brace group, was 1.9 cm for the SAO and 1.4 cm for both the lace-up and semirigid braces. Although a significant difference was found, the mean difference between the SAO and no brace was less than 2 centimeters, thus calling into question the clinical relevance of the difference. Follow-up analysis of the SAO found an effect size of d = –0.27 (95% confidence interval, –0.84, 0.30). According to Cohen,[13] an effect size of 0.27 is considered to have small to weak clinical importance. In addition, the effect size confidence interval encompasses zero, indicating uncertainty regarding the robustness of any performance effect. Our findings, although statistically significant, present small effect sizes, which align with Cordova et al,[7] who reported questionable differences in maximum jump height. In our study, the SAO resulted in the lowest vertical jump height, although it was not significantly less, compared with the other 2 braces. The potential cause for the reduction in vertical jump could be the restriction in dorsiflexion ROM. Previous research evaluating dorsiflexion and vertical jump height has shown that an increase in dorsiflexion ROM is related to an increased vertical jump height.[10,15,16] Overall, we conclude that the SAO should be considered to have little practical effect on vertical jump performance; however, more research needs to be conducted.

Our other outcome measures, BESS and SEMO, resulted in no significant differences between the braced and unbraced conditions. Our findings for static balance agree with the previously published literature, which found that ankle prophylactic braces do not alter static[17-19] or dynamic balance.[20,21] Kinzey et al[18] evaluated the effect of various braces on the center of pressure excursions in healthy participants and found no detrimental effects. We should mention that our values for the BESS test are somewhat higher than those previously reported in the ankle literature.[9] The reasons for this discrepancy are unknown at this time. In addition, ankle prophylactic braces have been previously reported to have virtually no effect on agility performance.[17,22-28] Cordova et al,[7,29] in their reviews of the ankle brace literature, concluded that in healthy participants, ankle braces probably do not affect agility or postural control. Although our results agree with previous research, we believe that more research on the SAO should be conducted to assess its potential sensorimotor effects.

Our results show that the SAO was equivalent to the other 2 braces tested in that it does not have a detrimental effect on agility, balance, and, arguably, no clinically meaningful restriction in vertical jump. This concurs with previous research on other braces available to clinicians and athletes.[5,7,14,29] This study also demonstrates that the SAO is similar to other braces in ROM restrictions, although it appears to restrict IV ROM to a greater extent.

LIMITATIONS

As with all research, our study has its limitations and brings into light more questions to be researched regarding the SAO brace. The first important limitation is that this study evaluated only the performance of the SAO and not the efficacy. Further research is needed to determine whether this ROM restriction corresponds with improved ankle sprain prevention. Second, this study was conducted on healthy men only; performance effects related to the SAO need to be assessed in healthy female athletes and in both men and women with a history of ankle sprains. Another limitation is that we used only one particular brand and style of shoe for this study. Other shoes that allow the anchors to be drilled into the soles should be evaluated. Finally, because the SAO is a new product, research is needed to investigate the subjective opinions of brace users in terms of comfort and willingness to wear an external brace during sporting activities.

IMPLICATIONS FOR CLINICAL PRACTICE

The SAO brace may reduce the incidence of ankle sprains by restricting inversion range of motion. It also appears to perform similarly as lace-up and semirigid braces during agility, balance, and vertical jump activities. However, more research should be conducted on this brace.

CONCLUSION

All 3 braces (SAO, lace up, and semirigid) caused significant ROM restriction and diminished maximum vertical jump height, compared with the no brace condition, but none of the braces hindered agility or static balance performance. The SAO produced changes in ROM and vertical jump performance comparable to the semirigid and lace-up braces. ■

REFERENCES

1. Tropp H, Askling C, Gillquist J. Prevention of ankle sprains. *Am J Sports Med*. 1985;13(4):259-262.
2. Sitler M, Ryan J, Wheeler B, et al. The efficacy of a semirigid ankle stabilizer to reduce acute ankle injuries in basketball. A randomized clinical study at West Point. *Am J Sports Med*. 1994;22(4):454-461.
3. Surve I, Schwellnus MP, Noakes T, Lombard C. A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. *Am J Sports Med*. 1994;22(5):601-606.
4. Olmsted LC, Vela LI, Denegar CR, Hertel J. Prophylactic ankle taping and bracing: a numbers-needed-to-treat and cost-benefit analysis. *J Athl Train*. 2004;39(1):95-100.
5. Cordova ML, Ingersoll CD, LeBlanc MJ. Influence of ankle support on joint range of motion before and after exercise: a meta-analysis. *J Orthop Sports Phys Ther*. 2000;30(4):170-182.
6. Ubell ML, Boylan JP, Ashton-Miller JA, Wojtys EM. The effect of ankle braces on the prevention of dynamic forced ankle inversion. *Am J Sports Med*. 2003;31(6):935-940.
7. Cordova ML, Scott BD, Ingersoll CD, LeBlanc MJ. Effects of ankle support on lower-extremity functional performance: a meta-analysis. *Med Sci Sports Exerc*. 2005;37(4):635-641.
8. Young W, MacDonald C, Heggen T, Fitzpatrick J. An evaluation of the specificity, validity and reliability of jumping tests. *J Sports Med Phys Fitness*. 1997;37(4):240-245.
9. Docherty CL, Valovich McLeod TC, Shultz SJ. Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. *Clin J Sport Med*. 2006;16(3):203-208.
10. Metcalfe RC, Schlabach GA, Looney MA, Renehan EJ. A comparison of moleskin tape, linen tape, and lace-up brace on joint restriction and movement performance. *J Athl Train*. 1997;32(2):136-140.
11. Youdas JW, Bogard CL, Suman VJ. Reliability of goniometric measurements and visual estimates of ankle joint active range of motion obtained in a clinical setting. *Arch Phys Med Rehabil*. 1993;74(10):1113-1118.
12. Menadue C, Raymond J, Kilbreath SL, Refshauge KM, Adams R. Reliability of two goniometric methods of measuring active inversion and eversion range of motion at the ankle. *BMC Musculoskelet Disord*. 2006;7:60.
13. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: L. Erlbaum Associates; 1988.
14. Bot SD, van Mechelen W. The effect of ankle bracing on athletic performance. *Sports Med*. 1999;27(3):171-178.
15. Larkins C, Snabb TE. Positive versus negative foot inclination for maximum height two-leg vertical jumps. *Clin Biomech*. 1999;14(5):321-328.
16. Faiss R, Terrier P, Praz M, Fuchslocher J, Gobelet C, Deriaz O. Influence of initial foot dorsal flexion on vertical jump and running performance. *J Strength Cond Res*. 2010;24(9):2352-2357.
17. Paris DL. The effects of the Swede-O, New Cross, and McDavid ankle braces and adhesive ankle taping on speed, balance, agility, and vertical jump. *J Athl Train*. 1992;27(3):253-256.
18. Kinzey SJ, Ingersoll CD, Knight KL. The effects of selected ankle appliances on postural control. *J Athl Train*. 1997;32(4):300-303.
19. Barkoukis V, Sykaras E, Costa F, Tsorbatzoudis H. Effectiveness of taping and bracing in balance. *Percept Mot Skills*. 2002;94(2):566-574.

20. Hardy L, Huxel K, Brucker J, Nesser T. Prophylactic ankle braces and star excursion balance measures in healthy volunteers. *J Athl Train*. 2008;43(4):347-351.
21. Ambegaonkar JP, Redmond CJ, Winter C, et al. Ankle stabilizers affect agility but not vertical jump or dynamic balance performance. *Foot Ankle Spec*. 2011;4(6):354-360.
22. Beriau MR, Cox WB, Manning J. Effects of ankle braces upon agility course performance in high school athletes. *J Athl Train*. 1994;29(3):224-230.
23. Burks RT, Bean BG, Marcus R, Barker HB. Analysis of athletic performance with prophylactic ankle devices. *Am J Sports Med*. 1991;19(2):104-106.
24. Gross MT, Clemence LM, Cox BD, et al. Effect of ankle orthoses on functional performance for individuals with recurrent lateral ankle sprains. *J Orthop Sports Phys Ther*. 1997;25(4):245-252.
25. Greene TA, Hillman SK. Comparison of support provided by a semirigid orthosis and adhesive ankle taping before, during, and after exercise. *Am J Sports Med*. 1990;18(5):498-506.
26. MacKean LC, Bell G, Burnham RS. Prophylactic ankle bracing vs. taping: effects on functional performance in female basketball players. *J Orthop Sports Phys Ther*. 1995;22(2):77-81.
27. Pienkowski D, McMorrow M, Shapiro R, Caborn DN, Stayton J. The effect of ankle stabilizers on athletic performance. A randomized prospective study. *Am J Sports Med*. 1995;23(6):757-762.
28. Verbrugge JD. The effects of semirigid Air-Stirrup bracing vs. adhesive ankle taping on motor performance. *J Orthop Sports Phys Ther*. 1996;23(5):320-325.
29. Cordova ML, Ingersoll CD, Palmieri RM. Efficacy of prophylactic ankle support: an experimental perspective. *J Athl Train*. 2002;37(4):446-457.