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# Comparison Between Rigid Double Upright and Lace-up Ankle Braces on Ankle Range of Motion, Functional Performance, and User Satisfaction of Brace Characteristics

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**Background:** Braces are often used before returning to activity following ankle sprains and also prophylactically in sports considered the high risk for ankle sprains. The purpose of this study was to compare range of motion (ROM) limitations, functional performance, and satisfaction of rigid double upright and lace-up braces.
**Subjects:** In total, 30 healthy adults >18 years of age (Mean, 22.6 ± 2.7 years) without lower extremity injury and involved in regular physical activity participated in this study.
**Materials/Methods:** Ankle ROM assessment and lower extremity performance testing (figure-of-8 hop, side hop, 6-m single-limb crossover, and square hop) was administered under the following 3 conditions: unbraced, rigid braces, and lace-up braces. A questionnaire was completed following the test protocol on brace characteristics and satisfaction. Repeated-measures ANOVA was used to determine the main effects on outcome variables of ROM, hop performance, and satisfaction. Tukey LSD post hoc comparisons were conducted on significant main or interaction effects ($P < .05$) to determine differences between group by condition means.
**Results:** In total, 30 participants completed the study. The lace-up brace limited plantarflexion and inversion ROM more than the rigid brace. When compared to the unbraced condition, both braced conditions resulted in better performance times, although not statistically significant. Higher satisfaction was reported with the lace-up brace on appearance, fit, prevention, and overall satisfaction.
**Conclusions and Clinical Relevance:** The ankle braces primarily limited ankle plantarflexion and inversion ROM, which are motions related to common reported mechanisms of ankle sprains. The braces did not negatively affect hop performance, and user satisfaction indicated a slight preference for the lace-up brace.

**Keywords:** prophylactic bracing; functional performance; ankle orthoses; ankle brace

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**Key Points:** The ankle braces used in the current study did not negatively affect functional performance of the participants. Both braces controlled ankle range of motion, but the lace-up brace had a greater effect on limiting plantarflexion and inversion. Participants in this study expressed a slight preference for the lace-up braces.

## BACKGROUND AND INTRODUCTION

Ankle sprains are one of the most common lower extremity (LE) musculoskeletal injuries. In the USA, it has been estimated that 25,000 ankle sprains occur each day,[1] and about half of these sprains (49.3%) are likely sustained during an athletic activity.[2] Fong et al. reported in a systematic review that ankle sprains were the most common athletic injuries accounting for 34% of all injuries sustained in 33 of 43 sports played worldwide.[3] However, the overall incidence of ankle sprains may be highly underestimated, as it has been reported that ~50% of those sustaining an ankle sprain may not seek formal attention from a healthcare professional after injury.[4] The risk for re-injury of ankle sprain increases following the index injury, particularly for those involved in high-risk sports or activities such as basketball,[5] volleyball,[6,7] soccer,[8] and those serving in the military.[9–11]

Because of the relatively high prevalence and risk of ankle sprain, ankle braces are widely used and have been recognized as an effective prophylactic intervention to reduce the incidence, severity, and recurrence of ankle sprains.[4,12–21] There are many different types of ankle braces available commercially, and most can be classified into categories of rigid, semi-rigid, or lace-up based upon their general design. A recent study by Denton et al. regarding clinicians' (ie, physical therapists and athletic trainers) recommendations and perceptions associated with ankle brace use reported that lace-up braces were the type of ankle brace that were most frequently recommended prophylactically to prevent ankle sprain injuries.[22] Denton et al. also asked clinicians about whether recommending ankle braces was affected by their concerns about potential negative side effects of brace use such as reduced strength, compromised proprioception, compromised dynamic balance, and risk of injury to the knee joint.[22] Although some clinicians reported concerns about the aforementioned side effects, reduced ankle strength was the potential adverse effect that affected recommendation of brace use, although evidence is insufficient to support or contradict this concern. Although a preponderance of literature generally supports ankle bracing for the prevention of initial ankle sprains and their recurrence in high-risk sports, additional investigation is needed to better understand the effects of specific ankle braces on limiting the range of motion (ROM), functional performance, and user preference. Understand-ing these factors could have a direct influence on the recommendation for wear, choice of brace type, and user compliance. The purpose of the current study is to compare the ROM limitations, effects on functional performance, and user satisfaction of brace characteristics between rigid double upright and lace-up ankle braces when worn bilaterally in a sample of healthy active adults.

## METHODS

The study was reviewed and approved by the Bellarmine University institutional review board (IRB#415). Participants were recruited from a university setting, were at least 18 years of age, without current LE injury, and self-reported to be involved in regular moderate-to-vigorous physical activity such as running or a team sport. After explaining the risks and benefits and obtaining consent, each participant underwent ankle ROM assessment using a standardized procedure with a

universal goniometer of the following cardinal motions: plantarflexion (PF), dorsiflexion (DF), inversion (INV), and eversion (EV). Participants were then subjected to LE functional performance testing under the following 3 different conditions: natural (unbraced), bilateral rigid brace (T2 Active Ankle, Akron, OH), and bilateral lace-up brace (AS1 Pro Active Ankle, Akron, OH). The 4 hopping tests were selected on the basis of previous studies by Buchanan et al.[23] and Caffrey et al.[24] who used these tests to determine functional deficits in individuals with functional ankle instability (Figure 1). These hop tests have been well described previously and have been determined to exhibit good to excellent reliability.[4] The unbraced condition was conducted first as a familiarization trial, followed by randomization of the 2 braced conditions. The 4 functional performance tasks included the following tests: figure-of-8 hop, side hop, 6-m single-limb crossover hop, and square hop. The time to complete each test was recorded to the nearest 0.01 second, and each test was repeated twice, with an ~1-minute rest between trials. The braced conditions involved completion of a questionnaire immediately following the test protocol using a 7-point Likert scale ranging from 1 (*extremely dissatisfied*) to 7 (*extremely satisfied*) and included the following characteristics: appearance, ease of application, fit, comfort, stability, interference with ability to move, ability of the brace to prevent ankle injury, and overall satisfaction (Figure 2).

## Statistical Analysis

Repeated-measures ANOVA was used to determine the main effect of ordering and conditions and the interaction of ordering and conditions on outcome variables of ROM, functional performance, and satisfaction. Tukey LSD post hoc comparisons were conducted on the significant main or interaction effects ($P < .05$) to determine differences between the groups by condition means.

## RESULTS

All 30 participants (male, 15; female, 15; average age, 22.6 ± 2.7 years; age range, 18–29 years) completed the study. As indicated by the inclusion criteria, all participants were generally in good health, displayed relatively low body mass index (24.6 ±3.3 kg/m$^2$; range: 19.8–36.0 kg/m$^2$), involved in regular moderate-to-vigorous physical activity, and did not exhibit any current LE injury. Ankle ROM was observed to be the greatest in the unbraced condition (Tables 1–3). Both braced conditions were observed to have an effect of

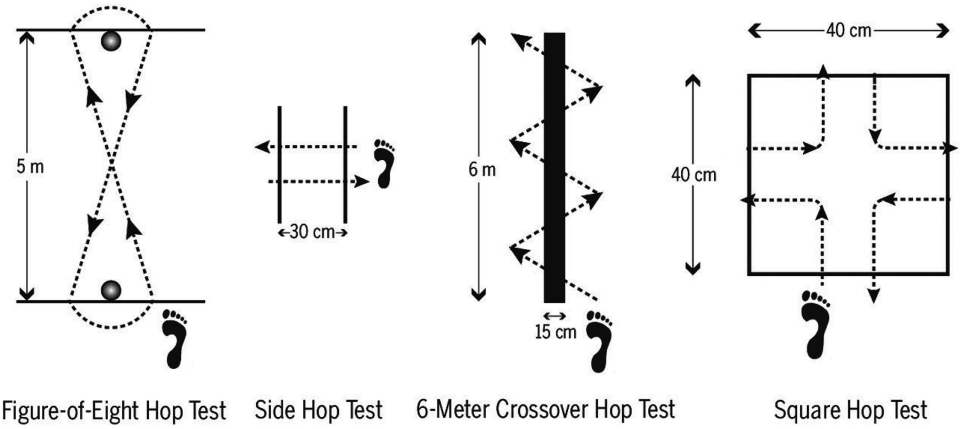


**Figure 1.** Functional performance timed hop tests used in the current study. Reprinted with permission from Caffrey et al.[24] https://doi.org/10.2519/jospt.2009.3042. ©Journal of Orthopaedic & Sports Physical Therapy®.

## Ankle Brace FEEDBACK

Please rate the Rigid / Lace-Up Brace on the following scale with (Circle one):

1- Extremely Dissatisfied
2- Very Dissatisfied
3- Dissatisfied
4- Somewhat Satisfied
5- Satisfied
6- Very Satisfied
7- Extremely Satisfied

**Appearance and look of the brace:**

1 2 3 4 5 6 7

**Clarity of the written instructions and illustrations:**

1 2 3 4 5 6 7

**Ease of Application of the brace:**

1 2 3 4 5 6 7

**Fit of the brace:**

1 2 3 4 5 6 7

**Comfort of the brace:**

1 2 3 4 5 6 7

**Stability provided by the brace:**

1 2 3 4 5 6 7

**Interference with your ability to move around:**

1 2 3 4 5 6 7

**Your belief in the ability of the brace to prevent an ankle injury:**

1 2 3 4 5 6 7

**Overall satisfaction of the brace:**

1 2 3 4 5 6 7

**Any additional comments regarding the Rigid/Lace-up Brace (circle one):**

**Figure 2.** Ankle brace feedback questionnaire.

limiting ROM (degrees), with the greatest total limits observed in PF and INV. When comparing differences in absolute ROM limits to the unbraced condition, the lace-up brace limited PF ROM (R, 10°; L, 11°) and INV ROM (R, 8°; L, 10°) more than the rigid brace (PF: R, 7°; L, 9° and INV: R, 3°; L, 4°). Neither of the two braces had any considerable effect on limiting DF (1–2°) and EV (1–4°).

Regarding functional testing using the 4 timed hop tests, compared with the unbraced condition, both the rigid and lace-up brace conditions resulted in better performance

**Table 1.** Dorsiflexion and eversion ROM

| Condition | Right DF (degrees) | Left DF (degrees) | Right EV (degrees) | Left EV (degrees) |
|---|---|---|---|---|
| No brace | 12 | 10 | 15 | 14 |
| Rigid brace | 12 | 10 | 13 | 13 |
| Lace-up brace | 11 | 8 | 11 | 10 |

Note: There were no differences noted between the unbraced and 2 braced conditions; an absolute difference of more than ±5° was considered to be a clinically meaningful difference.

**Table 2.** Plantarflexion ROM differences noted between the unbraced and 2 braced conditions

| Condition | Right PF (degrees) | Left PF (degrees) | Change in PF ROM Between No Brace and Braced Conditions, Right and Left (degrees) | |
|---|---|---|---|---|
| No brace | 38 | 39 | – | – |
| Rigid brace | 31 | 30 | 7 | 9 |
| Lace-up brace | 28 | 28 | 10 | 11 |

Note: An absolute difference of more than ±5° was considered to be a clinically meaningful difference; when compared with the unbraced condition, PF ROM was limited by the rigid brace and lace-up brace by 18%–23% and 26%–28%, respectively.

**Table 3.** Inversion ROM differences noted between the unbraced and 2 braced conditions

| Condition | Right INV (degrees) | Left INV (degrees) | Change in INV ROM between No Brace and Brace Conditions (degrees) | |
|---|---|---|---|---|
| No brace | 40 | 36 | – | – |
| Rigid brace | 37 | 32 | 3° | 4° |
| Lace-up brace | 32 | 26 | 8° | 10° |

Note: An absolute difference of +5° was considered to be a clinically meaningful difference; when compared with the unbraced condition, INV ROM was limited by the rigid brace and lace-up brace by 8%–11% and 20%–28%, respectively.

times (Tables 4–7). That is, the participants could perform the timed hops faster when wearing braces, and all were determined to be significantly different than the unbraced condition, with the exception of the figure-of-8 hop test. Only the right LE lace-up brace condition was significantly different compared with the unbraced and rigid brace condition. The brace satisfaction questionnaires showed a high degree of internal consistency (Cronbach alpha) and allowed for calculation of composite satisfaction scores. Composite scores indicated a slightly higher satisfaction with the lace-up brace. Participants preferred the lace-up over the rigid brace with regard to appearance, fit, belief that the brace could prevent an ankle injury, and overall satisfaction (Table 8).

## DISCUSSION

The purpose of the study was to compare the ROM limitations, effects on

**Table 4.** Results of the timed side hop test

| Condition | Left side hop (in seconds) | Right side hop (in seconds) | Change in Performance Between No Brace and Brace Conditions |
|---|---|---|---|
| No brace | 9.39* | 9.56* | |
| Rigid brace | 8.14 | 8.26 | 1.25–1.30 s (13%) |
| Lace-up brace | 7.93 | 8.02 | 1.46–1.54 s (16%) |

Note: The unbraced condition was significantly different ($P < .05$) than the 2 braced conditions; there was no difference between the 2 braced conditions; *indicates significance.

**Table 5.** Results of the timed square hop test

| Condition | Right Square Hop (in seconds) | Left Square Hop (in seconds) | Change in Performance Between No Brace and Brace Conditions |
|---|---|---|---|
| No brace | 17.02* | 17.90* | |
| Rigid brace | 14.73 | 15.05 | 2.29–2.85 s (13%–16%) |
| Lace-up brace | 14.59 | 14.89 | 2.43–3.01 s (14%–16%) |

Note: The unbraced condition was significantly different ($P < .05$) than the 2 braced conditions; there was no difference between the 2 braced conditions; *indicates significance.

**Table 6.** Results of the timed crossover hop test

| Condition | Right Crossover Hop (in seconds) | Left Crossover Hop (in seconds) | Change in Performance Between No Brace and Brace Conditions |
|---|---|---|---|
| No brace | 3.05* | 2.89* | |
| Rigid brace | 2.59 | 2.53 | 0.36–0.46 s (12%–15%) |
| Lace-up brace | 2.56 | 2.52 | 0.37–0.49 s (13%–16%) |

Note: The unbraced condition was significantly different ($P \leq .05$) than the 2 braced conditions; there was no difference between the 2 braced conditions; *indicates significance.

functional performance as measured by the 4 timed hop tests, and user satisfaction of brace characteristics between rigid double upright and lace-up ankle braces when worn bilaterally by healthy active adults. As might be expected, when compared to the unbraced condition, ankle ROM was found to be more limited under both braced conditions. In addition, the lace-up brace restricted ankle ROM (degrees) to a greater extent than the rigid brace (Tables 1–3). This finding of greater restriction in ROM can likely be explained by

**Table 7.** Results of the timed figure-of-8 hop test

| Condition | Right Figure-of-8 hop (in seconds) | Left Figure-of-8 hop (in seconds) | Change in Performance Between No Brace and Brace Conditions |
|---|---|---|---|
| No brace | 5.15 | 5.20 | |
| Rigid brace | 5.14 | 5.15 | 0.01–0.05 s (1%–2%) |
| Lace-up brace | 5.04* | 5.12 | 0.08–0.11 s (1%–2%) |

Note: Only the right LE in the lace-up brace condition was found to be significantly different ($P \leq .05$) from the unbraced condition, but this was deemed virtually negligible (0.11s); *indicates significance.

the basic differences in the brace design. The ankle–foot complex is a dynamic structural assembly and comprises a number of functionally interdependent articulations, none more crucial than the talocrural, the subtalar, and the midtarsal joints, all recognized and described as having complicated triplanar motion. The lace-up brace extends further distally and may possibly have a greater effect at stabilizing the midtarsal or transverse tarsal joints, which contribute to the overall mobility and ROM of the ankle–joint complex. This recognition may assist clinicians in their clinical decision-making on brace recommendations to choose a lace-up brace when more distal or transverse tarsal joint control is desired. It is recognized that the assertion of possible biomechanical influences of the different braces is based only on empirical observations, opinion, and osteokinematic findings (eg, ROM) from the current study; further investigation will be required to validate these statements.

With regard to the results of the 4 timed hop tests, the participants' performances were not negatively affected by either of the two braced conditions. In nearly every hop test, the unbraced condition was significantly different (slower) than both the braced conditions. The only exception was noted in a single instance (right LE lace-up brace condition) and deemed to be practically negligible as none of the scores for this timed hop test varied by >0.16 seconds (Table 7).

The participants were generally satisfied with the functionality, fit, and performance of both braces used in this study, but an overall preference for the lace-up brace was indicated when given a choice between the 2 (Table 8). When asked the following global question: *Based on your experience today with the 2 different ankle braces, which one would you prefer to wear*?", 21 of the 30 participants (70%) indicated their preference for the lace-up brace. In addition, other characteristics of the lace-up brace that were preferred and indicated by the participants' responses on the questionnaire found to be statistically different included the appearance of the brace, the fit of the brace, the belief that the brace could prevent future injury, and the overall satisfaction. There were no statistically significant differences between the 2 braces as indicated by participants' responses on the other characteristics (eg, clarity of the written instructions and ease of brace application, comfort, and interference with ability to move), although these scores were consistently slightly higher.

As with all clinical trials, there were several limitations in the current study. The sample size was limited to 30 participants and included both males and females. The current study did not seek to ascertain gender differences, but this could be a focus of additional future analysis. Another issue not addressed in the current study was that of LE limb dominance. It is unknown whether the results of the ROM limitations or timed hop tests were

**Table 8.** Results of participant satisfaction of brace characteristics

| Brace Characteristics | Mean | N | Standard deviation | Standard Error Mean |
|---|---|---|---|---|
| Satisfaction with Rigid (R) | 42.6667 | 30 | 9.06427 | 1.65490 |
| Satisfaction with Lace-Up (L) | *47.7333 | 30 | 5.86594 | 1.07097 |
| R – Appearance and Look | 4.733 | 30 | 1.2015 | 0.2194 |
| L – Appearance and Look | *5.567 | 30 | 1.0400 | 0.1899 |
| R – Clarity of Instructions | 4.933 | 30 | 1.3629 | 0.2488 |
| L – Clarity of Instructions | 5.367 | 30 | 0.9279 | 0.1694 |
| R – Ease of Application | 4.733 | 30 | 1.1725 | 0.2141 |
| L – Ease of Application | 4.967 | 30 | 0.9643 | 0.1761 |
| R Fit of Brace | 4.667 | 30 | 1.3218 | 0.2413 |
| L – Fit of Brace | *5.633 | 30 | 0.9994 | 0.1825 |
| R – Comfort of Brace | 4.733 | 30 | 1.3629 | 0.2488 |
| L – Comfort of Brace | 5.200 | 30 | 1.1861 | 0.2166 |
| R – Stability of Brace | 4.767 | 30 | 1.5687 | 0.2864 |
| L – Stability of Brace | 5.367 | 30 | 0.8503 | 0.1552 |
| R – Interference with Mobility | 5.033 | 30 | 1.2452 | 0.2273 |
| L – Interference with Mobility | 5.233 | 30 | 1.1043 | 0.2016 |
| R – Belief of Injury Prevention | 4.400 | 30 | 1.5888 | 0.2901 |
| L – Belief of Injury Prevention | *5.133 | 30 | 1.0417 | 0.1902 |
| R – Overall Satisfaction | 4.667 | 30 | 1.2954 | 0.2365 |
| L – Overall Satisfaction | *5.267 | 30 | 0.9072 | 0.1656 |

Note: Composite satisfaction, appearance and look of the brace, fit of the brace, belief of injury prevention, and overall satisfaction were higher when wearing the lace-up brace; significant differences are noted by highlighted areas and asterisks (*).
Abbreviations: R, Rigid; L, Lace-up.

affected by limb dominance, as the determination of limb dominance can be controversial and was not considered as a variable of interest in the current study.

Several participants had reported a history of previous ankle sprains, but many were uncertain which ankle was sprained, and most reported not seeking any professional attention from a healthcare provider, which is quite common and has been reported in the literature.[4] Furthermore, none of the participants acknowledged any functional deficits or current symptoms limiting them in their chosen physical activities, so previous history of ankle injury was likely not a factor in the current study. The reliability of the goniometric ROM assessments may have impacted the results in the study, although care was taken to instruct the participants to repeat the active movements (minimum of 3 times) so that the investigators could be assured that the maximal active end range was attained in each

assessed condition (eg, unbraced and braced). Active ankle ROM assessment was chosen instead of passive ROM, because during pilot testing, it was a realized that assessment of a true passive ROM was not possible in the braced conditions (eg, limited by brace). In addition, the braces had a tendency to obscure anatomical landmarks (eg, lateral malleolus, midpoint of talocrural joint), but the clinical experience of the examiner, careful attention to standard procedure, and knowledge of anatomy was believed to make amends for this limitation. Another concern, as alluded to the above, is that at the time of the study, all participants were determined to be free of ankle pathology, limiting the generalizability beyond normal individuals. Using actual patients with known pathology may have yielded different findings, and future studies could include subjects with recent or current injury or pathology. However, despite these apparent limitations, ankle braces are increasingly being used prophylactically, making the current study's findings potentially highly relevant.

Finally, it is unclear if the improved performances noted during the braced conditions, compared with those during the unbraced condition, were because of familiarization and practice (eg, a learning effect). Future trials may include a different randomization order, that is, to assess ankle ROM and administer functional performance tests with the braced conditions before the unbraced or the natural condition. However, the investigators believe that establishing the natural or unbraced condition first was a reasonable procedure to familiarize the participants with the testing procedure without the influence of the braces and to establish a true baseline of the participants' ROM and functional ability.

## CONCLUSIONS AND CLINICAL RELEVANCE

The 2 ankle braces used in this study limited ankle ROM to a greater degree in PF and INV, which interestingly is related to one of the most commonly recognized and reported mechanisms of lateral ankle sprains, and therefore, potentially a desirable effect of the braces. Functional performance as measured by the timed hop tests was not negatively affected by wearing ankle braces, and was, in fact, enhanced in most cases. This finding may be important to some clinicians and athletes who perceive that ankle braces have a negative influence on performance. Whether the ankle braces used in this study improved the actual performance or this result was obtained because of the effects of learning or practice, requires future investigation. Participants in this study were generally satisfied with both ankle braces, but there was a slight preference for the lace-up brace over the rigid brace as indicated by the users.

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## REFERENCES

1. Footcare MD. A step in the right direction. Sprained Ankle. American Orthopaedic Foot and Ankle Society (AOFAS). www.aofas.org/footcaremd/conditions/ailments-of-the-ankle/Pages/Sprained-Ankle.aspx Accessed 12/12/15.
2. Waterman BR, et al. The epidemiology of ankle sprains in the United States. *J Bone Joint Surg Am.* 2010 Oct 6;92(13):2279–2284.
3. Fong DT, et al. A systematic review on ankle injury and ankle sprain in sports. *Sports Med.* 2007;37:73–94.
4. Martin RL, et al. Ankle stability and movement coordination impairments: ankle ligament sprains: clinical practice guidelines linked to the international classification of functioning, disability and health from the orthopaedic section of the American Physical Therapy Association. *J Orthop Sports Phys Ther.* 2013;43(9):A1–A40.
5. McKay GD, et al. Ankle injuries in basketball: injury rate and risk factors. *Br J Sports Med.* 2001;35:103–108.
6. Bahr R, Bahr IA. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. *Scand J Med Sci Sports* 1997;7(3):166–171.

7. Bahr R, et al. Incidence and mechanisms of acute ankle inversion injuries in volleyball. A retrospective cohort study. *Am J Sports Med.* 1994;22(5):595–600.
8. Ekstand J, Gillquist J. Soccer injuries and their mechanism: a prospective study. *Med Sci Sports Excerc.* 1983;15(3):367–370.
9. Milgrom C, et al. Risk factors for lateral ankle sprain: a prospective study among military recruits. *Foot Ankle.* 1991;12(1):26–30.
10. Cameron KL, et al. Incidence of ankle sprains among active-duty members of the United States Armed Services from 1998 through 2006. *J Athl Train.* 2010;45(1):29–38.
11. Waterman BR, et al. Epidemiology of ankle sprain at the United States Military Academy. *Am J Sports Med.* 2010;38(4):797–803.
12. Kaminski TW, et al. National athletic trainers' association position statement: conservative management and prevention of ankle sprains in athletes. *J Athl Train.* 2013;48(4):528–545.
13. McGuine TA, et al. The effect of lace-up ankle braces on injury rates in high school football players. *Am J Sports Med.* 2012;40(1):49–57.
14. McGuine TA, et al. The effect of lace-up ankle braces on injury rates in high school basketball players. *Am J Sports Med.* 2011;39(9):1840–1848.
15. Frey C, et al. Prophylactic ankle brace use in high school volleyball players: a prospective study. *Foot Ankle Int.* 2010;31(4):296–300.
16. Pedowitz DI, et al. Prophylactic bracing decreases ankle injuries in collegiate female volleyball players. *Am J Sports Med.* 2008;36(2):324–327.
17. Surve I, et al. 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.
18. Sharpe SR, et al. Ankle braces effectively reduce recurrence of ankle sprains in female soccer players. *J Athl Train.* 1997;32(1):21–24.
19. Tropp H, et al. Prevention of ankle sprains. *Am J Sports Med.* 1985;13:259–262.
20. Verhagen, E.A.L.M., Bay K. Optimising ankle sprain prevention: a critical review and practical appraisal of the literature. *Br J Sports Med.* 2010;44(15):1082–1088.
21. Petersen W, et al. Treatment of acute ankle ligament injuries: a systematic review. *Arch Orthop Trauma Surg.* 2013;133(8):1129–1141.
22. Denton JM, et al. Clinician recommendations and perceptions of factors associated with ankle brace use. *Sports Health* 2015;7(3):267–269.
23. Buchanan AS, et al. Functional performance testing in participants with functional ankle instability and in a healthy non-FAI group. *J Athl Train.* 2008;43(4):342–346.
24. Caffrey E, et al. The ability of 4 single-limb hopping to detect functional performance deficits in individuals with functional ankle instability. *J Orthop Sports Phys Ther.* 2009;39(11):799–806.