Brace beats Balance Board

Janssen, K.W.

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Round 7

User survey of three different ankle braces in soccer, volleyball and running: which brace fits best?

Kasper W Janssen, Anjulie van den Berg, Willem van Mechelen, Evert Verhagen

Submitted

ABSTRACT

Context: Recurrence rates for ankle sprains are high. Therefore, preventive measures like ankle bracing during sports are recommended.

Objective: To systematically evaluate the perceived ease of use, quality, comfort, stability, hindrance and overall satisfaction of three different contemporary brace types in three types of sports.

Design: Randomized comparative user survey.
Setting: Recreational sports: soccer, running and volleyball.

Participants: Young adults, recreational athletes.
Intervention(s): Compression brace (C), lace-up brace (L) and semi-rigid brace (S).

Main Outcome Measure(s): Perceived ease of use, quality, comfort, stability, hindrance and overall satisfaction of the brace-types during sports on a 1 to 5 Likert scale. Secondary outcome measure was participants' willingness to buy the tested brace.

Results: Overall, the three brace types received high mean scores for ease of use and quality. Soccer players preferred the compression brace over both alternatives, considering the significantly higher scores for comfort (C 4.0 vs S 2.8, L 3.5), hindrance (C 3.7 vs S 2.8, 2.9), overall satisfaction (C 3.6 vs S 2.5, L 3.0) and highest willingness to buy this brace. Volleyball players preferred the lace-up brace over both alternatives, considering the significantly higher scores for stability (L 4.2 vs S 3.3, C 3.2), overall satisfaction (L 3.8 vs S 3.0, C 3.0) and highest willingness to buy this brace. Runners preferred the compression brace over both alternatives considering the significantly better score for hindrance (C 3.6 vs S 2.9, L 2.8) and highest willingness to buy this brace.

Conclusions: The studied ankle brace-types all scored high on perceived ease of use and quality. The brace types significantly differred with respect to subjective evaluation of comfort, stability, hindrance, overall satisfaction and willingness to buy the brace in soccer players, volleyball players and runners. Soccer players and runners preferred the compression brace, while volleyball players preferred the lace-up brace.

INTRODUCTION

Ankle injury is the most frequently occurring sports-related injury,[1-3] of which about 85% is ankle sprains [4]. This common injury is associated with a short and long-term burden to the athlete, as well as with a societal burden in the form of injury-related costs. Additionally, recurrence rates for ankle sprains are high, even after (para-)medical treatment, due to an increase in injury risk after an initial injury [5]. Therefore, primary and secondary preventive measures against ankle sprains are recommended. While taping is still a widely used preventive measure [6], in the last two decades most evidence supports the preventive effectiveness of neuromuscular training (NMT) and bracing [5, 7-11].

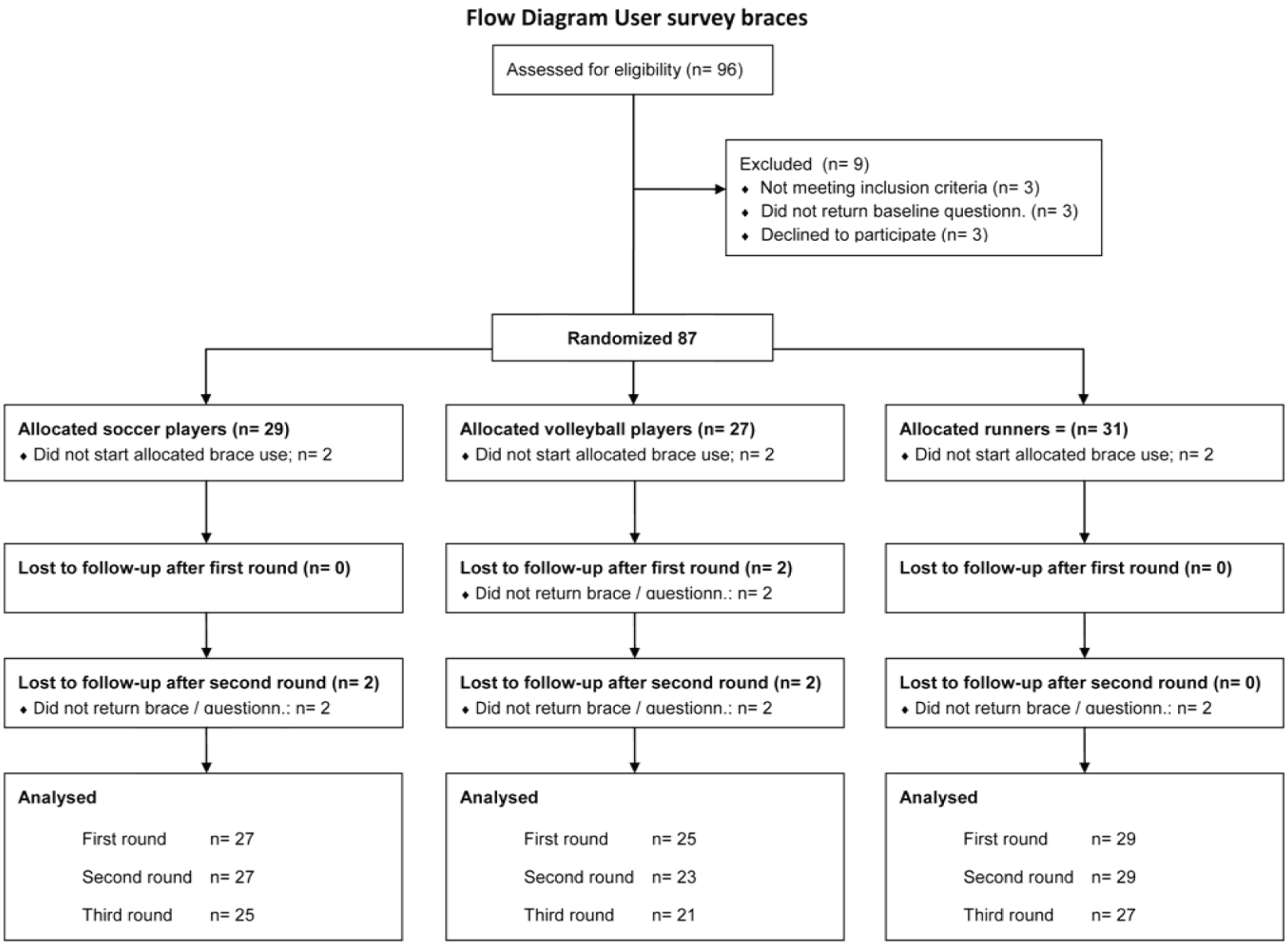
In a recent trial conducted by our group [9] bracing was found to be dominant over neuromuscular training, providing the most cost-effective secondary preventive intervention [12]. Other studies confirmed the strong preventive effect of lace-up braces and semi-rigid braces in basketball and football, respectively [7, 8]. Despite the substantial evidence that bracing is an effective measure against ankle sprains, surveys in high risk sports, like recreational soccer and basketball, found that only 27% and 33% of athletes wore an ankle brace, respectively [6]. This raises questions in regards to the implementation and barriers of brace use. In regards to braces, next to a lack of public knowledge on effectiveness, the perceived comfort is argued to be an important barrier against brace use [6, 13, 14]. Also, other subjective factors influencing brace use have been proposed, amongst which are perceived stability and perceived hindrance of performance during sports [15-17]. Such subjective factors need to be addressed when promoting the use of ankle braces.

A recent survey in sports physical therapists [18] found that evidence on effectiveness was their primary consideration for the prescription of a specific brace. Comfort was a secondary consideration, by which implicitly practitioners seem to be aware of the importance of subjective barriers to brace use. Nonetheless, to our knowledge, no formal evaluation has been done to evaluate subjective factors regarding the use of different types of braces. Such an evaluation could quantify the importance of subjective factors to athletes, eventually allowing clinicians and trainers to provide a more specific, better-adopted and maintained brace advise. Therefore, the objective of our current study was to systematically evaluate amongst athletes the perceived ease of use, quality, comfort, stability, hindrance and overall satisfaction with three different types of braces (i.e. compression brace, lace-up brace and semi-rigid brace), in three types of sports (i.e. soccer, running and volleyball).

METHODS

Participants

We recruited participants by posting a flyer at various universities and sport clubs in Amsterdam and by e-mailing this poster to local sports clubs and physical therapy students. Information on the study design and a call for participation were available for potential participants on a dedicated study website. As no relevant information on subjective factors was available to perform a power analysis we decided arbitrarily to include 5 participants per factor per sport. We planned to investigate 6 factors, leading to 30 participants per sport to be included. Recreational athletes, with or without a history of ankle sprain, aged 18 years or older, and who were actively participating at least once a week in either soccer, volleyball or running were eligible to participate. Participants with a recent ankle injury (i.e. within two months from inclusion in the survey) were excluded, as any swelling or pain due to a recent injury may influence the subjective evaluation. This user survey is a sub study of the main RCT that was approved by the medical ethics committee of the VU University Medical Center, Amsterdam, Netherlands, (protocol number 31785.029.10) trial register number NTR 2157. All athletes gave individual informed consent. The flow of the participants is shown in the flow diagram in Figure 1.


Flow Diagram User survey braces
Assessed for eligibility (n= 96)
Excluded (n= 9)
Not meeting inclusion criteria (n= 3)
Did not return baseline questionn. (n= 3)
Declined to participate (n= 3)
Randomized 87
Allocated soccer players (n= 29)
Did not start allocated brace use; n= 2
Allocated volleyball players (n= 27)
Did not start allocated brace use; n= 2
Allocated runners = (n= 31)
Did not start allocated brace use; n= 2
Lost to follow-up after first round (n= 0)
Lost to follow-up after first round (n= 2)
Did not return brace / questionn.: n= 2
Lost to follow-up after first round (n= 0)
Lost to follow-up after second round (n= 2)
Did not return brace / questionn.: n= 2
Lost to follow-up after second round (n= 2)
Did not return brace / questionn.: n= 2
Lost to follow-up after second round (n= 0)
Did not return brace / questionn.: n= 2
Analysed
First round n= 27
Second round n= 27
Third round n= 25
Analysed
First round n= 25
Second round n= 23
Third round n= 21
Analysed
First round n= 29
Second round n= 29
Third round n= 27

Round 7

Brace-types

We selected three current brace-types to be evaluated: a semi-rigid brace (DJO Aircast A60 Ankle support, Figure 2), a lace-up brace (McDavid 195 Ultralight, Figure 3) and a soft compression & figure of eight strap brace (Bauerfeind Malleotrain S, Figure 4). The DJO Aircast A60 Ankle support was selected, because it was the study brace in our recent trial on measures preventing ankle ligament injuries [9]. The McDavid 195 Ultralight was selected, because it was recently proven effective in preventing ankle ligament injuries in football and basketball [7, 8]. The Bauerfeind Malleotrain S was selected, because it is a new preventive 'Sports' version of the previous model (Malleotrain) that was previously proven effective in treatment of acute sprains [19]. All braces were provided free of cost by their respective manufacturers or national distributors.

Figure 2. Semi-rigid & velcro strap ankle brace
DJO Aircast A60 Ankle support

Figure 3. Lace-up & velcro strap ankle brace
McDavid 195 Ultralight

Figure 4. Compression & figure of eight strap brace
Bauerfeind Malleotrain S

Study procedure
The order in which the different brace-types were worn, was assigned at random for each participant. This ensured that the order by which braces were evaluated could not influence the results. Each participant was asked to use the three braces during sports participation for a round of three consecutive weeks per brace, with a minimum of three sports sessions in total. This resulted in three rounds of brace evaluation. After every three-week round a questionnaire was completed to evaluate the respective brace. The second brace was mailed only once. The previous brace was returned via mail by the participant, to rule out overlapping brace use. After the entire test period participants were mailed the brace they preferred, if available.

Questionnaire
At baseline participants completed an online questionnaire on demographics (body weight and height and mean hours of sport participation per week), ankle sprain history, and previous experience with braces. In online follow-up questionnaires participants were asked to evaluate the following constructs: perceived ease of use of the brace, perceived quality of the brace, perceived comfort of the brace, perceived stability of the brace, perceived hindrance of the brace during sports, and overall satisfaction of brace use. Each construct consisted of multiple five-point Likert scale items, where one was the most negative and five the most positive feedback score. Items were asked at random in an opposite positive or negative formulation to prevent scoring bias. Finally participants were asked if they would be willing to buy the tested brace-type for personal use to prevent ankle sprains (yes/no).

Statistical analyses
We extracted the data from the completed questionnaires into SPSS Statistics (IBM, version 20). The scores of items with an opposite formulation were converted before analysis. In order to assess the construct validity, and therefore an option of providing summation scores per construct within the questionnaire, an exploratory factor analysis with varimax rotation was performed. Mean scores and 95% confidence intervals (95%CI) for each construct were calculated and compared using one-way analysis of variance (ANOVA). A Tukey post hoc test was used to determine if between group differences were significant

($p < 0,05$). Cell frequencies of numbers 'willing to buy' the tested brace-types were compared by the Chi-squared test for independence.

RESULTS

We included 29 soccer players, 27 volleyball players and 31 runners in the study. Six participants (2 in each group) did not receive the first brace according to protocol and therefore never started the study. They were excluded from the analysis. Eight participants were lost to follow-up and, therefore, did not test all brace types. Available data from these participants was included in the analyses for those brace types for which a response was received (Figure 1). Participants from the different sports were comparable with respect to percentage of females, mean age, mean body weight and mean body height per group. The included runners had significantly lower sports participation per week, and a significantly lower percentage of them was experienced in brace use, compared to the other 2 athlete groups (Table 1).

Table 1 Characteristics of athletes per sport.

GROUP (n)	All (86)	Soccer (29)	Volleybal (26)	Running (31)
No of females (%)	45 (52)	12 (41)	16 (62)	17 (55)
Mean (SD) age in years	26	23 (4)	27 (11)	28 (12)
Mean (SD) weight in kg	73	70 (8)	77 (10)	73 (13)
Mean (SD) height in cm	180	179 (10)	182 (9)	178 (9)
Mean (SD) exposure in hours/wk	5	6 (3)	5 (3)	*3 (2)
History of ankle sprain (%)	71 (83)	26 (90)	22 (85)	23 (74)
Experience in ankle brace use (%)	25 (29)	10 (35)	12 (46)	*3 (10)

*Significant difference compared to other groups ($P < 0,05$)

The exploratory factor analysis demonstrated that the questionnaire constructs (i.e. perceived ease of use; quality; comfort; stability; hindrance; and overall satisfaction) were valid, i.e. the items within each construct all loaded on one factor. The questions within each construct were therefore combined into a single summation score for each construct.

Perceived ease of use and perceived quality

The mean scores for perceived ease of use of the three brace types (application and adjustment) are given in Table 2. The perceived ease of use of the compression brace was significantly higher compared to the perceived ease of use of the lace-up brace (4.1, 95% CI: 3.9 to 4.3 vs 3.7, 95% CI: 3.5 tot 3.8). The braces scored diverse on perceived quality (look and feel), with the semi-rigid brace gaining a mean of 3.6 points (95% CI: 3.4 to 3.8) as opposed to 4.1 (95% CI: 3.9 to 4.3) for the compression brace. The perceived quality of the compression brace was significantly higher compared to the perceived quality of the semi-rigid brace ($p= 0.002$).

Sport-specific perceived 'ease of use' and 'quality'

For both soccer players and runners the ease of use of the compression brace was significantly higher than for the lace-up brace. We found no sport-specific differences for the semi-rigid brace. In volleyball players we found no differences between brace types for 'ease of use'. In regards to 'quality' we only found for soccer players a significant difference between the compression brace (4.2 points; 95% CI: 4.0 to 4.5) and the semi-rigid brace (3.5 points; 95% CI: 3.2 to 3.9, p= 0,002).

Table 2 Mean scores per brace type (semi-rigid, compression, lace-up) overall and per sport (soccer, volleyball, running) for subjective ease of use, quality, comfort, stability, hindrance and satisfaction. Scores present the mean group value of each construct on a 1 to 5 scale followed by the 95% CI.

Variable	Brace-type	Overall		Soccer		Volleyball		Running	
		Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Ease of use	semi-rigid	3.9	3.7-4.1	3.8	3.4-4.2	3.9	3.6-4.4	4.0	3.7-4.2
	compression	4.1	3.9-4.3	4.2	3.9-4.5	3.9	3.4-4.4	4.2	3.9-4.4
	lace-up	3.7	3.5-3.8	3.5	3.2-3.9	4.0	3.6-4.3	3.5	3.2-3.8
Quality	semi-rigid	3.6	3.4-3.8	3.5	3.2-3.9	3.7	3.3-4.1	3.5	3.2-3.8
	compression	4.1	3.9-4.3	4.2	4.0-4.5	3.9	3.4-4.4	4.1	3.7-4.4
	lace-up	3.8	3.6-4.0	3.8	3.5-4.0	4.1	3.7-4.5	3.6	3.2-4.0
Comfort	semi-rigid	3.1	2.9-3.4	2.8	2.4-3.3	3.4	3.0-3.8	3.2	2.9-3.5
	compression	4.0	3.8-4.1	4.0	3.8-4.3	4.0	3.6-4.4	3.9	3.6-4.2
	lace-up	3.7	3.5-3.8	3.5	3.2-3.7	3.9	3.6-4.2	3.6	3.3-4.0
Stability	semi-rigid	3.1	2.9-3.4	2.9	2.4-3.5	3.3	2.8-3.7	3.2	2.8-3.6
	compression	3.6	3.4-3.8	3.8	3.4-4.1	3.2	2.7-3.7	3.7	3.5-4.0
	lace-up	4.0	3.8-4.2	3.9	3.7-4.1	4.3	4.0-4.5	3.9	3.5-4.2
Hindrance	semi-rigid	3.0	2.7-3.2	2.8	2.4-3.2	3.2	2.7-3.6	2.9	2.5-3.3
	compression	3.7	3.5-3.9	3.7	3.5-4.0	3.7	3.3-4.1	3.6	3.3-3.9
	lace-up	2.9	2.8-3.1	2.9	2.6-3.2	3.2	3.0-3.4	2.8	2.4-3.2
Satisfaction	semi-rigid	2.7	2.4-2.9	2.5	2.0-2.9	3.0	2.4-3.5	2.6	2.2-3.0
	compression	3.4	3.1-3.6	3.6	3.2-4.0	3.0	2.5-3.5	3.4	3.0-3.8
	lace-up	3.3	3.0-3.5	3.0	2.7-3.4	3.8	3.5-4.2	3.0	2.6-3.5

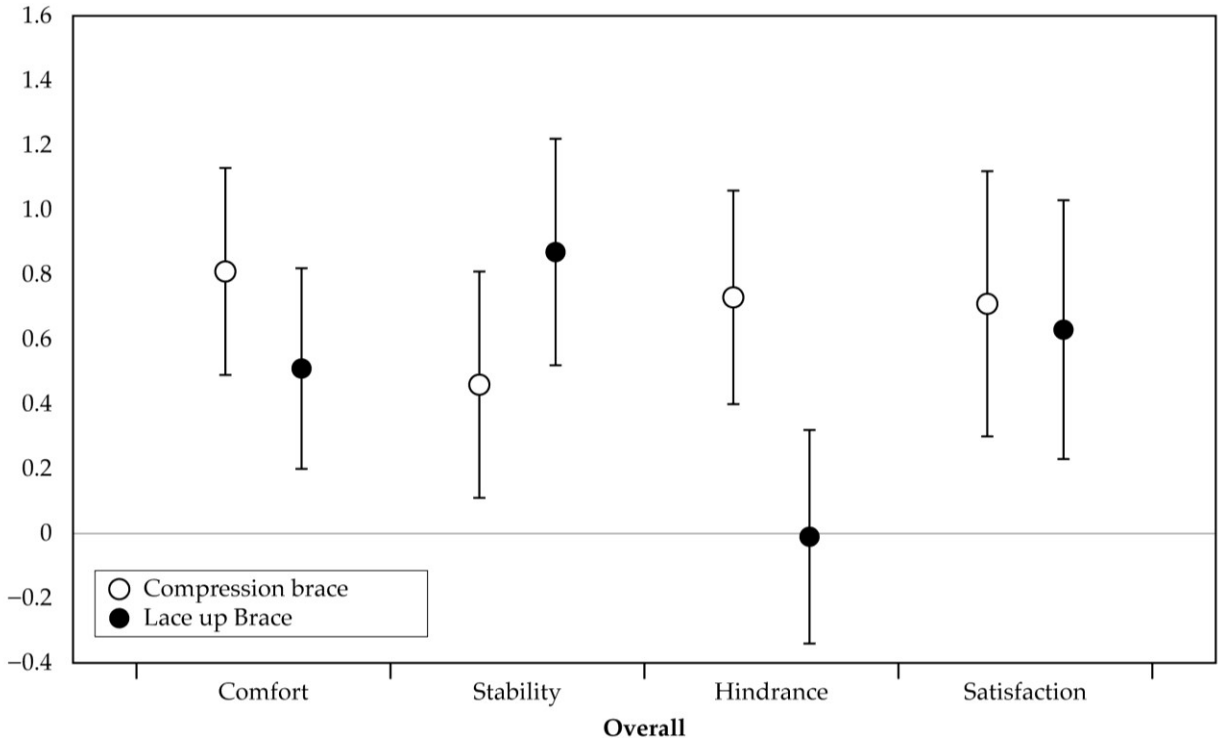
Perceived comfort, stability, hindrance and satisfaction per sport

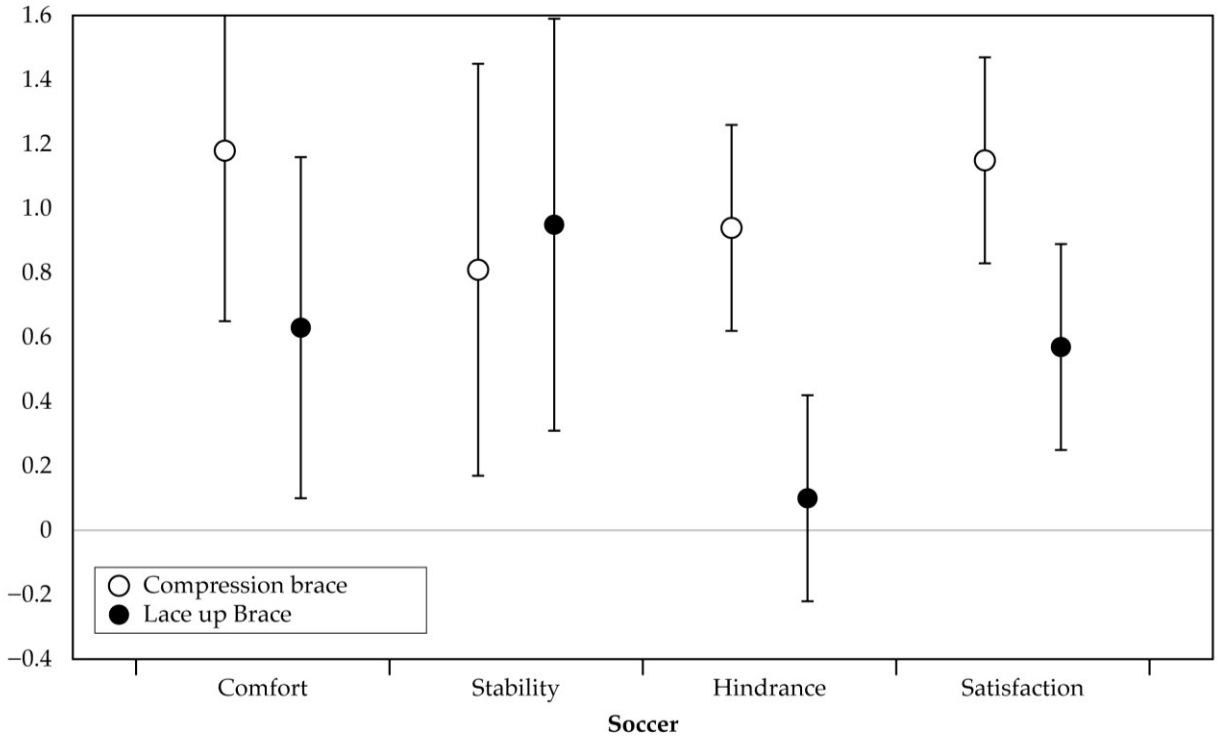
Figure 5 shows the differences between the mean scores of the various constructs for the compression brace and the lace-up brace relative to the semi-rigid brace. The scores for the semi-rigid brace act as a baseline, because this brace scored close to 3 (from 1 to 5) on all constructs. Soccer players gave the compression brace significantly higher scores over the semi-rigid brace for perceived comfort, perceived hindrance, and overall satisfaction. For soccer players even for perceived stability the compression brace, together with the lace-up brace, received significantly higher scores compared to the semi-rigid brace. Volleyball players gave the lace-up brace significantly higher scores over the semi-rigid brace for perceived comfort, perceived stability, and overall satisfaction. Runners gave the compression brace significantly higher scores over the semi-rigid brace for perceived comfort, perceived stability, perceived hindrance, and overall satisfaction.

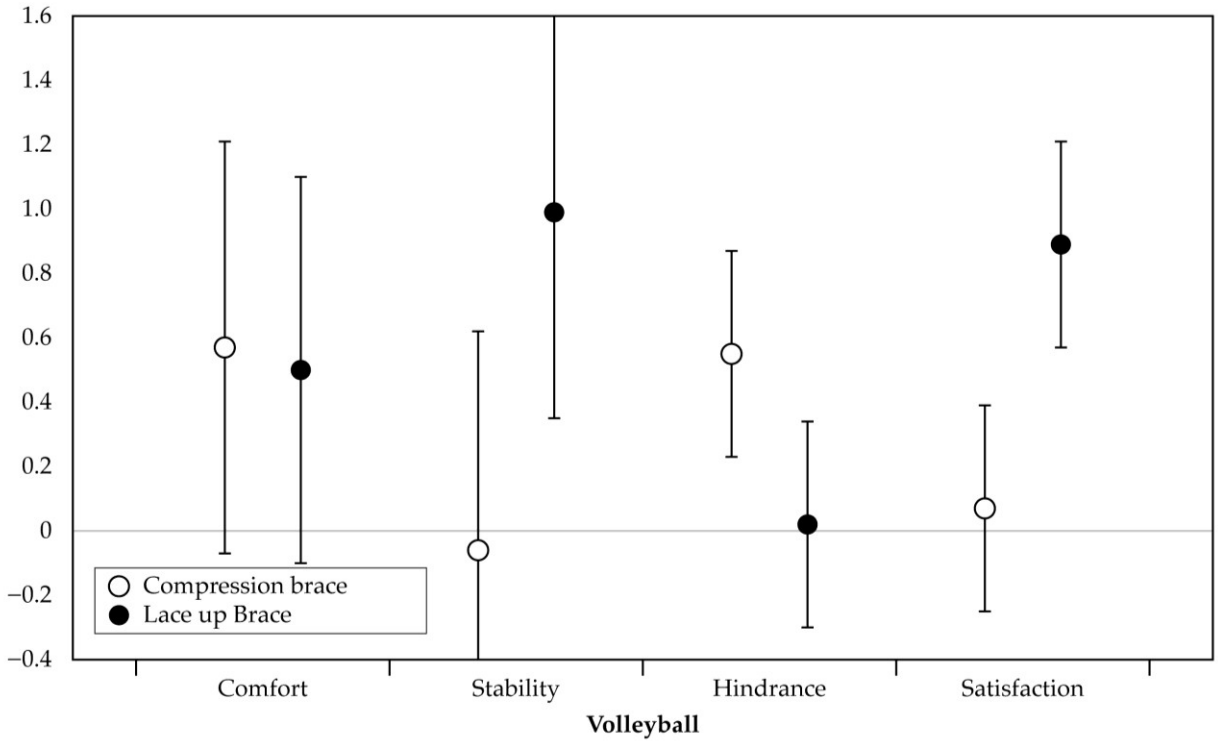
Figure 5

Differences between the mean scores of the various constructs for the compression brace and the lace-up brace relative to the semi-rigid brace.

Mean differences (error bars indicate 95%CI of the difference) between scores of the constructs 'comfort', 'stability', 'hindrance', and 'satisfaction' for the compression brace and the lace-up brace relative to the semi-rigid brace. The X-axis depicts the scores for the semi-rigid brace and acts as a baseline, because this brace scored close to 3 (on a 1 to 5 scale) for all constructs. A positive difference means a higher value for that construct as compared to the semi-rigid brace, a negative differences indicates a lower value.




1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
−0.2
−0.4
Compression brace
Lace up Brace
Comfort
Stability
Hindrance
Satisfaction
Soccer


1.6
1.4
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0.6
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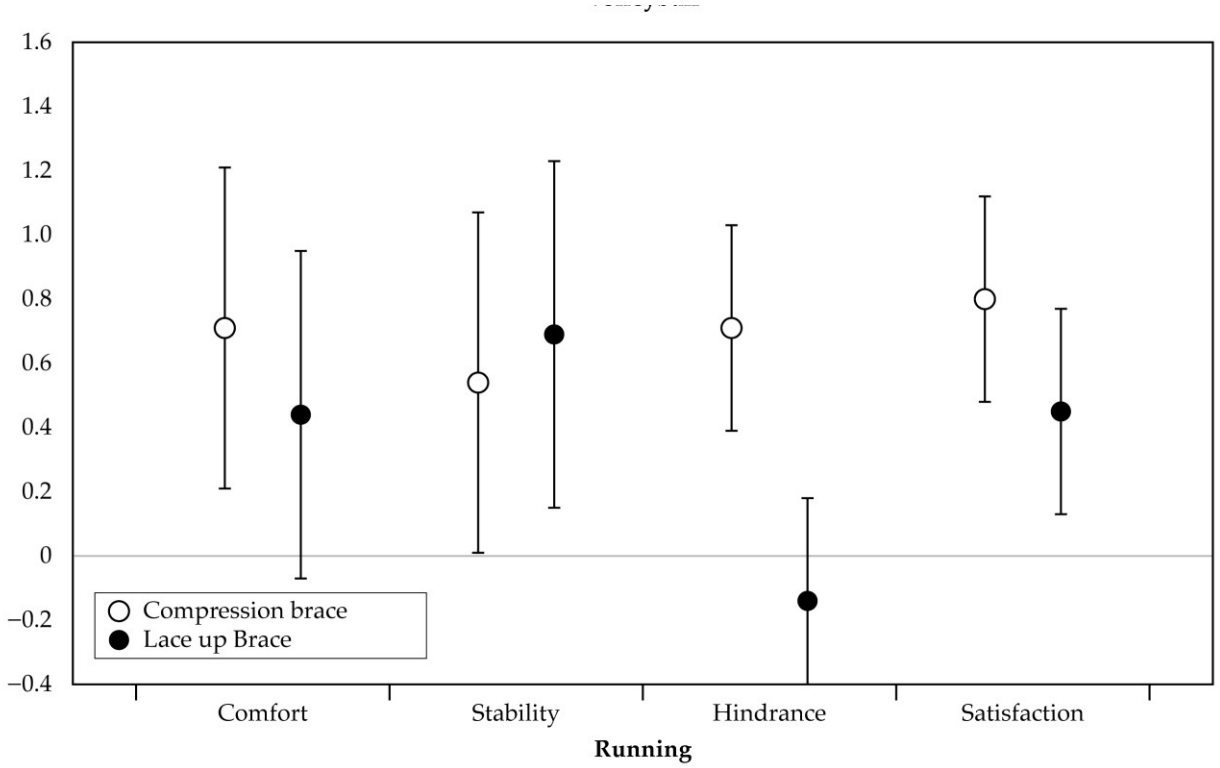
Compression brace
Lace up Brace
Comfort
Stability
Hindrance
Satisfaction
Volleyball



Willingness to buy the tested brace

After testing all braces a significant higher proportion (Chi^2 p= 0.01) of the soccer players (56%) were willing to buy the compression brace for personal ankle sprain prevention, versus lace-up brace (27%) and semi-rigid brace (13%). More than half of the volleyball players (58%) were willing to buy the lace-up brace versus compression brace 21% and semi-rigid brace 33% (Chi^2 p= 0.04). A comparable portion (57%) of the runners were willing to buy the compression brace compared to lace-up brace (39%) and semi-rigid brace (22%) (Chi^2 p= 0.03).

DISCUSSION

The objective of our current study was to systematically evaluate amongst athletes subjective factors of brace use in three different types of braces (i.e. compression brace, lace-up brace and semi-rigid brace), in three types of sports (i.e. soccer, running and volleyball), to allow clinicians and trainers to provide a more specific, better adopted and better maintained brace advise. Overall, the three brace types received high (>3.5 out of 1 to 5) mean scores for perceived ease of use (i.e. application and adjustment) and quality (i.e. look and feel). The compression brace was overall best appraised: the mean score for perceived ease of use was significantly higher compared to the lace-up brace and the mean score for perceived quality was significantly higher compared to the semi-rigid brace. Overall the compression brace was also best appraised on perceived comfort, perceived hindrance and overall satisfaction compared to the alternatives. The exception was the appraisal of perceived stability; on this factor the lace-up brace was significantly higher

rewarded, compared to the compression brace. Remarkably, the perceived stability of the compression brace was significantly higher rewarded than the perceived stability of the semi-rigid brace, i.e. the former standard in preventive bracing [20].

Per sport brace scores

Soccer players gave the compression brace significantly higher scores over the semi-rigid brace. The lace-up brace was not a real alternative for soccer players, due to significantly lower scores on perceived comfort and perceived hindrance, compared to the compression brace. Volleyball players gave the lace-up brace significantly higher scores over the semi-rigid brace. The compression brace was not a real alternative option for volleyball players due to significantly lower scores on perceived stability and overall satisfaction, compared to the lace-up brace. Runners gave the compression brace significantly higher scores over the semi-rigid brace (only for perceived comfort). The lace-up brace might be an alternative option for runners when considering comparable scores for perceived stability versus the compression brace, but when considering significantly lower scores for perceived hindrance compared to the compression brace, this might not be the case.

Relation to other studies

There is evidence that subjective factors, like perceived comfort, are an important barrier for active brace use [6, 13, 14]. However, there is very limited knowledge on other subjective factors that may facilitate or hamper active brace use. Most brace studies are lab studies that focused on the effect of ankle orthoses on functional performance in athletes [21, 22]. Because ankle braces resist ankle motion they can potentially influence athletic performance [15, 17]. Yet, it is unlikely that wearing modern ankle braces consistently affects performance [16, 17, 21-24]. Only one study also evaluated, besides objective performance-related parameters, subjective parameters related to performance comfort and stability [16]. With regard to the objective parameters, Rosenbaum (14) found no significant differences between braces, whereas in contrast the subjective evaluation revealed significant differences in favor of the soft braces (i.e. the compression and the lace-up braces) over the semi-rigid braces. This is in line with the results of our current study. Furthermore, Rosenbaum (14) did not find a distinction in the subjective evaluation of stability between the braces according to their design. Even more so, in our current study we found that the soft braces (i.e. the compression and the lace-up brace) scored significantly higher on perceived stability versus the semi-rigid brace. Taking these considerations into account athletes could be advised to select an appropriate ankle brace type according to the specific subjective properties instead of the objective specifications of the manufacturers.

Mechanical versus perceived instability

Most studies that have examined functional aspects of ankle braces have focused on mechanical properties [25, 26] or the influence of brace use on performance [16, 17, 21-24], instead of on subjective aspects of brace use. Recently Hiller et al [27] proposed a new model for the classification of 'chronic ankle instability' (CAI) that further stressed the need to account for subjective measures of stability. Following the proposed model, known CAI patients were classified in subgroups: mechanical instability, functional instability (were we prefer the term perceived instability), recurrent sprains and overlapping groups. They found that perceived instability alone, in combination with recurrent sprains, characterized the

majority of participants. It was concluded that specific prevention programs should be developed for these CAI subgroups. These findings further support the need to include the effect of preventive ankle braces on subjective or perceived stability in their evaluation.

Methodological considerations

Our study had a high degree of internal validity. The groups of athletes (soccer, volleyball and running) were comparable with respect to age, body height, body weight, and percentage history of ankle sprain. The percentage of athletes with experience in brace use differed significantly between the groups of athletes, but this may be attributable to the type of sport. Where brace use is more common in volleyball, and to a lesser extent in soccer, bracing is not considered a common preventive measure against ankle sprains in running due to the nature of the sport. As per brace-type scores for perceived ease of use were comparable for all groups of athletes we do not expect substantial bias due to the difference in brace use experience. Our design of repeatedly testing different brace types on the same athletes could have introduced some testing effects. By randomly assigning the brace-types to the different athletes we have minimized this type of bias.

There are some limitations with respect to the degree of external validity of this study. Although we had representation by 81 players from three sports, i.e. soccer, volleyball and running, our convenience sample of subjects mainly concerned young adults (mean age of 27 years). A larger more heterogeneous sample size of athletes from more different sports, ages and competition levels would have allowed for a more in-depth subjective evaluation of the brace-types. In this respect external validity is high for young adults and recreational athletes, but lower for athletes in the general population. Following the same argument ideally we would have wanted to test more brace-types. Though we would argue that the tested brace types are a representative sample of the most used brace-types in the Netherlands.

Finally, we only assessed if our participants had a history of ankle sprain, while stability was not assessed clinically. As recent research has shown that a large percentage of patients with chronic ankle instability concerned patients with perceived instability, we feel that our results are also applicable to this large group of patients [27], but may not be as valid for athletes or patients with mechanical ankle instability.

Clinical relevance and implications for future research

Future studies on subjective factors in preventive brace use should include a large sample size (current results imply minimally 5 participants per factor) with athletes from various high-risk sports for ankle sprain, and should ideally test various brace-types. Subjective factors to be included in future studies are: perceived comfort, stability and hindrance, as they could likely assist in selecting the appropriate brace type for individual athletes.

Our study shows that subjective factors in preventive brace use differ considerably among the spectrum of brace-types. As discussed, sports physical therapists consider comfort to be an important factor for successful adoption of preventive ankle brace prescription in athletes. While sports medicine practitioners implicitly seem to be aware of the importance of subjective barriers to brace use, we have shown that these subjective factors can be quantified. Future studies should further test if compliance to brace prescription can be enhanced when these subjective factors are accounted for. Self-evidently, increased compliance to brace prescription could lead to a higher effectiveness of the intervention.

From a broader perspective the effectiveness of other preventive interventions, like neuromuscular training, could also be influenced, or enhanced, when accounting for subjective factors. We have shown that both having had a previous ankle injury and high-risk sport participation increase overall compliance with neuromuscular training and bracing [28]. A possible explanation is that athletes adapt their behaviour due to a higher perception of susceptibility to re-injury. The subjective factors of brace use are actually subjective factors that influence behaviour, in this case adoption, or rejection of the intervention. Eventually, if we can better understand these subjective factors, we can influence behaviour, which will lead to individualized, better implemented, and finally more efficient interventions for prevention of ankle sprains.

Conclusion

The investigated ankle braces, semi-rigid, compression and lace-up, scored high on perceived ease of use and perceived quality. The various brace types significantly differed with respect to the subjective evaluation of comfort, stability, hindrance and overall satisfaction between soccer players, volleyball players and runners. These subjective factors influence the acceptability of the brace use by athletes, and consequently current results will assist athletes, coaches and practitioners in selecting the optimal ankle brace for each individual athlete.

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References

1. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* Apr-Jun 2007;42(2):311-319.
2. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sports Med.* 2007;37(1):73-94.
3. Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ, Jr. The epidemiology of ankle sprains in the United States. *J Bone Joint Surg Am.* 2010;92(13):2279-2284.
4. Garrick JG. The frequency of injury, mechanism of injury, and epidemiology of ankle sprains. *Am J Sports Med.* Nov-Dec 1977;5(6):241-242.
5. Hupperets MD, Verhagen AL, van Mechelen W. Effect of unsupervised home based proprioceptive training on recurrences of ankle sprain: randomised controlled trial. *BMJ.* 2009;339:b2684.
6. Jongert MWAH, L; Hespen, A.T.H. van; Stege, J.P.; Chorus, A.M.J.; Zande, M.E. van der. Gebruikersonderzoek enkelbraces. *TNO Kwaliteit van Leven.* 2007;KvL/B&G/2007.022 1-85. http://www.laurenshellingwerf.nl/docs/Gebruikersonderzoek_enkelbraces.pdf. Accessed 06-04-2015.
7. McGuine TA, Brooks A, Hetzel S. The effect of lace-up ankle braces on injury rates in high school basketball players. *Am J Sports Med.* 2011;39(9):1840-1848.
8. McGuine TA, Hetzel S, Wilson J, Brooks A. The effect of lace-up ankle braces on injury rates in high school football players. *Am J Sports Med.* 2012;40(1):49-57.
9. Janssen KW, van Mechelen W, Verhagen EA. Bracing superior to neuromuscular training for the prevention of self-reported recurrent ankle sprains: a three-arm randomised controlled trial. *Br J Sports Med.* 2014;48(16):1235-1239.
10. Schiftan GS, Ross LA, Hahne AJ. The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: a systematic review and meta-analysis. *J Sci Med Sport.* May 2015;18(3):238-244.
11. Farwell KE, Powden CJ, Powell MR, McCarty CW, Hoch MC. The effectiveness of prophylactic ankle braces in reducing the incidence of acute ankle injuries in adolescent athletes: a critically appraised topic. *J Sport Rehabil.* May 2013;22(2):137-142.
12. Janssen KW, van Mechelen W, Verhagen EALM. The cost-effectiveness of measures to prevent recurrent ankle sprains; results of a three arm randomised controlled trial. *Am J Sports Med.* 2014;2014 Jul(42(7)):1534-1541.
13. Denton JW. *Clinician Patterns of Ankle Brace Recommendation and Perception of Factors Associated with Brace Use*. Chapel Hill: Division of Physical Therapy, University of North Carolina; 2007.
14. Cusimano MDFA, Luong W.P.; Amin K.; Eid, J; , Abdelshaheed TRK. Factors Affecting Ankle Support Device Usage in Young Basketball Players. *J Clin Med.* 2013;2:22-31.
15. Bot SD, van Mechelen W. The effect of ankle bracing on athletic performance. *Sports Med.* Mar 1999;27(3):171-178.
16. Rosenbaum D, Kamps N, Bosch K, Thorwesten L, Völker K, Eils E. The influence of external ankle braces on subjective and objective parameters of performance in a sports-related agility course. *Knee Surg Sports Traumat Arthrosc.* 2005;13(5):419-425.
17. Greene TA, Wight CR. A comparative support evaluation of three ankle orthoses before, during, and after exercise. *J Orthop Sport Phys Ther.* 1990;11(10):453-466.
18. Denton JM, Waldhelm A, Hacke JD, Gross MT. Clinician Recommendations and Perceptions of Factors Associated With Ankle Brace Use. *Sports Health.* May 2015;7(3):267-269.
19. O'Hara J, Valle-Jones JC, Walsh H, O'Hara H, Davey NB, Hopkin-Richards H, Butcher RM. Controlled trial of an ankle support (Malleotrain) in acute ankle injuries. *Br J Sports Med.* Sep 1992;26(3):139-142.
20. Handoll HH, Rowe BH, Quinn KM, de Bie R. Interventions for preventing ankle ligament injuries. *Cochrane Database Syst Rev.* 2001(3):CD000018.
21. Gross MT, Clemence LM, Cos 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.
22. Yaggie J, Armstrong W, Smith S, Miller A, Trimbach R. Effects of semi-rigid ankle orthoses on tasks related to athletic performance following a bout of fatiguing exercise. *Open J Ther Reh.* 2013;1(2):10-16.
23. Macpherson K, Sitler M, Kimura I, Horodyski M. Effects of a semirigid and softshell prophylactic ankle stabilizer on selected performance tests among high school football players. *J Orthop Sports Phys Ther.* Mar 1995;21(3):147-152.
24. 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.* Apr 1997;32(2):136-140.
25. 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.* Nov-Dec 2003;31(6):935-940.
26. Eils E, Demming C, Kollmeier G, Thorwesten L, Volker K, Rosenbaum D. Comprehensive testing of 10 different ankle braces. Evaluation of passive and rapidly induced stability in subjects with chronic ankle instability. *Clin Biomech.* Aug 2002;17(7):526-535.
27. Hiller CE, Kilbreath SL, Refshauge KM. Chronic ankle instability: evolution of the model. *J Athl Train.* Mar-Apr 2011;46(2):133-141.
28. Janssen KW, van der Zwaard BC, Finch CF, van Mechelen W, Verhagen EA. Interventions preventing ankle sprains; previous injury and high-risk sport participation as predictors of compliance. *J Sci Med Sport.* Jun 16 2015.