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## The influence of external ankle braces on subjective and objective parameters of performance in a sports-related agility course

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**Abstract** With lateral ankle sprains being the most frequent sports-related injury, there is an evident demand for the preventive measures in active individuals with chronic ankle instability. Braces are commonly used for prevention and treatment of ankle injuries. Various investigations—mostly performed with healthy subjects—focused on this problem, yet they often compared only a few models or used only limited testing procedures. However, controversy exists whether braces affect sports performance. The purpose of the present study was to compare the effects of ten different ankle braces—one rigid, five semi-rigid, four soft models—in a comprehensive evaluation with multiple testing procedures in 34 subjects with self-reported chronic ankle instability. The multiple testing procedures evaluated objective performance-related parameters and subjective parameters related to comfort and stability. The subjects performed an agility course with maximal effort. The course included a vertical jump and a cutting maneuver, both on a force platform, a single leg hopping test on level and inclined plates, a combined straight and curve sprint and sidesteps. Three valid trials were measured and averaged for each brace and every subject. Subjective

aspects were evaluated with a questionnaire about handling, perceived restrictions, support and comfort; it was completed after each brace was worn and tried. With regard to the objective parameters, no significant differences were found between the braces except for the rigid brace which showed decreased values for the vertical jump and longer times for the other tests compared to all other braces. The subjective evaluation of the braces revealed significant differences with respect to comfort and handling and therefore, permitted a distinction between semi-rigid and soft braces. Although significant differences between braces were found in subjective performance restriction, no significant differences were revealed in the objective evaluation. From that point of view, patients could choose a brace model according to their individual needs. A comfortable brace might have a positive influence on the athlete's state of mind although other aspects like the brace's stabilizing effect play an additional role and should also be taken into account for recommendation of braces.

**Keywords** Ankle joint instability · Ankle braces · Sports performance · Agility course · Perceived comfort

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## Introduction

Recent reports claim that ankle sprains continue to be the most frequent injuries in sports [4, 12]. They usually occur in high-risk sports that are characterized by contact, a high rate of jumping, or indoor activities [2] and may lead to a marked impairment of sports and daily life activities. Ankle braces are an accepted treatment option for acute injuries as well as for the prevention of recurrent injuries in athletes with previous injuries or known instabilities during sports activities [14, 15]. Their main objective is to provide mechanical support for the unstable or jeopardized joint by restricting the range of eversion and inversion without limiting plantar- and dorsiflexion [5]. High performance athletes at risk do not only expect a mechanical stabilizing effect but are also concerned with potential performance limitations. This aspects has been investigated before but was deemed as inconclusive even though the majority of the studies indicated no or only a small effect of braces on various sports activities [5]. Furthermore, recent reports focused mainly on healthy subjects and did not evaluate the effects in patients with a history of ankle instability.

However, patient compliance is an important aspect because braces can only be effective if they are worn during the potentially dangerous activities. Thus, their acceptability based on the user's subjective impression is of foremost importance. Numerous studies examined aspects of stability and performance [5], yet they usually focused on performance restriction as the main aspect. Only a few studies investigated subjective parameters as a possible source of influence on physical performance and stability [1]. Furthermore, only a few brace designs were compared in previous studies and a comprehensive investigation of different brace designs is lacking. Therefore, we carried out a comprehensive investigation of ten different ankle braces that involved the evaluation of functional aspects with regard to passive and dynamic stabilizing effects [7]. Consequently, it has been stated that these aspects need further investigation [5].

Therefore, the purpose of the present study was twofold:

1. To examine in a comprehensive evaluation whether ten different ankle braces impair sports-related per-

formance in a combined agility course in patients with self-reported chronic ankle instability.

2. To evaluate subjective parameters concerning perceived comfort, performance and stability. The ultimate goal was to provide detailed information about the specific characteristics of different brace designs in order to support the selection process between different braces.

## Materials and methods

Thirty-four subjects with self-reported chronic ankle instability participated in the study (Table 1). Prior to participation, all subjects were informed about the procedures and signed an informed consent form. Due to the fact that the objective assessment should be based on personal experience with previous ankle problems only subjects with self-reported chronic instability of the ankle joint were included. The mean frequency of ankle sprains of the group was 22.8 inversion accidents per year (ranging from three times per year to twice per week). Only subjects without recent ankle injuries (free of a painful/disabling injury within the last 3 months) and no history of knee or hip injuries were included. All subjects except one actively participated in regular sports activities (8 h/week, ranging from 2 h to 18 h).

In a complex sports performance test ten different braces—one rigid, five semirigid and four soft braces—were evaluated and compared to the no-brace condition. The following models were provided by the respective manufacturers or distributors: Caligamed (1), Aircast (2), Air Gel (3), Air Brace (4), Ligacast (5), Malleoloc (6), Kallassy (7), Kallassy S (8), Fibulo Tape (9), and Dynastab (10) (Table 2). The three different brace categories were characterized as follows.

1. The rigid brace consisted of an l-shaped plastic component on the lateral aspect of the ankle that was individually adapted for each subject. As this brace is not primarily designed for athletic use it served as a reference model.
2. The semirigid braces consisted of a lateral and medial plastic shell that could be adjusted by Velcro bands, except for one brace which was based on a U-shaped shell instead.
3. The soft braces were modifications of the lace-up design and were made of elastic material that was tightened with Velcro bands.

The subjects wore the same shoe model in their appropriate size (Air Max Triax, Nike Inc., USA) and uniform socks throughout the investigation. In order to exclude a potential influence of fatigue, each subject performed the test with all braces and without brace (native) in randomized order. The subjects were

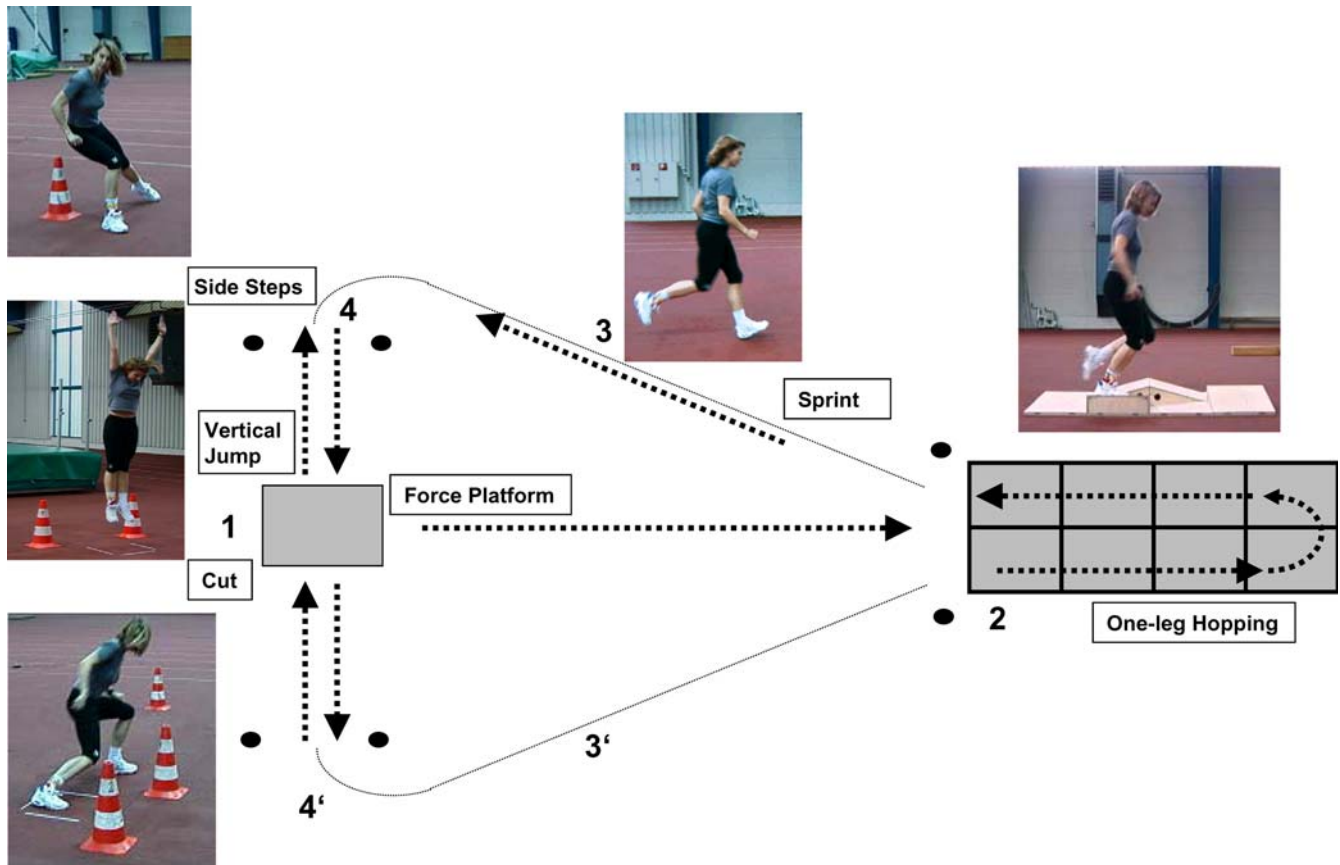
**Table 1** Anthropometric data of the subjects ( $n=34$ , 19 ♀, 15 ♂)

Parameter	Mean (SD)	Range
Age (years)	23.9 (2.8)	16–30
Height (cm)	177.2 (8.3)	165–194
Weight (kg)	69.9 (11.6)	53–107
Sports activity (hours per week)	8.0 (4.7)	2–18
Frequency of ankle sprains (per year)	22.9 (17.0)	3–104

**Table 2** Categories of the investigated brace models and manufacturers or distributors

Code	Model	Manufacturer/distributor	Category
01	Caligamed	Bauerfeind GmbH Co. KG, Kempen, Germany	Rigid
02	Aircast	Europa GmbH, Neubeuern, Germany	Semirigid
03	Air Gel	NeaTec mbH, Neu-Ulm, Germany	Semirigid
04	Air Brace	Ruthner, Neckargemünd, Germany	Semirigid
05	Ligacast Anatomic	Thuasne GmbH & Co. KG, Burgwald, Germany	Semirigid
06	Malleoloc	Bauerfeind GmbH Co. KG, Kempen, Germany	Semirigid
07	Kalassy	NeaTec mbH, Neu-Ulm, Germany	Soft
08	Kalassy S	NeaTec mbH, Neu-Ulm, Germany	Soft
09	Fibulo Tape	Sporlastic GmbH, Nürtingen, Germany	Soft
10	Dynastab	Thuasne GmbH & Co. KG, Burgwald, Germany	Soft

**Fig. 1** Schematic of the agility course with the following segments: 1 force platform for measurements of the vertical jump and the cutting movement; 2 tilted plates for the single-leg hopping test; 3 sprint; 4 side steps; the course is symmetrical to accommodate patients with left- or right-sided ankle instability



introduced to the agility course and several test runs were performed to prevent a potential influence of learning effects. The same investigator applied all braces to the subject's leg according to the manufacturer's instructions to ensure accurate fit. The subjects completed an agility course with the following four sections (Fig. 1):

1. Maximum vertical jump on a force platform
2. Single-leg hopping test with the unstable leg on a self-constructed wooden platform that featured four inclined plates (15° inversion, eversion, plantarflexion and dorsiflexion)
3. A combined straight and slalom sprint
4. Sidesteps with a cutting maneuver on a force platform.

The subjects were encouraged to perform the test with maximum effort. The course was designed to be short enough to prevent fatiguing effects during the measurements. One trial took less than 10 s. For each subject, three valid trials for each condition were measured and the mean was calculated. The objective parameters were (a) the time needed for each of the sections and (b) the total time as determined with light gates (Timing System DLS-LA, AF Sport, Wesel, Germany). Furthermore, the force maximum and flight time were measured during the vertical jump and the jump

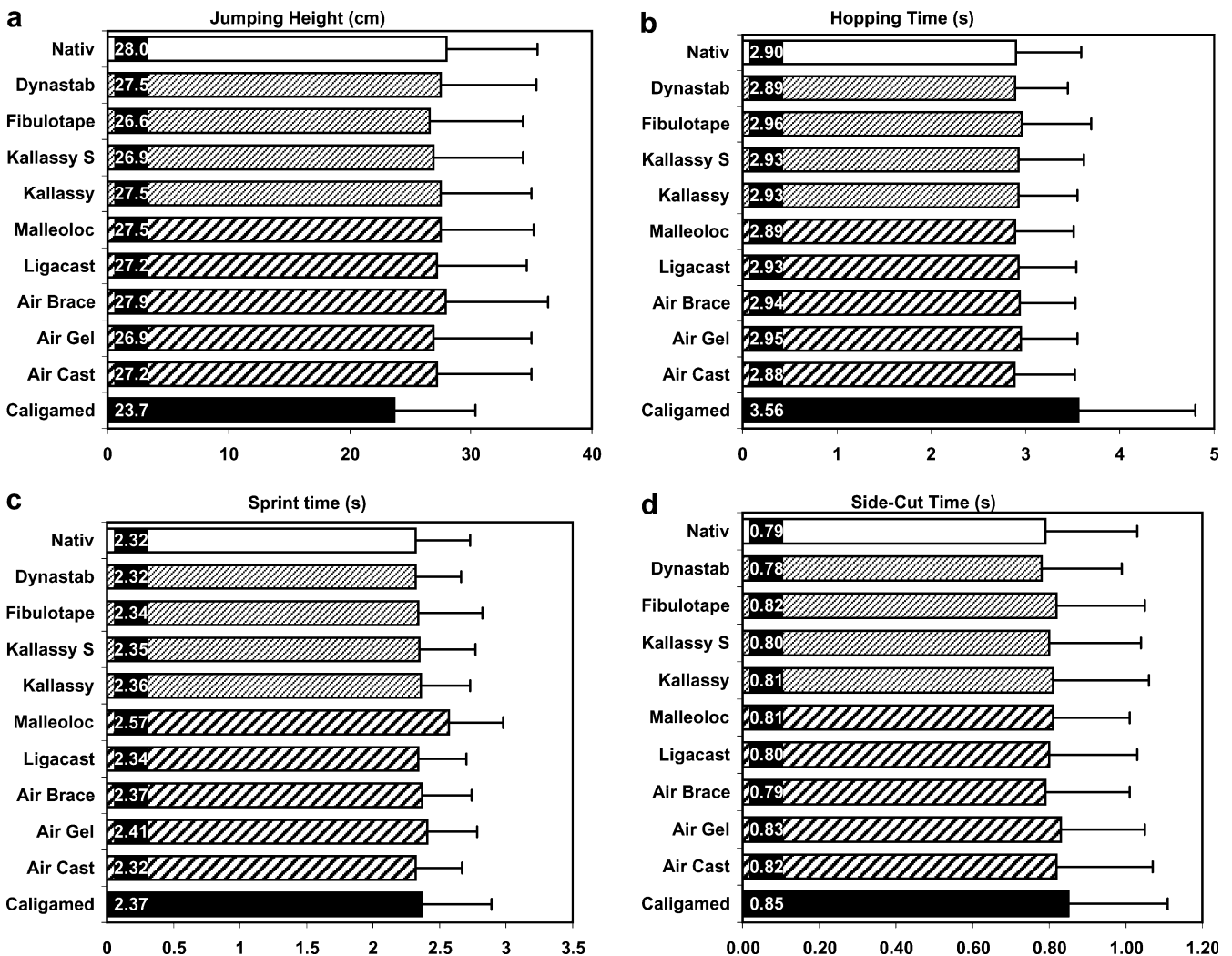
height was calculated. The following equation was used to calculate the jump height (with  $g$  corresponding to gravitational acceleration)

$$h = \frac{1}{2}g(t_{\text{flight}})^2 \quad [8]$$

After three valid trials with each ankle brace, the subjects filled out a questionnaire consisting of four sections for subjective evaluation of the braces:

1. Ease of application and handling of each brace.
2. Performance restriction, in which the perceived impairment of performance due to each brace was rated for the different motions performed in the agility course.
3. Stability, in which the perceived stabilizing effect provided by each brace was to be evaluated, again referring to the different sections of the agility course.

**Fig. 2** Means and standard deviations for the parameters of the agility course sections: **a** vertical jumping height, **b** single-leg hopping time, **c** sprint time and **d** side-cut time



4. Comfort, i.e. the satisfaction with each brace concerning several aspects of comfort. The subjective evaluation was recorded on a 10-point rating scale. For statistical analysis, a repeated measures ANOVA with the alpha-level at 5% and Tukey/Kramer test for post hoc comparisons were used (StatView 5.0, SAS Institute Inc. Cary, NJ, USA).

## Results

As far as the objective parameters are concerned, means of all conditions showed similar values in each of the four test procedures (vertical jumping height, single leg hopping time, sprint time and side-cut time; Fig. 2a–d). None of the semirigid and soft braces revealed significant differences, except for the rigid reference brace with significantly lower values for vertical jumping height and longer contact times for the side-cut.

Although the subjects reached the largest jumping height in the native condition, these values were not significantly different from the other conditions (except for the rigid reference brace). Furthermore, the values for hopping, sprinting and side-cut time without brace revealed no significant differences.

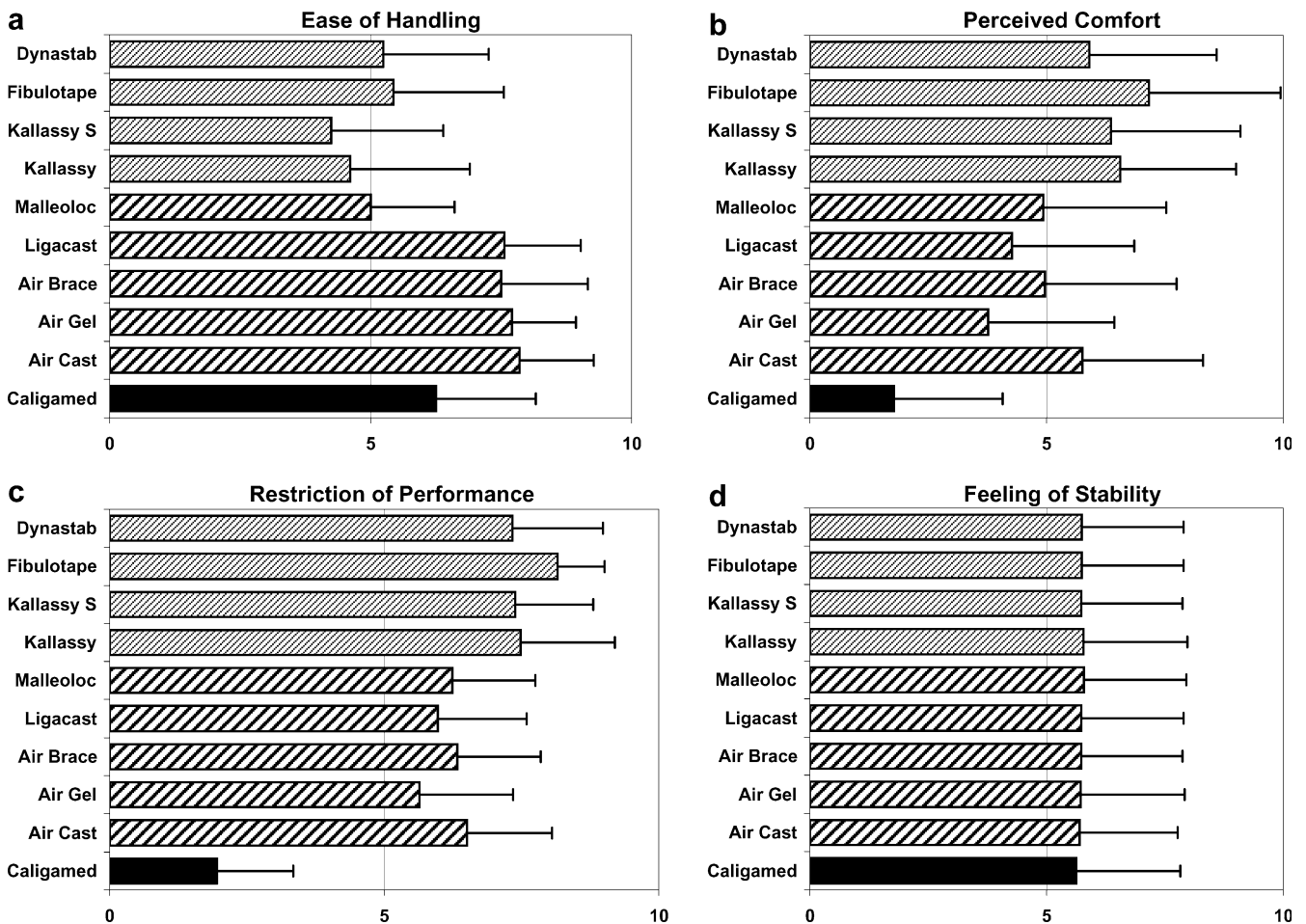
Regarding the subjective parameters, handling, perceived comfort and restriction of performance, significant differences between the semirigid and soft braces were found (Fig. 3). Subjects perceived the handling of braces with a stirrup design easier compared to other designs ( $P=0.05$ ; Fig. 3a). Concerning the comfort, there was a tendency to perceive soft braces as more comfortable than the semirigid braces ( $P=0.014$ ; Fig. 3b). Furthermore, the rigid brace was rated as most uncomfortable. The soft braces were rated to cause the least performance impairment while the semirigid and rigid braces appeared to restrict performance more

(significantly different between semirigid and soft braces,  $P=0.014$ ; Fig. 3c). Concerning the evaluation of support provided by the braces, the semirigid braces were rated to be only slightly more stable than soft braces ( $P<0.05$ ; Fig. 3d). All semirigid and soft braces showed significant differences when compared to the rigid brace, both for stabilization and support.

## Discussion

Even though it appears commonly accepted that braces can be used successfully in order to prevent recurrent ankle injuries, there is no consensus on whether the design of ankle braces has an influence on performance in sports related activities. The results of the present study indicate that no significant performance impairment is caused by semirigid or soft braces in a high intensity, short duration agility course. It was shown, however, that the investigated ankle braces differed with respect to subjective evaluation of ease of handling, perceived comfort, and restriction of performance. This may influence the acceptability of products for patients with high demands on sports activities.

**Fig. 3** Means of the subjective evaluation of the braces' characteristics: **a** handling, **b** comfort, **c** performance and **d** stability (please note that a value above five describes positive impressions, values below five negative impressions; the line at five indicates a neutral impression)



The discussion on performance aspect of ankle braces has been controversial because some studies reported a performance restriction [6, 9, 10], while other reports did not reveal any limiting effects [11, 13]. The present results of the objective parameters showed that, except for the rigid brace, no significant differences in performance exist. Due to the fact that the rigid brace is not specifically designed and recommended for athletic use it will be excluded from further discussion. However, it should be noted that the significant difference for the rigid brace underlines the ability of the testing procedures to distinguish between different brace designs.

The fact, that no significant difference to the native condition was found demonstrates that there are no objective performance restrictions for subjects with chronic ankle instability while wearing a brace in an agility course. As no other significant differences occurred, there is no evidence of performance restriction based on the objective parameters even though it should be realized that the agility course was fairly short as a consequence of the experimental design. A longer activity requirement might have accentuated potential differences between braces. With respect to the objective results of a short-duration activity it can be stated that ankle braces did not affect performance. A further potential reason for the results differing from other reports could be the bilateral use of braces [6, 9] which might have a more pronounced effect. However, braces are mostly used unilaterally in real life since they are worn only on the affected limb. Therefore, we feel that the present approach is more realistic. Furthermore, it might have made a difference as our tests were performed in a single experimental session and not on separate days as in other studies [9, 10]. From our point of view, this should have helped to ensure a better repeatability since day-to-day variations in athletic performance were prevented. Finally, it should be noted that—contrary to other reports [6, 9]—in the present study, subjects with chronic ankle instability performed the tests because they are the ones who should benefit the most from ankle braces.

Similar to the results regarding performance, the subjective evaluation of stability did not show a distinction between the braces according to their design. In general, the subjects did not perceive the soft models as providing a stabilizing effect that was worse than the semirigid models.

However, the other subjective parameters revealed a clear distinction between semirigid and soft braces. Especially, the subjective perception of performance restriction showed a clear distinction between semirigid and soft braces. In all sections of the agility course, especially during the hopping test and the curve run, semirigid braces were perceived to restrict performance more than the soft models. Considering only the subjective parameters, it appears that the subjects' performance ought to be better when wearing a soft

brace and should be limited when wearing a semirigid ankle brace. However, this could not be proven since subjects did not run faster or jump higher when wearing a soft brace. The only brace that showed significant differences was the rigid reference model.

In contrast to this study, Beriau et al. [3] found differences in performance in an examination of four different brace models in an agility course containing sprints, curve runs and sidesteps. However, similar to the present study, the subjects felt restricted by the different braces. It was concluded that the subjects' perceived comfort, stability and performance restriction directly influenced the effectiveness of the braces.

Previous investigations examined the subjective stability and found differences in models of different design [1, 3]. The authors regarded the stabilizing effect of an ankle brace as the first priority and proposed the subjective perception as a source of influence. Gross et al. examined the aspect of perceived stability and concluded that the patients' individual preferences which are based on subjective perception have a strong influence on the effectiveness of an ankle brace [10]. In the present study, however, there was no tendency to perceive semirigid braces as more stabilizing than soft braces.

Although subjective performance restriction was significantly different between braces, only minor differences in the objective performance parameters of an athlete could be found. Therefore, the following recommendations appear warranted.

- Based on the present results it may be concluded that patients should be able to choose the brace that appears most appropriate for their individual needs. However, it appears essential to consider subjective parameters of stability and comfort as well because these factors might influence the patient's compliance.
- If the handling of braces is of primary interest, then semirigid braces with stirrup design should be recommended. If comfort is of primary interest, then soft braces may be recommended. An optimal brace should include both these aspects.

An informed decision between different products is facilitated based on the present information in combination with the previously reported results of the passive and dynamic stability measurements [7]. If stability is a key point for the athlete, then semirigid braces with stirrup design are recommended for an optimal solution. It has to be considered that stirrup braces may wear out shoes and are often not compatible to other equipment. An optimal solution would be a soft brace that also provides sufficient stability.

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