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Protection and performance effects of ankle bracing

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Abstract We investigated the protection afforded to ankle ligaments by ankle supports and the extent to which these were associated with a diminution of motor performance. Eleven volunteers were subjected to a 10° tilt in four directions (inversion, eversion, plantar flexion and dorsiflexion) on a rocking platform. Three-dimensional videography was used to record complex ankle kinematics. The prophylactic ankle supports used were a semi-rigid brace, a lace-up cloth brace, and taping. The ankle supports provided similar initial protection against acute ligamentous inversion sprains. The semi-rigid ankle brace produced a smaller restriction of plantar flexion-dorsiflexion movement than either the lace-up cloth brace or taping.

Résumé Les auteurs ont étudié la protection qu'une cheville assure aux ligaments de la cheville, ainsi que la mesure dans laquelle le port d'une cheville perturbe la motricité de l'articulation. A l'aide d'une plate-forme de perturbation, 11 volontaires ont été soumis à des inclinaisons de 10° dans quatre sens (inversion, éversion, flexion plantaire, flexion dorsale). La cinématique de l'articulation talo-crurale a été analysée pour chaque épreuve par vidéographie tridimensionnelle. Les chevillères employées à cette fin étaient de trois types: semi-rigide, laccée et bandage. Les résultats révèlent que les chevillères étudiées assurent initialement le même degré de protection contre les entorses par inversion. La cheville semi-rigide limite moins les mouvements de flexion plantaire et dorsale que les deux autres types.

Introduction

The goal of prophylactic ankle supports is to stabilise the ankle ligaments against inversion or eversion strains without decreasing function. Several authors have reported the prophylactic effects of ankle braces and taping on the ankle ligaments by controlling the range of ankle movement [8, 9]. However, this ignores the effects of ankle supports on muscle activity and on stiffness [11, 16]. This is particularly important with respect to plantar flexion-dorsiflexion. If an ankle support interferes with activity it is likely to be discarded, even if it is effective in improving ankle stability.

The purpose of the present study was to assess both the degree of protection given to the ankle joint ligaments by using prophylactic ankle supports during inversion and eversion as well as motor performance in relation to plantar flexion-dorsiflexion movement.

Materials and methods

Eleven healthy subjects volunteered to participate in the study. There were nine men and two women with a mean age of 33 (26–35) years, body weight of 67.4 (49–82) kg and height of 170.7 (158–180) cm. All the subjects gave informed consent and during the experiment they stood with their arms relaxed on a specially made rocking platform. Approximately equal weight was placed on each foot. The feet were parallel to one another, heels aligned, and approximately 20 cm apart. All the subjects wore the same model of sport shoes.

The rocking platform is an electronically activated device that moves under the influence of gravity through a user-specified angle about a user-specified axis (Fig. 1). Subjects were unable to anticipate when either movement was to commence, or its direction. In the study, 10° of tilt was applied in four directions (plantar flexion, dorsiflexion, inversion, eversion) and the subjects wore either one of three supports, or none at all. The supports used were tape (Zonas tape; Johnson and Johnson, Skillman, N.J., USA) using a closed basket weave method; a semi-rigid ankle brace (Aircast Air-Stirrup; Aircast, Summit, N.J., USA), or a lace-up cloth brace (RocketSoc; Smith and Nephew Donjoy, Carlsbad, Calif., USA). The same investigator using a thin foam underwrap and 2-inch cloth adhesive tape with a standard closed basket weave

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Fig. 1 Position of subject after sudden inversion of the right ankle

technique did all taping. The steps of this technique included pre-wrap, anchor strips, stirrups, shingles, figure-of-eight and double heel lock. Three experiments were made with each subject of the four groups.

Data collection. Foot and shank positions were recorded using a Motion Analysis system (Motion Analysis, Santa Rosa, Calif., USA). Four video cameras operating at 60 Hz were used to record the motion of six 2.5-cm-diameter hemispherical passive reflective markers. Those on the shoes were placed on the medial aspect of the base of the first metatarsal, the lateral aspect of the fifth phalanx, and the heel. Shank markers were placed over the medial and lateral knee joint axis and the anterior side of the tibial shaft. Calibration of a 15-cm-long, 11-cm-wide and 18-cm-high rectangular volume occupied by the markers on the foot and shank revealed position errors of less than 1 mm [13].

Cartesian reference systems for both the foot and shank were determined from the marker sets. The axes of these two reference systems were defined to be parallel in the neutral standing position. The axes of the reference systems in the neutral position were directed medially (z -axis), superiorly along the long axis of the shank (x -axis), and anteriorly along the long axis of the foot (y -axis). For the data collection trials the position of the foot was determined relative to this neutral foot position and was specified by Cardan angles in the following order: plantar flexion-dorsiflexion, inversion-eversion and abduction-adduction. Measurement of Cardan angles has been described as an acceptable method of calculating angles between rigid segments, and this angle is related to clinical and anatomical definitions of joint angle [3]. The angular velocity (derivative of the joint angle) and angular acceleration (derivative of joint velocity) curves were obtained by differentiating the smoothed joint time-displacement data. For a given direction of rocking the variables extracted were (a) maximum angular velocity and (b) maximum angular acceleration.

Statistical analyses. The primary statistical analysis was a repeated measures analysis of variance (ANOVA) that was used to test the null hypothesis that ankle supports had no effect on the maximum velocity in inversion-eversion rocking and on the maximum acceleration of the ankle complex movement in plantar flexion-

Fig. 2 Maximum inversion and eversion velocity of the ankle during sudden angular rocking of 10°. Bars illustrate the average (+ standard deviation) in the 11 subjects for the 4 test conditions. Significant differences are indicated by asterisks (* $P<0.05$, ** $P<0.01$)

dorsiflexion rocking. Post hoc multiple comparisons were performed when indicated by the ANOVA using Bonferroni-corrected t -tests.

Results

In the test of any rocking direction, no significant change of displacement pattern of the platform was observed in any of the tests. All three types of brace decreased the maximum inversion and eversion angular velocities of the ankle when compared to a non-braced ankle (Fig. 2). In contrast to the maximum inversion velocity observed in a non-braced ankle, taping, a semi-rigid brace and a lace-up cloth brace were associated with reductions of 25% ($P<0.05$), 34% ($P<0.01$) and 32% ($P<0.01$), respectively. The differences between the three ankle supports were not significant.

The taping, semi-rigid brace, and lace-up brace supports decreased maximum eversion velocity by 12%, 16% ($P<0.05$) and 10%, respectively. The differences between the ankle supports were not significant.

Changes in the kinematic data of angular acceleration produced by the ankle supports were subtle. However, statistically the tape and lace-up brace significantly de-

Fig. 3 Maximum plantar flexion and dorsiflexion acceleration of the ankle during sudden angular rocking of 10°. Bars illustrate the average (+ standard deviation) in the 11 subjects for the 4 test conditions. Significant differences are indicated by asterisks (* $P < 0.05$, ** $P < 0.01$)

creased maximum plantar flexion acceleration compared to the non-braced condition ($P < 0.05$ and $P < 0.01$, respectively). Compared to the non-braced condition none of the supports significantly affected the maximum dorsiflexion acceleration (Fig. 3).

Discussion

In the visco-elastic model (a standard linear solid model) force is determined by displacement and velocity by using the following formula [6]:

$$\text{Force} = a (\text{displacement}) + b (\text{velocity}) \quad (1)$$

(a , b : constant).

Thus the force applied to ankle ligaments is in part dependent on the displacement and the velocity of ankle movement. Since rocking platform displacement was constant under all the test conditions and the computed maximum velocity was accurately calculated, we speculated that the reduced inversion velocity associated with the braced conditions suggested that there was a reduced force being applied to the lateral ankle ligaments.

In all the support conditions in simulated inversion we found a 30% reduction in inversion velocity. These

results are similar to those of Shapiro et al. [18] who found resistance to an applied inversion movement by prophylactic bracing or taping. They also found that relative to the freshly taped ankle the semi-rigid brace increased resistance by about 10%. This is in agreement with our findings. It was also reported that resistance to inversion movements was two to three times greater with tape or brace than without. These differences are larger than ours and may be attributable to the use of cadaveric specimen [18]. Since neuromuscular feedback plays an important role in this kind of experiment and ankle supports may increase the afferent feedback from cutaneous receptors, it would be ideal if an experiment were conducted under conditions which did not preclude reflex response and muscle stiffness [5, 16].

Alt et al. [2] measured the maximum inversion angle during injury simulation and found that taping resulted in a significant reduction (less than 15°). Under our test conditions, the subjects needed to attain the same angle in every trial in order to assess the force applied to the ankle ligaments. In order not to injure a healthy volunteer fully weight-bearing in an extreme position, we decided to limit our measurement to 10° of rocking.

Inversion sprains involving stretching or rupture of the lateral ligaments are much more common than sprains of the medial ligaments due to eversion. All the previous studies have essentially emphasised the effect of prophylactic ankle braces in protecting against excessive inversion. However, in an unstable ankle joint the stabilising effect against excessive eversion is also important [19].

The literature on the influence of taping and bracing on motor performance is inconclusive. Performance is greatly influenced by the support's resistance torque against ankle motion, which includes passive resistance of the bone, soft tissue, shoes and prophylactic ankle supports. Muscle activity may also play an important role.

The semi-rigid brace was associated with the smallest effect on maximum plantar flexion acceleration. This means that a semi-rigid brace has the smallest negative effect on ankle plantar flexion performance, i.e. this brace would tend to provide the least amount of resistance to active plantar flexion movements. This is of obvious importance to sports performance, which includes jumping or running.

There have been several reports [1, 15, 20] that motor performance is unaffected by taping. However, Juvenal [10] and Mayhew [14] reported compromised jumping abilities in athletes following the application of athletic taping, and Burks et al. [4] reported a decrease in sprinting performance. In addition, MacKean et al. [13] reported that tape and several types of ankle brace all impaired vertical jumping and running performance. In contrast, Pienkowski et al. [17] reported that other types of braces did not. Different taping techniques, experimental protocols, type of motor skills used, or loosening of materials during testing may have contributed to these disparate findings. In addition, the level of subject motivation is a

potential confounding problem. Our standardised protocol reduced the effects of all these conflicting possibilities. The method we have described has advantages over those previously reported in which the passive range of motion was assessed [7, 8] or in which the performance of complex motor tasks was required. Firstly, the experimental conditions were consistent and independent of subject fatigue and/or loosening of the supports. Secondly, our method allowed assessment of both biomechanical protection and performance-related variables to be extracted from the same trials. Thirdly, our rocking platform made it possible to interpret the data not only from the effect of static ankle supports but also from any dynamic effects which may include altered muscle response and stiffness.

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