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Comparison of custom-moulded ankle orthosis with hinged joints and off-the-shelf ankle braces in preventing ankle sprain in lateral cutting movements

Abstract

BACKGROUND: A custom moulded ankle orthosis with hinged joints potentially offers a better control over the subtalar joint and the ankle joint during lateral cutting movements, due to total contact design and increase in material strength. **OBJECTIVES:** To test the above hypothesis by comparing it to three other available orthoses. **STUDY DESIGN:** Repeated measures. **METHODS:** Eight subjects with a history of ankle sprains (Grade 2), and 11 subjects without such history performed lateral cutting movements in four test conditions: 1) non-orthotic, 2) custom-moulded ankle orthosis with hinges, 3) Sport-Stirrup, and 4) elastic ankle sleeve with plastic support. A VICON motion analysis system was used to study the motions at the ankle and subtalar joints. **RESULTS:** The custom-moulded ankle orthosis significantly lowered the inversion angle at initial contact ($p = 0.006$) and the peak inversion angle ($p = 0.000$) during lateral cutting movements in comparison to non-orthotic condition, while the other two orthoses did not. The three orthoses did not affect the plantarflexion motions, which had been suggested by previous studies to be important in shock wave attenuation. **CONCLUSIONS:** The custom-moulded ankle orthosis with hinges could better control inversion and thus expected to better prevent ankle sprain in lateral cutting movements. **CLINICAL RELEVANCE:** Custom-moulded ankle orthoses are not commonly used in preventing ankle sprains. This study raises the awareness of the use of custom-moulded ankle orthoses which are expected to better prevent ankle sprains.

Keywords

movements, ankle, lateral, custom-moulded, cutting, joints, hinged, braces, off-the-shelf, sprain, orthosis, preventing, comparison

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Comparison of custom-moulded ankle orthosis with hinged joints and off-the-shelf ankle braces in preventing ankle sprain in lateral cutting movements

Keywords: ankle sprain, subtalar joint, inversion, braces, orthoses

ABSTRACT

Study Design: Repeated measures.

Background: A custom moulded ankle orthosis with hinged joints potentially offers a better control over the subtalar joint and the ankle joint during lateral cutting movements, due to total contact design and increase in material strength.

Objectives: To test the above hypothesis by comparing it to three other orthoses available in the markets.

Methods: Eight subjects with a history of ankle sprains (Grade 2), and eleven subjects without such history performed lateral cutting movements in four test conditions: 1) non-orthotic, 2) custom-moulded ankle orthosis with hinges, 3) Sport-Stirrup, and 4) elastic ankle sleeve with plastics support. A VICON motion analysis system was used to study the motions at the ankle and subtalar joints.

Results: The custom-moulded ankle orthosis significantly lowered the inversion angle at initial contact ($P=0.006$) and the peak inversion angle ($P=0.000$) during lateral cutting movements in comparison to non-orthotic condition, while the other two orthoses did not. The three orthoses did not affect the plantarflexion motions, which was suggested by previous studies to be important in shock wave attenuation.

Conclusions: The custom-moulded ankle orthosis with hinges could better control inversion and thus expected to better prevent ankle sprain in lateral cutting movements.

Clinical Relevance

Custom-moulded ankle orthoses are not commonly used in preventing ankle sprains. This study raises the awareness of the use of custom-moulded ankle orthoses which are expected to better prevent ankle sprains.

Keywords: sprain, ankle, subtalar, inversion, orthosis

2022 words from Background to Conclusion

BACKGROUND

Ankle sprain is a common injury in people involved in sports activities. Previous studies have indicated the high occurrence and recurrence rates of ankle sprain in both recreational and professional athletes¹⁻⁴. While most people can get full recovery from ankle sprains after appropriate treatments, recurrent ankle sprains may cause significant disability and leave residual symptoms⁵⁻⁶ due to functional instability⁷.

Many sports activities require some rapid changes in moving directions and lateral cutting movements⁸⁻¹¹. Inappropriate positioning of the ankle joint complex during such motions is the major cause of ankle sprain^{7,12}. This condition occurs more frequently in people with proprioceptive deficits and ligament laxity^{13,14}. When a foot lands in an inverted position, a high amount of inverted moment is produced at the subtalar joint producing high strain at the lateral ligament and the capsule^{15,16}.

Some studies suggested that an ankle orthosis significantly reduced the number of ankle sprains¹⁷⁻¹⁹. However, some suggested an ankle orthosis could be ineffective²⁰, and was not as good as technical training²¹ in preventing ankle sprains. There is a wide variety of ankle orthoses in the market. Because there is no consistency about the effectiveness of ankle orthoses in preventing ankle sprains, the decision on which design should be used is usually based on availability and subjective perception.

Some ankle orthoses reduce inversion and eversion motions of the subtalar joint, but at the same time restrict dorsiflexion and plantarflexion motions^{22,23}. The lack of ankle motion reduces the ability to absorb shock during landing²⁴, leading to

increased stresses over the knee joint¹⁶. Some utilizes strapping techniques around the ankle area, and some use foam padded, gel padded or inflatable air bladders to provide mild control over the ankle. Previous studies did not reach a consensus about their effectiveness in preventing ankle sprain¹⁷⁻²⁰. Another approach is to custom make a plastics orthosis to fit to an individual person with a leg section and heel cup connected with a pair of mechanical hinges. The total contact design and the strength of the orthosis might give better control over the subtalar joint, and the hinges allow free plantarflexion and dorsiflexion motions. However, custom-moulded orthosis is not commonly used because of the extent of time and manpower involved.

This study compared among three ankle orthoses in subtalar joint motions during lateral cutting movements. It was hypothesized that the custom-moulded ankle orthosis with hinges could have better control of the subtalar joint than the inflatable air bladders and the elastic ankle sleeve with plastics support. This study recruited subjects with and without histories of ankle sprains. It was also hypothesized that people with previous history of ankle sprains would have larger ankle and subtalar joint motions when performing lateral cutting movements.

METHODS

Subjects:

This study was approved by the Human Subjects Ethics Sub-committee of Xxx Xxxx Xxxx XXXXXXXXXXXX XXXXXXXXXXXX, and subjects gave informed consent to this work. Eight subjects (32±3 years old; 173±6 cm in body height; 67±7 kg in body weight) with a history of ankle sprains in the past 18 months (Sprained group) were recruited.

They had experienced an ankle sprain of Grade 2 ²⁵. Another eleven subjects (32±5 years old; 172±5 cm in body height; 68±4 kg in body weight) without a history of ankle sprains in the past 5 years (Non-sprained group) also participated in this study. Table 1 shows the characteristics of each subject. All nineteen subjects were recreational athletes and did not have a history of lower extremity arthritis and fracture as well as neurological, cardiac and balance problems. They were all male so that gender effect, as reported in a previous study²⁶, would not affect the results of this study.

Orthoses and shoes:

Three different ankle orthoses were tested: 1) custom-moulded ankle orthosis with hinges (Figure 1), 2) *AircastTM Sport-Stirrups, and 3) *A60TM elastic ankle sleeve with plastics support. The leg section and the heel cup of the custom-moulded orthosis were made from low-temperature thermoplastics and fitted to the subjects by an experienced orthotist. The two sections were connected by a pair of hinge joints. The AircastTM Sport-Stirrup consisted of medial and lateral plastic bands with inner inflatable air cells that could be conformed over the malleoli. The A60TM elastic ankle sleeve with plastics support stabilized the ankle-foot complex by tightening the elastic strap around the foot and ankle over the medial and lateral plastics supports located at both sides of the malleoli. All orthoses were fitted and checked by an orthotist before the experiment. During the experiment, standardized laboratory shoes were provided to all subjects to minimize the mechanical difference that might be caused by different shoe designs²⁷. To allow direct attachment of the reflective markers on the foot, openings were created at the toe-box and the posterior heel counter of the shoes.

*Products of DJO Incorporated, CA, USA

Experimental tests:

Each subject was asked to perform sideward lateral cutting movements in each of the four test conditions: 1) non-orthotic, 2) custom-moulded ankle orthosis with hinges, 3) AircastTM Sport-Stirrups, and 4) A60TM elastic ankle sleeve with plastics support. The testing order was randomized. The subjects were required to shuffle laterally from a standing position for at least four steps, land into a square marked on the floor with the dominant foot, and shuffle back to their starting positions²². The entire motions were performed as fast as possible. The dominant legs of the subjects were determined by identifying the sides of the leg which kicked a ball placed in front of them. All subjects were given time to familiarize with the movement and acclimate to each orthotic condition before data collection. The time required to complete the entire movements was measured. A trial was rejected if the time required to complete the movements was not consistent with others during repeated trials. All subjects completed the movements within 10 seconds. The procedure was repeated until six successful trials were recorded with each subject for each of the three orthotic conditions. The average inversion and plantarflexion angles at initial foot contact and the peak inversion angle at the instance that the subject's foot stepped on the marked square were evaluated.

A VICON 370 motion analysis system (Oxford Metrics Ltd, Oxford, UK) was used to collect the three-dimensional kinematics data of the dominant leg of each subject. Six infrared-emitting cameras capturing 60 frames per second were used. Reflective markers of 25mm in diameters were attached to the lateral and medial malleoli, fibular head, tibial tuberosity, heel, as well as the first and the fifth metatarsal heads²³.

Six infrared-emitting cameras, with a sampling frequency of 60 frames per second were used to capture the image. The three-dimensional joint kinematics between each lower limb segment was calculated using Euler's rotation theory²⁸.

Statistical analyses:

One-way repeated measures ANOVA was performed to study if significant difference exists among the four testing conditions in both the Sprained and the Non-sprained groups. Post-hoc Bonferoni tests were subsequently performed to compare each testing condition. To study if there is any significant difference between the Sprained group and the Non-sprained group, independent t-test was performed independently in each of the four test conditions. The level of significance was set at $\alpha=0.05$. When performing multiple comparisons among the four testing conditions, Bonferoni correction was performed adjusting α to be 0.008.

RESULTS

Figure 2 shows the typical changes in inversion angles when the dominant foot stepped on the marked stance during the lateral cutting movement. As the subjects shuffled laterally, the foot was inverted throughout the entire stance time and the inversion angles had two peaks. The mean and standard deviation values at the initial floor contact and the peak comparing the four test conditions are shown in Table 2. The custom moulded ankle orthosis significantly lowered the inversion angle at initial contact as compared to the non-orthotic condition in both the Sprained ($P=0.004$) and Non-sprained group ($P=0.006$). The custom-moulded ankle orthosis with hinges also significantly lowered the peak inversion angle, when compared to the AircastTM

Sport-Stirrups, the A60TM elastic ankle sleeve with plastics support as well as the non-orthotic condition in Sprained ($P=0.000$) and Non-sprained groups ($P=0.000$).

The Sport-Stirrup and the elastic ankle sleeve with plastics support did not produce statistical difference in the inversion angle at initial contact and the peak inversion angle, when compared to the non-orthotic condition. Although the plantarflexion angle was in average the lowest in the Sprained group when using the custom moulded ankle orthosis, the differences in plantarflexion angles were not statistically significant among all the four test conditions.

Although the inversion and plantarflexion angles at initial contact as well as the peak inversion angles of the Sprained group were in average higher than the Non-sprained group in each of the test condition, the difference did not reach a statistical significance. Larger standard deviations were noted in plantarflexion angles. These suggested that various strategies in positioning the plantarflexion/dorsiflexion angles during initial contacts were used among different subjects.

DISCUSSION

Previous studies^{15,30,31} identified the importance of controlling inversion in preventing ankle sprain. This study looked into the amount of control of three different ankle orthoses over the subtalar and ankle joints. Lateral cutting movements were investigated as uncontrolled inversion during such movements producing ankle sprains commonly occurs¹⁵. It was showed that a custom-moulded ankle orthosis with hinges significantly reduced the inversion angle, while the Sport-Stirrup and the elastic ankle sleeve with plastics support did not. It suggested that the hinged ankle

orthosis might outperform the two other orthoses in preventing ankle sprains during lateral cutting movements on smooth floor surfaces. More studies, however, are required to compare these orthoses in real sports activities.

Better control of the subtalar joint by custom moulded ankle orthoses can be explained by the higher stiffness of the material used. The custom moulding of the heel cup and the leg section also enabled well fit and total contact. The orthosis did not restrict plantarflexion motions, thanks to the introduction of the hinge joints, which was suggested to be important in shock absorption¹⁶. Hinge joints could add prices, fabrication time, and overall weight. To confirm that the hinge joints are necessary, the hinged orthoses can be compared to non-hinged custom-moulded orthoses in future studies. While previous studies were inconsistent in determining the effectiveness of off-the-shelf ankle orthoses^{17-19,20-21,32}, this study provides objective information to show that the custom moulding and incorporation of a hinged joint would likely improve preventive outcomes.

The custom-moulded approach is not commonly used in treating sprained ankle because of the time and manpower involved. However, with the objective information provided in this study, this approach should be re-considered. Further investigations are suggested in the choice of materials for the provision of lighter and more comfortable design so that the users need not sacrifice their performances with the intervention. Large contact area between the skin and the orthosis and relief over the bony prominence such as the malleoli could provide better comfort. This study was conducted in a gait laboratory in which the ground condition was different from the actual ground conditions in sports activities. Future studies can also include

investigations of different orthotic designs different ground conditions and sports activities.

The specific aim of this study was to study the effectiveness of three kinds of ankle orthoses to control ankle and subtalar joint motions during lateral cutting movements. Ground reaction forces were not investigated in this study. However, the effects of ankle orthoses on mediolateral forces were investigated by other researchers³³⁻³⁴, however, contradictory results were obtained. A direct relationship between ground reaction forces and ankle sprains has not yet been identified.

CONCLUSION

This study compared the effectiveness of three different ankle orthoses in controlling ankle and subtalar motions when the subjects were performing lateral cutting movements. It was found that a custom-moulded ankle orthosis with hinges significantly reduced the inversion and plantarflexion angles, and the other two ankle orthoses did not. While previous studies have well documented the importance of controlling inversion, based on better control of the undesired inversion in lateral cutting movements, it is expected that a custom-moulded ankle orthosis with hinges could be more effective in preventing ankle sprain comparing to the using of Sport-Stirrup and the elastic ankle sleeve with plastics support.

Declaration of Conflicting Interests

None declared

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List of tables

Table 1. Subject characteristics (Sprained group: subject number 1-7; Non-sprained group: subject number 8-18)

Table 2: Comparison of mean plantarflexion/inversion angles and peak inversion in four test conditions and two subject groups performing lateral cutting movements.

Table 1. Subject characteristics (Sprained group: subject number 1-7; Non-sprained group: subject number 8-18)

Subject number	Age (year)	Body height (cm)	Body weight (kg)	Dominant side
1	20	176	67	Right
2	44	165	66	Right
3	34	172	74	Right
4	30	165	62	Right
5	30	170	70	Left
6	35	179	65	Left
7	30	172	69.5	Right
8	30	176	68	Right
9	29	171	63.5	Right
10	34	171	70	Right
11	30	178	72.5	Right
12	30	182	66	Right
13	33	166	62	Right
14	32	174	72	Right
15	38	165	55	Right
16	29	170.5	76.5	Right
17	30	173	70.5	Right
18	34	177	67	Right
Average	32	172	68	Right: 16 / Left: 2

Table 2. Comparison of mean plantarflexion and inversion angles (degrees) in four test conditions and two subject groups performing lateral cutting movements.

Test parameters	Subject group	Types of orthoses			
		Custom-moulded	Elastic ankle sleeve	Sport-Stirrup	Non-orthotic
Inversion angles at initial contact Mean(s.d.)	Sprained Group	*15.0 (6.9)	16.7 (7.8)	17.0 (6.8)	*18.9 (6.6)
	Non-Sprained Group	*13.8 (5.2)	15.7 (5.1)	15.5 (4.2)	*15.8 (6.2)
Peak inversion angles Mean(s.d.)	Sprained Group	^{*,+,^} 32.5 (9.7)	[*] 37.8 (7.9)	⁺ 36.2 (7.2)	[^] 38.1 (7.1)
	Non-Sprained Group	^{*,+,^} 30.8 (4.9)	[*] 34.5 (4.6)	⁺ 36.0 (5.9)	[^] 36.4 (5.6)
Plantarflexion angles at initial contact Mean(s.d.)	Sprained Group	8.3 (5.9)	10.1 (6.1)	11.5 (5.3)	10.0 (10)
	Non-Sprained Group	6.8 (12.1)	7.1 (12.7)	2.6 (9.5)	7.8 (14.2)

In comparing the four orthotic conditions, a pair of symbols of *, +, and ^ in a row indicated a statistical difference ($p < 0.05$).

No significant difference was found when comparing the three test parameters between the Sprained and the Non-Sprained group.

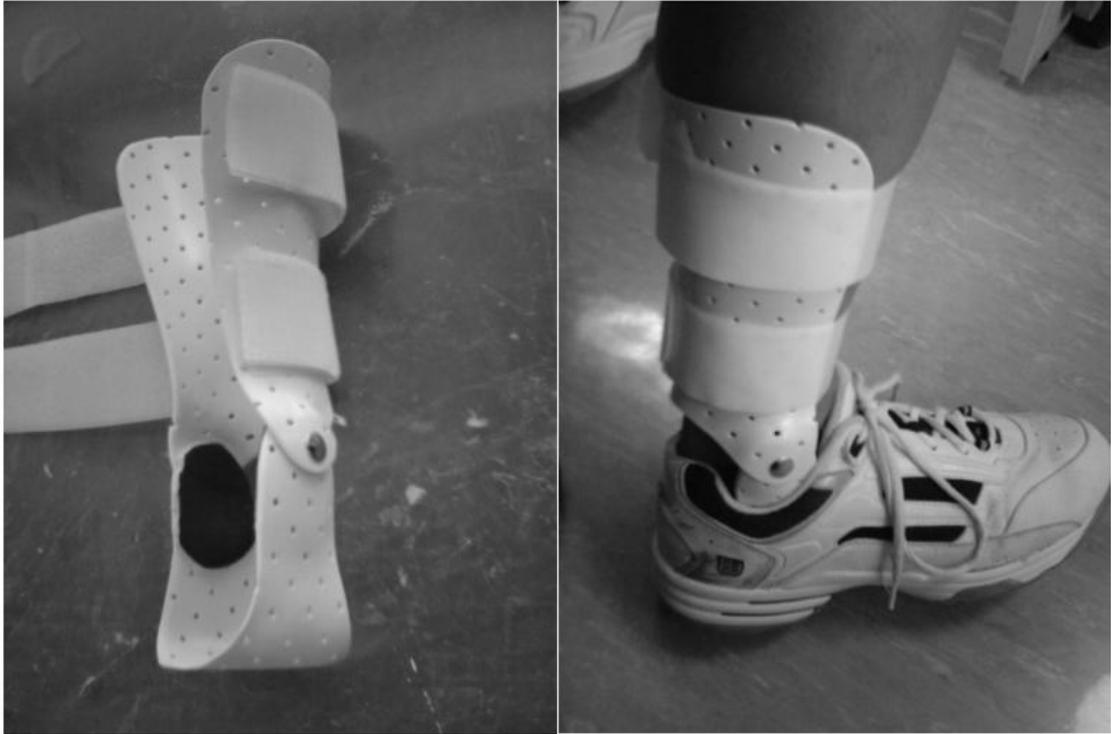


Figure 1. The custom-moulded and hinged ankle orthosis

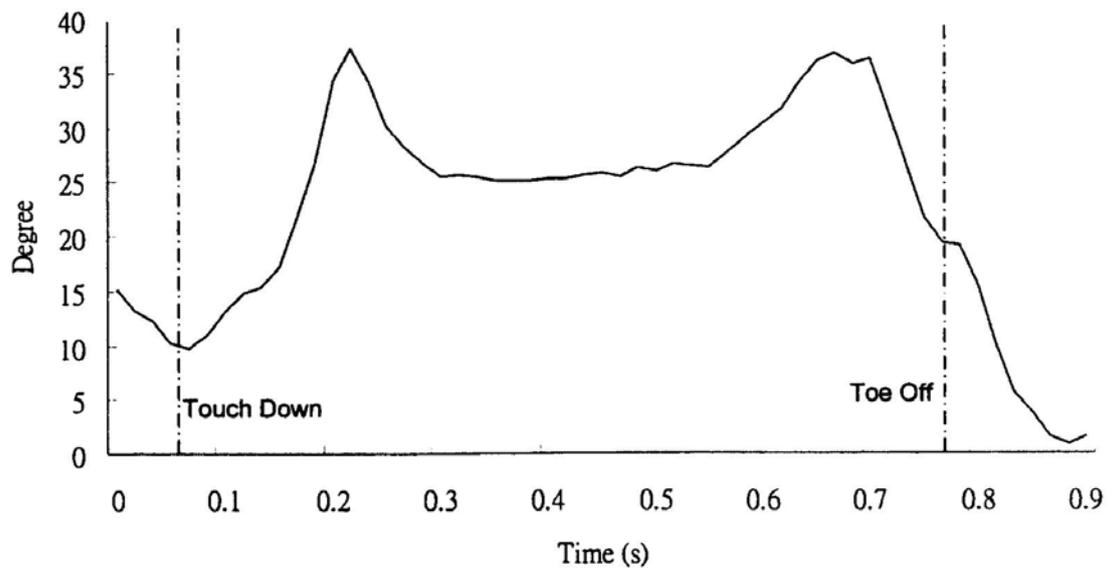


Figure 2. Typical changes in inversion angles in one complete stance during the lateral cutting movement