ANALYSIS OF THE STABILIZING EFFECT OF THE AIRCAST ANKLE BRACE FOR WALKING ALONG AN INCLINED PLANE

Reiner Fritsch, Silke Däumling, Hartmut Riehle,
University of Konstanz, Germany

INTRODUCTION: For functional treatment of acute ankle sprains various ortheses - special shoes and braces - are in use to prevent inversion movements of the ankle while allowing limited dorsi-plantar-flexion movement (Segesser 1986). For the evaluation of ankle orthoses most of the studies use static and quasi-static methods. In contrast to this, only a few studies are available that were made under dynamic or functional conditions (Kimura 1987, Stüssi 1989, McPoil 1991, Jerosch 1994, Nigg 1995). To compare seven different orthoses under functional conditions, Scheuffelen, Gollhofer and Lohrer (1993) applied controlled inversion movements of 20 and 30 degrees. A significant reduction of the induced inversion displacement was observed in all devices, although a complete inhibition of this movement was not possible. Of the seven different ankle braces, the AIRCAST stirrup offered the best protection against stationary induced inversion displacement, while simultaneously maintaining high functional innervation. Nigg (1995) recommends, on the basis of his examination report, analyzing the functionality of ankle braces with a combination of quasi-static and dynamic movement-tests. In particular, he proposes checking the functionality of orthoses with movement-tasks in real-life situations.
Therefore the purpose of this experimental study is the verification of the joint stabilizing effect of the AIRCAST ankle brace for walking on an inclined plane with induced inversion displacement in one foot. If the 'AIRCAST ankle brace' sufficiently protects against inversion movements, a foot walking along an inclined plane cannot take steps as extremely inverted as is the case with an unstabilized foot. Therefore stabilization with the 'AIRCAST ankle brace' should make it possible to walk with less deviation in the heel area.

METHODS AND PROCEDURES: For verifying the joint stabilizing effect of the AIRCAST ankle brace (Standard Air-Stirrup Brace, AIRCAST Ltd.) during walking, eight healthy physical education students with stable ankles and normal feet had to walk under various conditions along an inclined plane with induced inversion displacement of one foot.
Foot-loading data was collected using the PEDAR in-shoe plantar pressure analysis system (NOVEL Electronics, Inc.). Each PEDAR-insole uses 99 pressure-sensitive sensors which detect pressures as low as one Newton/cm². The applied PEDAR-insoles (EU-size 38/39 and 42/43) are connected via wires and intermediate boxes to a computer that provides a graphic representation of the areas of foot loading, as well as the extent of plantar pressure during the stance phase of gait, represented by gait-line data and vertical forces.
During preliminary examinations on a level surface we could not determine any change in the shape of the gait-line due to the AIRCAST ankle brace. When a subject walked with one foot on a horizontal plane and the other foot on a 10 degree inclined plane wearing the AIRCAST ankle brace, a shift in the gait-line to

medial was detectable in the foot with the AIRCAST ankle brace. This medial displacement of the hindfoot and the midfoot areas was, however, not statistically significant (p > 0.05), so that the test series were conducted with a 20° inclination. (Figure 1)

Data was collected under four different conditions with at least 10 steps for each run the subject's own shoes along the 20 degree inclined plane. Before each condition the subjects had one practice run. The first condition involved 5 runs with the left foot on the inclined plane without AIRCAST (L), and afterwards with the right foot without AIRCAST (R). Then the subject performed 5 runs with the left foot on the inclined plane wearing the AIRCAST on the left ankle (AL). After changing the AIRCAST to the right ankle, each subject had to walk 5 times with the right foot along the inclined plane (AR). Each person was asked to walk along the inclined plane with his medial shoe edge close to a marked line so that the medial side of his shoe was almost adjacent to the shoe on the horizontal plane.

For each run and each subject (5xL, 5xR, 5xAL, 5xAR), 1 to 1 print-outs of the mean gait-line (5 steps) were analyzed. At four defined points within the range from the calcaneus (points 1 and 2) to os naviculare (points 3 and 4), the distance from the gait-line to the medial insole edge was measured. The gait-line data of these distances from all tested persons without AIRCAST were compared (t-Test, dependent samples) with the corresponding values for all persons with AIRCAST ankle braces. The 0.05 level of significance (p) was used.

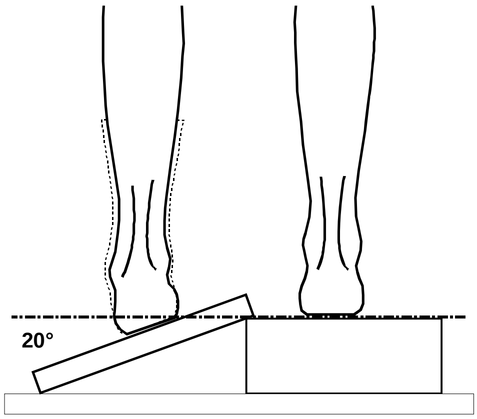

Figure 1: Walking along the 20 degree inclined plane - left foot wearing AIRCAST ankle brace (dashed line)

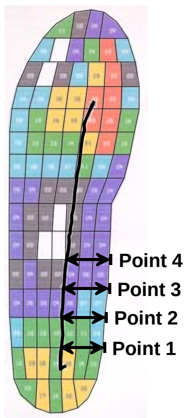

Figure 2: PEDAR print-out with mean gait-line (5 steps) and location of measured distances (1-4) from gait-line to the medial insole edge

RESULTS: The comparison of gait-line-to-edge distances at four defined points for walking along an the inclined plane showed a medial shift of the gait-line when the AIRCAST was worn. On the inclined plane, the right foot showed a significant shift ($p \leq 0.05$) to the medial on all measured points. On the left foot, the shifting to the medial was statistically significant only at points 1 and 2 ($p \leq 0.05$). At the measured points 3 and 4, there is an apparent tendency to this ($p \leq 0.10$).

Table 1: Means, Standard Deviations (SD) and Standard Error of the Mean Values (SEM) for the mean distances from gait-line to the medial insole edge at points 1, 2, 3 and 4 in millimeters

		L - Left	L ↔ AL	AL - Aircast L	R - Right	R ↔ AR	AR - Aircast R
Point 1	Mean	29.9		27.6	27.8		25.9
	SD	2.8		3.0	1.8		1.0
	SEM	1.0	**s**	1.1	0.6	**s**	0.3
Point 2	Mean	31.3		28.8	28.7		26.8
	SD	2.9		3.4	2.5		1.4
	SEM	1.0	**s**	1.2	0.9	**s**	0.5
Point 3	Mean	31.6		29.4	29.1		27.4
	SD	3.1		3.5	2.5		1.9
	SEM	1.1	**t**	1.3	0.9	**s**	0.7
Point 4	Mean	30.8		28.8	28.5		26.9
	SD	3.6		3.6	2.9		2.5
	SEM	1.3	**t**	1.3	1.0	**s**	0.9

s = $p \leq 0.05$ **t = $p \leq 0.10$** **(t - tendency)** **n = 8**

DISCUSSION: The study shows that the use of the AIRCAST ankle brace may provide greater stability to the hindfoot and midfoot during induced inversion movements of the ankle, as shown by the reduced distance from the gait-line to the medial edge of the insole. Almost all studies which analyze the stabilizing effect of orthoses show an average reduction in the tilt angle of the talus of 50 to 70 % with ankle orthoses (Scheuffelen et al. 1993). Usually angular positions or angular velocities are employed as parameters. Scheuffelen et al. (1993) analyzed the maximum angular velocities of seven ankle ortheses and one normal shoe during a controlled inversion movement of 20 degrees: subjects wearing normal shoes without an ankle brace had the highest values (Mean = 447.7°/s, SD = 114.1), and those wearing the AIRCAST enjoyed the best protection of all orthoses compared (Mean = 117.7°/s, SD = 37.9).

This study based on pressure distribution parameters under the foot employs a new method that to our knowledge has not been used before. The displacement of the gait-line may be explained as follows: with an inclination of 20° the non-stabilized foot lands as in normal walking in a slightly inverted position. A foot stabilized by the AIRCAST ankle brace cannot land in inverted position when walking on a slant. In fact, the inner side of the heel is the first part which touches the ground, which has the consequence that the foot's center of pressure is displaced toward the medial. This effect becomes clearly visible through the displacement of the gait-line toward the medial side in the heel area. Also, the results of the pilot tests show that a displacement of the gait-line can be detected with an inclination as low as 10°. Consequently the steeper the inclination is, the greater the displacement and the clearer the stabilizing effect of the AIRCAST will be.

The results of this study also show that the standard deviation from 'Point 1' to 'Point 4' increases steadily in each case. The low deviation at 'Point 1' speaks for

the relatively uniform touchdown of the heel with all subjects. Individual differences are increasingly apparent the farther the roll-off movement progresses; this points to individual differences and uncertainties in walking.
The results of our measurements confirm the stabilizing effect of the AIRCAST ankle brace at the measured points 1 and 2 - and also at point 3, corresponding to the projection of the 'articulatio talocruralis' (A), 'articulatio subtalaris' (B) and 'articulatio talocalcaneonavicularis' (C - Figure 3).

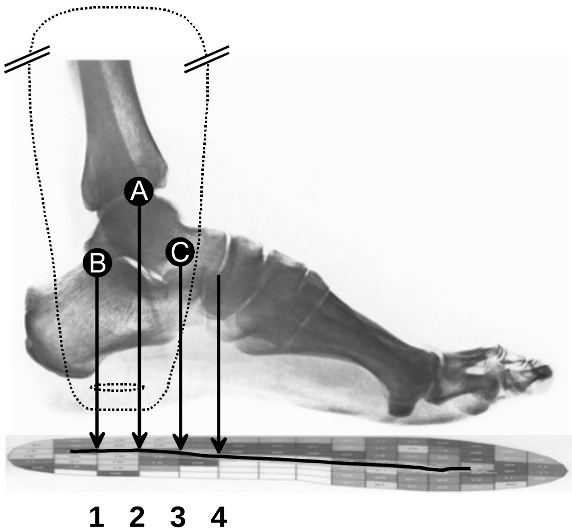

Figure 3: Joints of the upper (A) and lower ankle (B-C) with AIRCAST and four measured points

CONCLUSION: This newly developed method, based on the PEDAR in-shoe plantar pressure analysis system, confirms the significant reduction of induced inversion displacement for subjects walking along an inclined plane wearing the AIRCAST ankle brace. The application of the AIRCAST ankle brace for prevention and therapy in cases of capsule-ligamentum injuries of the ankle joint can be recommended on the basis of our results.

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