THE EFFECTIVENESS OF HEEL-BASED REPLACEMENT INSOLES ON THE KINETICS AND KINEMATICS OF LOCOMOTION

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INTRODUCTION

A new, over-the-counter, in-shoe orthotic with a unique, spring-based design was evaluated for shock absorbency, other biomechanical variables, and muscle activation patterns. The data was then used to determine the relationship between the stiffness of the metal springs and other parameters, such as footwear type and user weight.

REVIEW and THEORY

The collision of the foot with the ground usually takes place at the heel, especially during running, and generates an impact force that is 2-3 times the body weight. This impact force generates an impulse wave (IW) of very short duration (20 sec) that travels through the musculoskeletal system. The IW is believed to cause various injuries, such as fatigue/stress fractures (Finestone et al., 1997), shin splints (Shorten et al., 1992), lower back pain (Voloshin & Wosk, 1982), and osteoarthritis (Shorten et al., 1992). The extrinsic factors affecting the magnitude of IW, such as running speed, shoe construction, and surface gradient, are often measured using accelerometers and force platforms. Recent reports have also focused on the intrinsic factors, such as muscular activity and joint kinematics. Until today, only a few studies have considered the effect of an insole on reducing IW by extending the duration of the impact phase.

In the present study, the influence of a newly designed shoe orthotic—a spring-based heel cup (Springsoles®), by Springco Ltd. of Israel—on both the intrinsic and extrinsic aspects of the lower extremity is described. It was hypothesized that metal leaf springs arranged similarly to a pennate muscle fiber and situated in heel cups that are individually adjusted for spring stiffness can lower muscle activation, thereby contributing to shock dissipation and improving stability at the heel.

METHOD

Four, injury-free subjects weighing between 70-83 kg were asked to walk and run over a force platform (OR6-5-AMTI, MA, USA) under three test conditions: 1. ***Barefoot*** **(B)**, 2. Wearing commercially available ***running shoes*** **(S)**, and 3. Wearing the spring-based ***heel-cup (O)*** with a tight sock only and no shoe. The ground reaction forces (GRF) were collected at a sampling frequency of 1000Hz. Surface EMG (SEMG) was recorded from two knee antagonists—rectus femoris (RF) and biceps femoris (H)—and two ankle antagonists—tibialis anterior (TA) and lateral gastrocnemius (GAS). The SEMG signals were treated first by the preamplifier based on the electrode leads and then filtered (15-500 Hz, CMMR 110 dB, with a gain of 412) and digitized (12 bits sampled at 1 KHz). Both SEMG and GRF were recorded continuously on a portable data logger (Mega Electronics Ltd., Kuopio, Finland). During the trials, the subjects were video taped for post-test analysis (Winanalyze, Mikromak, gmbh).

Each subject performed two walking trials and two running trials under each of the three conditions. The subjects were trained to ensure consistency in the cadence and stride length.

The variables examined were: a) Angle (maximum knee flexion during single support), b) Time (time to maximum knee flexion during swing), c) P1 (weight acceptance-breaking phase of Fy of GRF), d) Ag/Ang-agonist/antagonist ratio (SEMG of Q/H activity at the knee and TA/GAS at the ankle). For reliability, the subjects replicated measurements made under the same conditions; these measurements were then compared across subjects to assess the functionality of the spring-based heel-cup with similar user weights.

RESULTS

	Angle (deg)		Time (sec)		P_1 (N)		Q/H		Ta/GAS	
	r	***w***	***r***	***w***	***r***	***w***	***r***	***w***	***r***	***w***
B	117 (33)	127 (2)	0.32 (0.2)	0.64 (0.15)	170/60	130/$_{120}$	1	1	1	–
S	129 (5.6)	130 (3.5)	0.18 (0.13)	0.75 (0.22)	120/75	140/$_{140}$	2	$^{1}/_{3}$	1	2
O	127 (4.4)	126 (2.1)	0.33 (0.3)	0.60 (0.43)	140/60	160/$_{130}$	1	3	3	$^{2}/_{3}$

Table: Variable values for each test condition for running [r] and walking [w] with standard deviations [sd]

The table provides the mean values for the four subjects from two walks and two runs for the three test conditions (B,S, and O). In addition (not reported here) the Fz records of the IW as the first peak were noted throughout the test.

DISCUSSION

It was striking that sagittal plane knee and ankle kinematics were affected under the O condition similarly to the S condition: both conditions were significantly different from the B condition in both walking and running. Joint motion has been found to decrease the IW measured between the tibia and the head (Paul et al.,1978). This study found that the angle of the ankle and hip were altered by the S and O test conditions.

During the walking trials, the subjects increased the H activity with S but decreased it during the O condition. Conversely, Q activity followed an opposite pattern, by increasing. It might be that during the S condition, the subjects needed to decelerate the shank more than during the other conditions. However, this hypothesis does not explain how minimum activity occurs during the O condition. During the running trials, this strategy altered: there was less need for deceleration (H activity) during the S condition, whereas the B condition used the most H activity due to switch in the target joint to absorb the shock..

Increased stiffness and co-contraction of the antagonist in the ankle took place in S, less in O, and almost not at all during the running trials of the B condition. The trend was opposite in the knee, showing that the strategy of the subjects was to absorb the shock at the knee when barefoot and at the ankle when shoed. This strategy accounts to some extent for the ratio between P1 (the breaking phase) and P2 (the propulsion phase) of Fy.

To summarize, only the O condition acted like the S in eliminating the Fz transients, decreasing the breaking phase (P1) of the Fy, and increasing the propulsion phase (P2). The S and O promoted similar changes on the knee musculature, but the O condition reduced co-contraction distinctly more than the S condition. The tested O, with its spring stiffness adjusted to the user’s weight, the footwear’s midsole hardness (a function of whether the footwear is a dress shoe, army boot, etc.), and the intended activity (walking, running, jumping), can provide some energy return and contribute to the much-needed cushioning at the heel of any shoe, improving both stability and comfort.

REFERENCES

Finestone,A. et al., 3rd ISB Symp on Footwear Biomech., 1997.
Shorten, M.R. et al., Int J Sport Biomech. 8:288-304, 1992.
Voloshin, A. and Wosk, J., Biomech. 15:21-27, 1982.
Paul, I.L. et al., J Biomech. 11:237-239, 1978.