THE EFFECTS OF SUSPENSION FUNCTION OF HIKING BOOTS ON THE STABILITY OF THE FOOT

Chisun Choi, Insik Shin, Ki-Kwang Lee*, Seondeok Eun, and Jungho Lee

Sports Biomechanics Lab, Seoul National University, Seoul, Korea
*** Biomechanics Lab, Kookmin University, Seoul, Korea**

The purpose of this study is to investigate the effects of suspension function of hiking boot on the stability of foot. 8 participants free from injury to the triceps surae muscle group in recent years and able to perform jumping participated in this test. 2-D kinematic analysis and kinetic analysis were conducted for the data acquisition. The maximum suspension angle of suspension boot was greater than that of normal boot for eversion condition; on the contrary the maximum loading rate of normal boot was greater than that of suspension boot for inversion condition. These results meant that the suspension function helps the boot keep stable shortly after landing through the control of rearfoot angle. Moreover, if we apply a lower threshold level at medial part of boot, suspension function will show its ability even though at medial landing. It was concluded that an improved suspension function may help to reduce fatigue and prevent injury such as ankle sprain in hiking on uneven surface.

KEY WORDS: hiking boot, outsole, foot stability

INTRODUCTION: Mountain hiking is one of the most popular physical activities in Korea. Due to Korea's geographical shape, hiking and mountaineering have become easily accessible leisure sports, so many people are enjoying their leisure time by mountaineering.

However, climbers often meet obstacles such as rocks and gravel during hiking. Therefore they are easily likely to suffer from ankle sprain, dislocation and strain, caused by excessive inversion and eversion (Hintermann, Nigg, Sommer & Cole, 1994). In order to overcome these obstacles, there are two methods to recover and control body balance. One is for changes of performance in ankle, knee, and hip joint, and the other is for the insertion of a prosthetic device inside the boots. Furthermore, Hettinga, Stefanyshyn, Fairbairn & Worobets (2005) found that hiking on a non-uniform surface might cause an injury potential, so suggested a special design and functional requirement for hiking boots under this condition.
A suspension function is one of the prosthetic devices. Only when the pressure caused by an obstacle exceeds a threshold, the suspension function is called into action. The tread of outsole is pushed into the insole, with the aim of stabilizing the foot on an uneven surface. And so did the suspension function built into the sole of the shoe really stabilize the foot's motion on an uneven surface, which was the main objective of this study. As Lafortune & Hennig (1992) described the importance of shoe cushioning and suspension for injury protection, these studies anticipated that the suspension function would be helpful for protecting injuries of mountaineers and provided fundamental data for related and further researchers.

METHOD:

Data Collection: There were 8 participants (33.4±4.4 years old & 85.7±10.7 kg). The participants had not experienced any injury to the triceps surae muscle group in recent years and were able to perform jumping exercises without feeling any undue discomfort. In order to get kinematic data, a high speed camera set at 250 Hz (DFK-HC1000, Dartfish Korea) was used. Also the AMTI Force platform (OR 6-5) was used to get ground reaction force and F-scan (Tekscan) for foot pressure distribution.

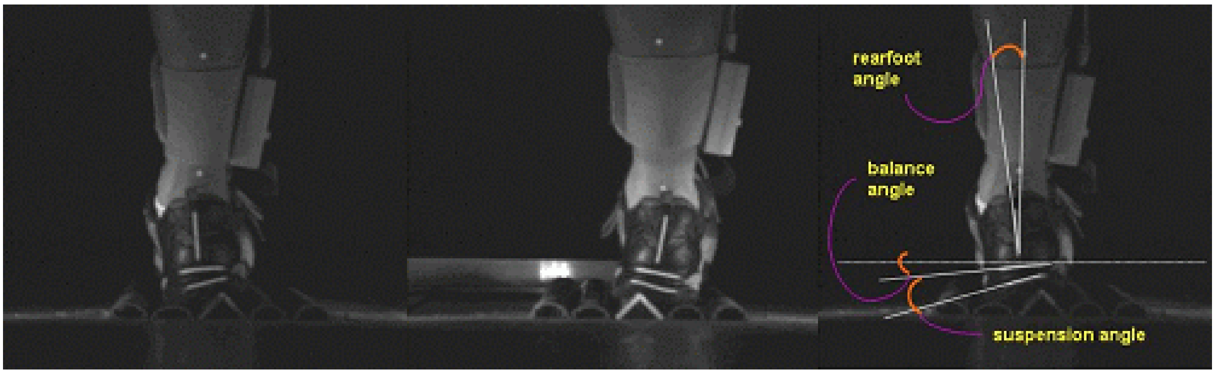


Figure 1: Lateral landing (left), medial landing (middle) and angle definition (right)

To mimic real mountaineering situations, two situations were conducted as above shown in Figure 1. The obstacle was set on top of the force platform. Three reflective lines of two horizontal lines and one vertical line were placed on the heel side of the boot and two markers were in the middle of the subject´s shank. The angle between line # 2 and surface line was defined as a **balance angle**. Next, the moment the balance angle reached the maximum, the angle between line # 1 and # 2 was defined as a **suspension angle**. Finally, the angle between vertical line and new line connecting two points (# 4 & # 5) was defined as an **eversion or inversion angle** (rearfoot angle).

Subjects jumped and landed on an uneven surface from the box which is 33.4cm of height and 84cm distant. The landing conditions either eversion or inversion were randomly assigned for 5 times. At the same time ground reaction force and foot pressure was measured. Maximum Vertical ground reaction force (**maximum impact force** & **maximum loading rate**) and GRF in anteroposterior direction (**braking force**) were normalized to the subject’s body weight.

Data Analysis: According to experimental conditions (lateral landing vs. medial landing), various kinematic and kinetic variables were calculated for normal and the suspension function boot. For foot pressure distribution analysis, Tekscan software was used. The independent T-test was applied as a statistical design for each landing condition after the Levene’s statistic test which showed that the variances of the two groups are equal.

RESULTS:

Table 1: Kinematic & kinetic results in lateral landing & medial landing

Boot condition Kinematics & Kinetics	Lateral landing for eversion		Medial landing for inversion	
	Normal boot	Susp. boot	Normal boot	Susp. boot
Max unbalance angle (deg)	19.23±5.57	13.03±3.87 **	17.60±4.65	15.41±4.61
Max suspension angle (deg)	1.82±1.19	6.65±4.04 **	2.89±2.60	0.28±2.11 **
Max eversion or inversion angle (deg)	21.01±6.26	12.58±5.60 **	11.43±6.77	12.69±6.38
Max impact force (BW)	2.35±0.24	2.18±0.27 *	2.48±0.33	2.25±0.33 *
Max loading rate (BW/s)	76.01±9.22	75.40±13.24	83.61±16.76	75.63±16.62
Max braking force (BW)	0.49±0.07	0.46±0.06	0.49±0.08	0.44±0.06 *

$p < .05$, * means statistically significant at $p<.05$, ** means statistically significant at $p<.01$

The kinematic results of lateral landing, eversion situations were summarized in Table 1 and Figure 2. The normal boot displayed a greater unbalance angle than that of the suspension boot for the eversion condition. The suspension boot portrayed a greater suspension angle about 3 times than normal boot. In other words, the deformation angle between line # 1 and # 2 of suspension boot was greater than the normal one. This meant that although the outsole and midsole of the boot deformed considerably, the boot was kept parallel to ground. So this function might affect to a significant reduction of pronation which is related to overuse injury. Maximum eversion angle in suspension boot decreased 40% of that in the normal boot. Maximum balance angle, maximum suspension angle, and maximum eversion angle were statistically significant.

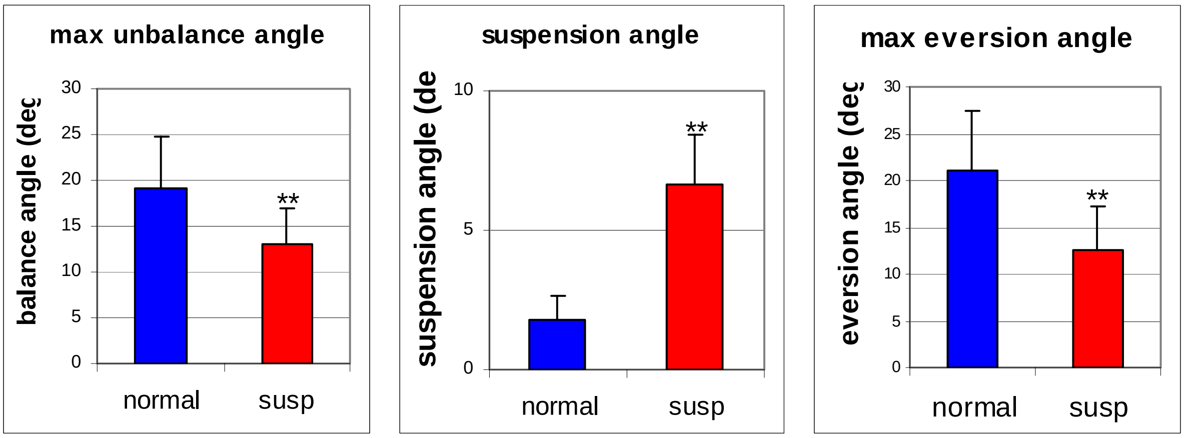


Figure 2: Comparison of regular and IST hiking boot for kinematics related to suspension in eversion

Eversion condition did not show much difference between normal and suspension boot in kinetic results. Normal boot showed a little greater vertical ground reaction force than suspension boot and that result was statistically significant. Maximum braking forces in suspension boot are smaller than those in normal boot.

The kinematic results of medial landing, inversion situations were summarized in Table 1 and Figure 3. Inversion condition did not show much difference between normal and suspension boot. In suspension angle and inversion angle, the contrary results were shown to eversion condition. For the suspension boot, the suspension angle was lower and the max inversion angle was greater than normal boot.

Maximum loading rate for the normal boot is greater than that of the suspension boot in inversion condition. Because the maximum loading rate is related to the chronic injuries according to the repetitive shock, suspension boot has a little advantage. However, statistical significance was not established.

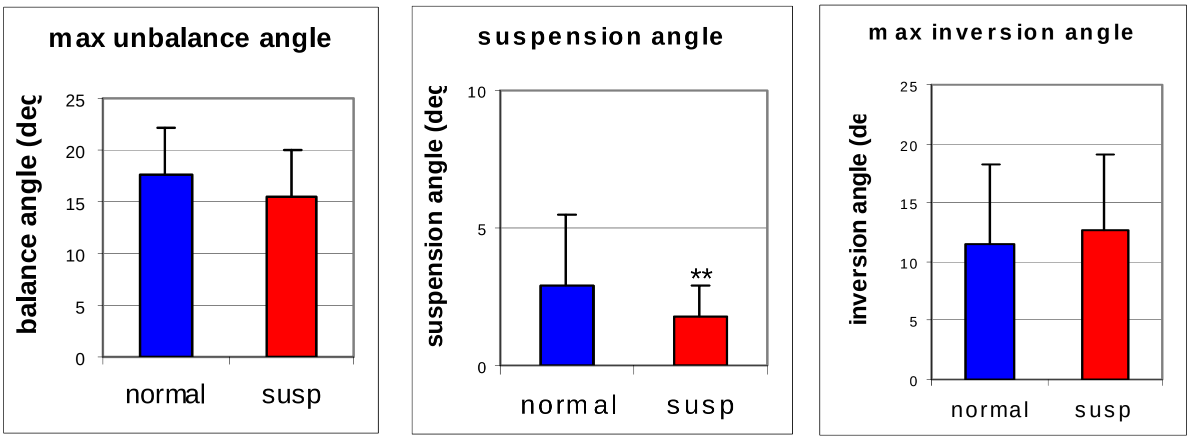
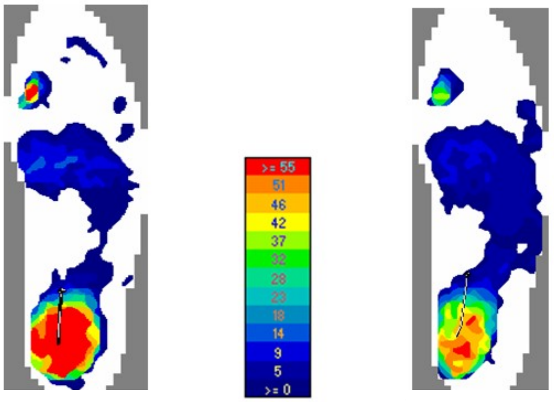


Figure 3: Comparison of regular and IST hiking boot for kinematics related to suspension in inversion



normal suspension

The insole pressure distribution is shown in Figure 4. Lower peak pressure was shown in the suspension boot than the normal boot, and it was well distributed. Especially the peak pressure one the heel and toe parts of the suspension boot decreased drastically.

Figure 4: Comparison of insole pressure distribution

DISCUSSION: That the suspension angle of suspension boot is greater than that of normal boot means that the deformation of line # 1 is greater than that of line # 2 at heel part of boot in eversion condition. It is considered that the suspension function absorbs the impact force by its own characteristic shortly after landing, so it helps to keep the boot stable horizontally. The control of rearfoot angle (max eversion angle) is another consideration for the boot stability.

The result of max suspension angle in inversion condition is a little unique. Because the impact force of normal boot was greater than that of suspension boot, the greater suspension angle was expected, if the same hypothesis would be applied. However, the actual suspension angle of suspension boot was smaller than that of normal boot. This result might be related to the possibility of not going further inversion of foot because of the constraints of human anatomical structure. Therefore, it is suggested that the suspension function with lower threshold would be applied to the medial part of the boot for the stability of the boots.

CONCLUSION: The suspension function helps the boot return to its original stability i.e. as horizontal as possible. The suspension function also supplies an advantageous cushioning effect. Later an improved suspension function may be able to help reduce fatigue and prevent injury such as ankle sprain in hiking on uneven surface.

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