COMPARISON OF THE INFLUENCE OF THREE TYPES OF MILITARY BOOT INSOLE UPON THE FORCE AND LOADING RATES EXPERIENCED IN DROP JUMP LANDING.

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Eight male subjects performed drop jumps from a 0.8 m high platform onto a force plate and landing forces were sampled at 1000Hz. Six jumps were completed wearing military boots fitted with three different insoles (Saran, Poron and Sorbathane), and also when barefoot. Comparison of the last five jumps in each case showed that mean peak forces were similar (7.5 BW) for all insoles, though the forefoot impact mean (±SE) loading rate was higher for Sorbathane (754 ± 77 BWs^{-1}) than for Saran (552 ± 58 BWs^{-1}) or Poron (636 ± 77BWs^{-1}). Mean peak loading rates for Poron, Saran and Sorbathane from forefoot to heel contact were similar for Saran (249 BWs^{-1}) and Poron (254 BWs^{-1}) and slightly higher for Sorbathane (300 BWs^{-1}). Barefoot peak forces and both forefoot impact and peak loading rate were less than when a boot was worn with an insole.

KEY WORDS: barefoot, impact, poron, saran, sole, sorbathane

INTRODUCTION: Research studies considering traumatic and overuse lower limb injuries in military personnel have focused on marching and running as reviewed by Barnes & Smith, (1994) and Jones & Knapik (1999). The effect of insole usage upon impact and injury is complex (Nigg et al, 1999), partially because of the body's inherent ability to adapt movement to sensory information. Windle et al. (1999) found that during marching and running insole usage with military boots attenuated shock and the greatest reduction occurred with Sorbathane. In military training, drop jumping is a common feature and the exposure of the lower limb to force is likely to be faster and greater.
The aim of this study was to assess, during drop jumping, the vertical forces and loading rates occurring when a military boot was fitted with three different insoles Saran, Poron and Sorbathane full strike. Saran is the current issue insole for the British combat boot and consists of a coarse weave plastic (polyvinyl chloride base) with a top sheet of nylon plastic (Windle et al. 1999). Poron, which is used within the United States military, is made of polyurethane micro cellular foam. Sorbathane full strike is made of a viscoelastic polymer with a top sheet of polyester fabric and has additional thickness and shaping at the heel and toe.

METHODS: Eight male subjects gave written informed consent to participate in the study after a full explanation of the experimental procedure. The mean height (± SD) and shoe size of the subjects was 1.81 ± 0.10m and 9.75 ± 1.28 respectively. Each subject was required to perform a total of 24 drop jumps from a 0.8 m high platform, which was typical of heights encountered on marine training courses, onto a 9865A force platform (Kistler, Alton, UK) located with its nearest edge 0.27 m in front of the drop platform. The height of the drop jump was considered a safe maximum for landing barefoot by a medical doctor and the procedure was given ethical committee approval. Six of the jumps were performed when barefoot, and also six jumps each when a Poron, Saran or Sorbathane (full strike) insole was placed in turn inside their military boots. Each type of insole was placed inside an in-service Combat Assault Boot (CAB), which consists of a leather upper and a semi-rigid plastic sole. Participants chose the most comfortable fitting boot between the sizes of 8-11. All boots were laced identically in a criss-cross formation, and participants wore olive green wool issue socks. Subjects were told to drop and land with no restriction on joint flexion or arm movement with the intention of aiding a natural and balanced drop jump. The order in which each subject jumped wearing the different types of insole or barefoot was randomised (Altman, 1991) and is shown in Table 1.
Peak Motus 5 software, running on a Pentium II processor, was used to collect data from the Kistler 9865A force plate at 1000 Hz. During the experiment the sagittal view of all drop jump landings were recorded on a Panasonic F15 video camcorder to aid subsequent analysis. Data

analysis was undertaken by exporting from Peak Motus 5 into Microsoft Excel. During data analysis the first drop jump in each different footwear condition was excluded from results analysis to allow for familiarisation of technique and to reduce the influence of the first time effect error. Peak vertical ground reaction force, impact loading rate from initial ground contact, and peak loading rate (from the minimum following the impact peak to highest peak force) were calculated with respect to each subject's body weight (BW) in the footwear condition. Analysis of variance was used to determine the significance of the results with a probability level of 0.05%.

Table 1 Randomised Testing Order for the Subject Group

Subject	1st test	2nd test	3rd test	4th test
A	Sorbathane	Saran	Barefoot	Poron
B	Saran	Poron	Sorbathane	Barefoot
C	Saran	Poron	Barefoot	Sorbathane
D	Sorbathane	Poron	Barefoot	Saran
E	Barefoot	Sorbathane	Poron	Saran
F	Barefoot	Saran	Poron	Sorbathane
G	Sorbathane	Saran	Poron	Barefoot
H	Poron	Barefoot	Saran	Sorbathane

RESULTS AND DISCUSSION: Subject weight when barefoot was less than when the military boot was worn with any of the three different types of insole (Table 2). Normalisation calculations performed on the force data used each individual subject's body weight in each barefoot or insole test condition.

Table 2 Mean Body Weight Values (N) Barefoot and With Insoles Inside Military Boots

	Barefoot	Poron	Saran	Sorbathane
mean	806.91	824.00	824.08	824.93
SD	98.97	99.30	99.31	99.36
SE	34.95	35.10	35.11	35.12

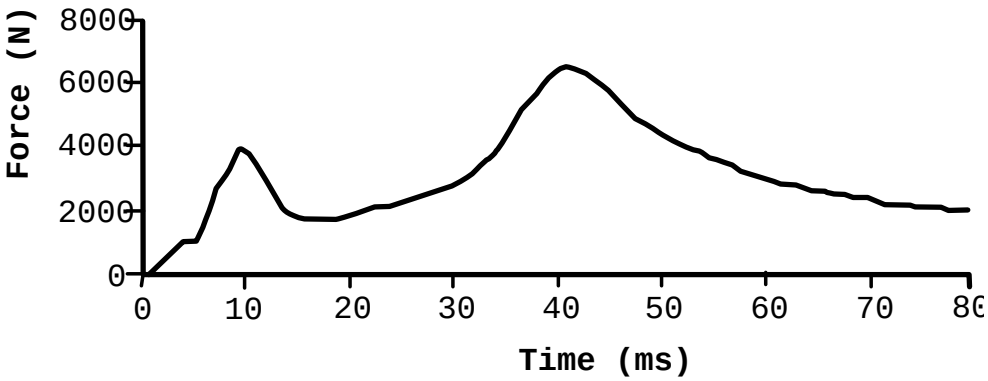


Figure 1 - Vertical force after landing in the barefoot condition.

A typical vertical force trace is shown in Figure 1. All subjects landed on the forefoot initially before the rest of the foot made contact with the platform whether barefoot or wearing military boots with insoles. Upon contact with the platform there was a swift rise to the initial impact peak, and this was followed by a reduction in force before the highest peak force occurred.

Figure 2 shows the relative peak vertical forces which occurred when landing barefoot and with the different insoles. Statistical analysis indicated that the barefoot peak force was not significantly less ($p=0.06$) than the forces which occurred when boots were worn with insoles.

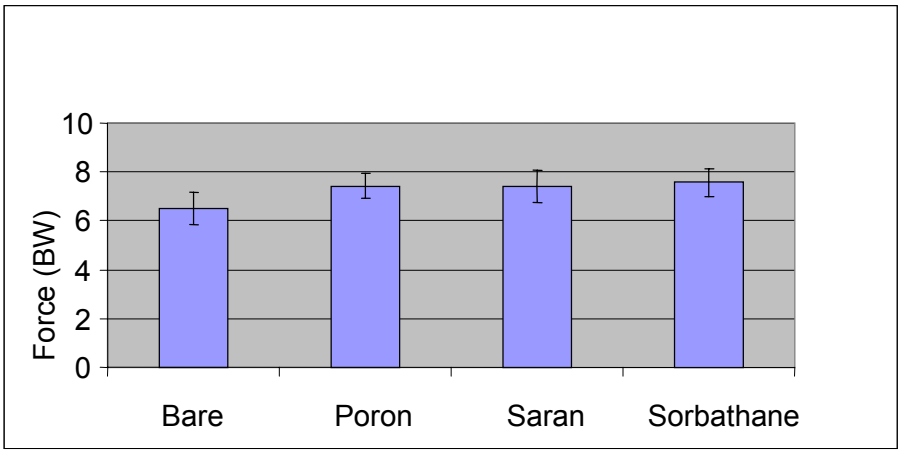


Figure 2 - Mean (±SE) peak vertical force with different insoles relative to landing barefoot.

The initial mean loading rate (LR) recorded at impact was significantly less ($p \leq 0.002$) when barefoot than when wearing any boot with an insole as shown in Table 3 and Figure 3.

Table 3 Mean Values ±SE for Barefoot and Different Insoles on Drop Landing

	Peak Vertical Force (BW)	Impact loading rate (BWs^{-1})	Peak loading rate (BWs^{-1})
Barefoot	6.498 ± 0.67	356 ± 42	186 ± 23
Poron	7.432 ± 0.527	636 ± 77	249 ± 34
Saran	7.423 ± 0.66	552 ± 58	254 ± 34
Sorbathane	7.563 ± 0.568	754 ± 77	300 ± 83

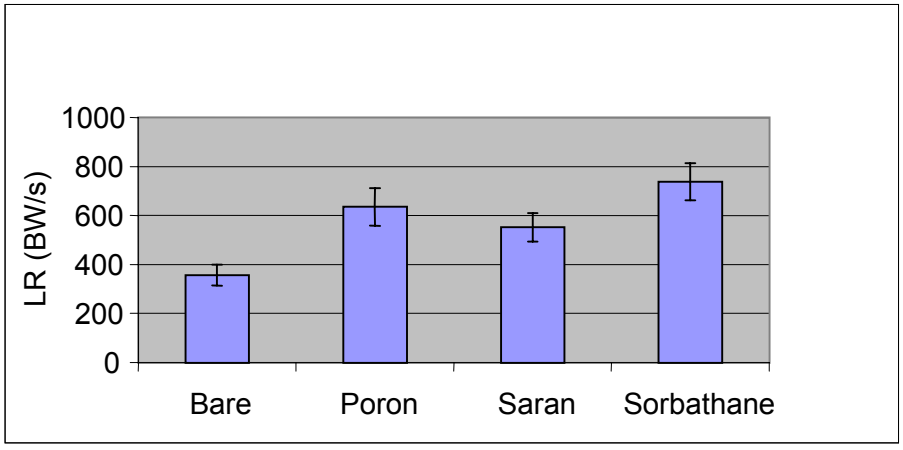
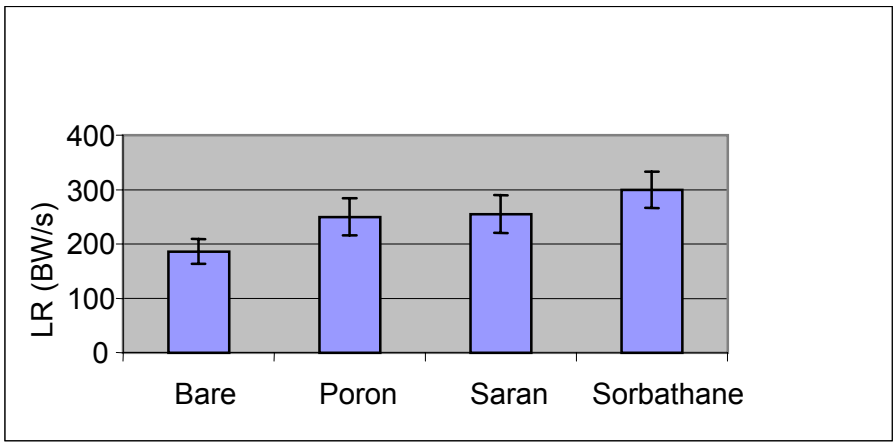


Figure 3 - Mean (±SE) impact loading rate with different insoles relative to landing barefoot.

The mean impact loading rate for Saran was 552 BWs^{-1} and this was less than occurred when the Poron insole was worn (636 BWs^{-1}). The impact loading rate when the Sorbathane insole was worn was much greater at 754 BWs^{-1}, and this was significantly greater than occurred with the Saran insole ($p=0.04$).

The impact loading rates, which followed initial foot contact, were typically half the value of the peak vertical loading rates calculated. When drop jumping barefoot the loading rate to the vertical peak was significantly less than occurred when any insole was worn inside the military boot. However, the calculated mean peak vertical loading rate was almost the same for the Poron and Saran insoles (Figure 4). Although the mean peak loading rate was slightly higher when the Sorbathane insole was worn, this difference was not statistically significant.

Figure 4: Mean (±SE) peak vertical loading rate with different insoles relative to landing barefoot from a drop jump.



CONCLUSION: For the 0.8 m drop jump landing the peak vertical force was approximately 7.5 BW with the insoles, yet only 6.5 BW if barefoot. Forefoot impact loading rate was much greater when a boot was worn with an insole, than when barefoot. Mediating sensory factors may be involved in the lower barefoot values, for example increased ankle, knee and hip flexion. With the insoles, the initial impact loading rate of landing on the forefoot was more than twice the loading rate experienced until peak vertical force occurred at heel contact, suggesting that this forefoot impact loading rate is of relatively more importance. The mean impact forefoot loading rate was much less (552 BWs^{-1}) with the harder Saran insole, while the softer more compressible Sorbathane insole allowed a 37% increase in forefoot mean impact loading rate (754 BWs^{-1}). Results suggest that impact loading rate should be considered a priority measure during comparative studies of boot and/or insole design for this type of activity.

REFERENCES:

Altman, D. (1991). *Practical statistics for medical research.* London: Chapman & Hall.

Barnes, R.A. & Smith, P.D. (1994). The role of footwear in minimizing lower limb injury. *J.Sports Sciences*, **12**, 341-353.

Jones, B.H. & Knapik, J.J. (1999). Physical training and exercise-related injuries. *Sports Med.* **27**, 111-125.

Nigg, B.M., Nurse, M.A., & Stefanyshyn, D.J. (1999). Shoe inserts and orthotics for sport and physical activities. *Medicine & Science in Sports and Exercise,* **31**, S421-428

Windle, C., Gregory, S. & Dixon, S. (1999). The shock attenuation characteristics of four different insoles when worn in a military boot during running and marching. *Gait and Posture,* **9**, 31-37.