DYNAMIC PRESSURE MEASUREMENT ABOUT THE FOOT AND ANKLE

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Measures about the foot and ankle within footwear are required to assess the full dynamic interaction. To address this, piezo resistive fabric sensors provide accurate pressure measurement that can be applied within the narrow confines of the footwear-to-foot/ankle interface. An example of this has been shown in studies focusing on ice hockey skate boots during forward skating. Sixteen flexible piezo-resistive sensors (1.2 cm x 1.8 cm x 0.2 cm thick, FSA Verg Inc.,Canada) were taped to discrete anatomical surfaces of the plantar foot, dorsal foot, the posterior aspect of heel and leg, medial aspect of foot, and lateral aspect of the foot. The results showed an increase in pressure during the stance phase of gait at each anatomical surface with a reciprocal decrease in pressure during swing.

KEY WORDS: pressure measurement, foot, ankle, dynamic, skating.

INTRODUCTION: Few studies have been undertaken that have looked at in boot pressure distribution patterns of the foot at surfaces other than plantar, with the exception of cases involving rotationplasty (Hillmann 1999). The relevance of surface pressures on other regions of the foot is revealed by Hosein and Lord (2000) in their study in shoe plantar shear measurements. The results of their study suggested that plantar shear does not sustain the majority of the anterior acceleration force acting on the body, in late stance phase, or the lateral force acting in early stance phase. This finding led the authors to deduce that the anterior acceleration forces 'must be reacted by pressure against the upper shoe.' They further went on to speculate that 'shoe design and fit may be critical factors in shod shear measurement.' Therefore by collecting pressure measurements about the global surface of the foot and ankle an indication of footwear "fit" is given. This issue of fit has implications for knowing the amount and temporal loading patterns between the foot - footwear interface and thus by extension some performance and health implications. An example application is shown in preliminary studies focusing on ice hockey skate boots during forward skating.

METHODS: A total of 5 subjects participated in the study. All of the subjects were varsity hockey players from McGill University. Pressure signals quantified forces normal to the surface were collected with flexible piezo resistive sensors dimensions (1.2 X 1.8 X 0.2 cm). The raw signals were recorded at 100 Hz and the data were stored on a portable data logger (FSA Verg Inc. Winnipeg, Manitoba). The stored data were subsequently downloaded onto a PC via a serial port connection. Before skating trials were conducted subjects remained in a standing 'neutral' position to identify in boot baseline pressures. See figure 1 for a schematic of the steps involved in data collection and data processing.

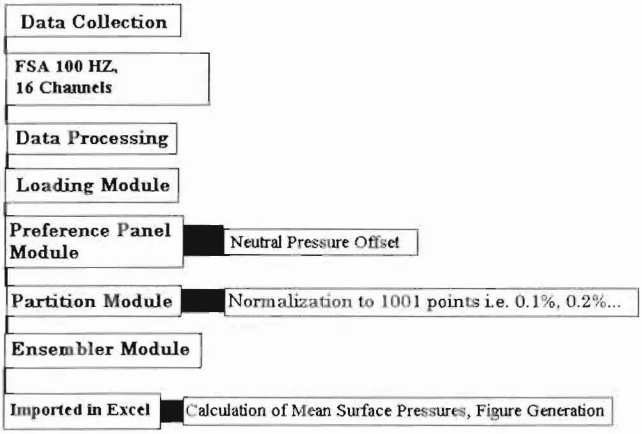

Figure 1: A flow chart of the data collection and data processing steps performed.

Transpose surgical tape (3M) was used to fix the flexible piezo resistive sensors, (FSA Verg Inc. Winnipeg, Manitoba) to the skin. Hair from the area around the skin was removed to restrict displacement of the piezo resistive sensors. All wires from the respective measurement systems were secured to the skaters with Athletic tape and bandages to remove a movement artifact from swinging cables and to avoid entanglement between the cables and the subjects were allowed to select their own preferential skate size and were instructed to lace the skates with the tension they deemed sufficient to provide the fit they are usually accustomed to. All subjects skated in the same skate model, the Bauer Vapor XX.

RESULTS AND DISCUSSION: The following figures depict individual and global surface pressures.

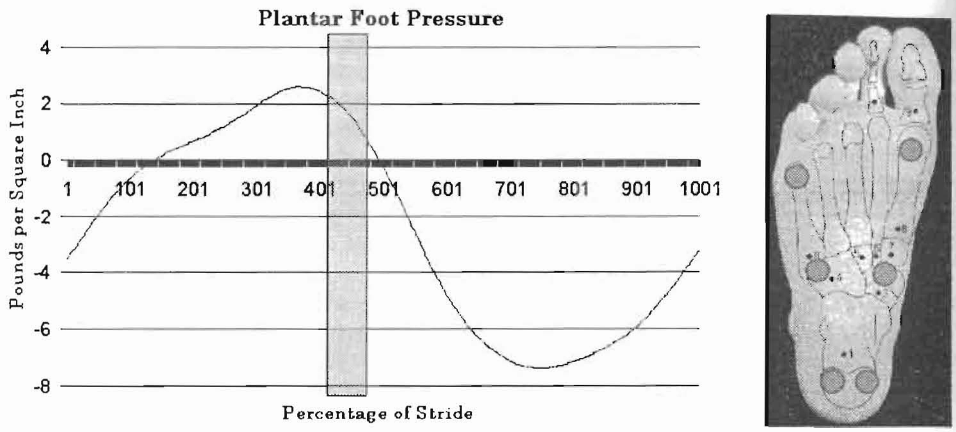

Figure 2: The average pressure value during forward ice hockey skating at the Medial and Lateral: Heel, Arch, and Forefoot sites. The shaded region identifies the termination of the foot contact phase.

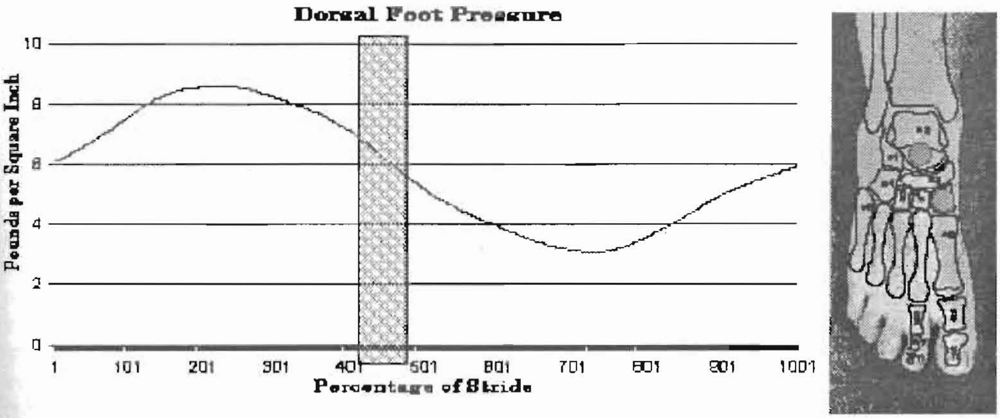

Figure 3: The average pressure value during forward ice hockey skating at the Dorsalis Pedis, and at the Dorsal: First Metatarsal base sites. The shaded region identifies the termination of the foot contact phase.

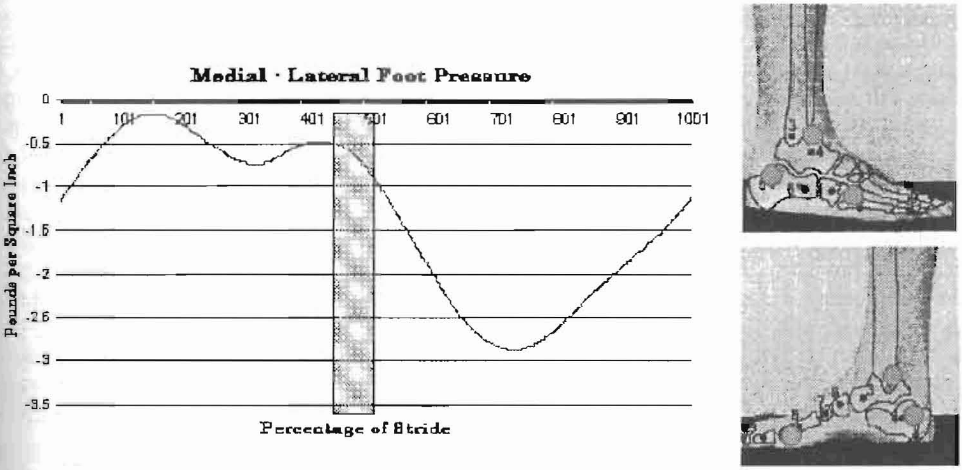

Figure 4: The average pressure value during forward ice hockey skating at the Medial Malleolus, Medial Calcaneus, Medial: First Metatarsal head, Lateral Malleolus, Lateral Calcaneus, and Lateral: Fifth Metatarsal base sites. The shaded region identifies the termination of the foot contact phase.

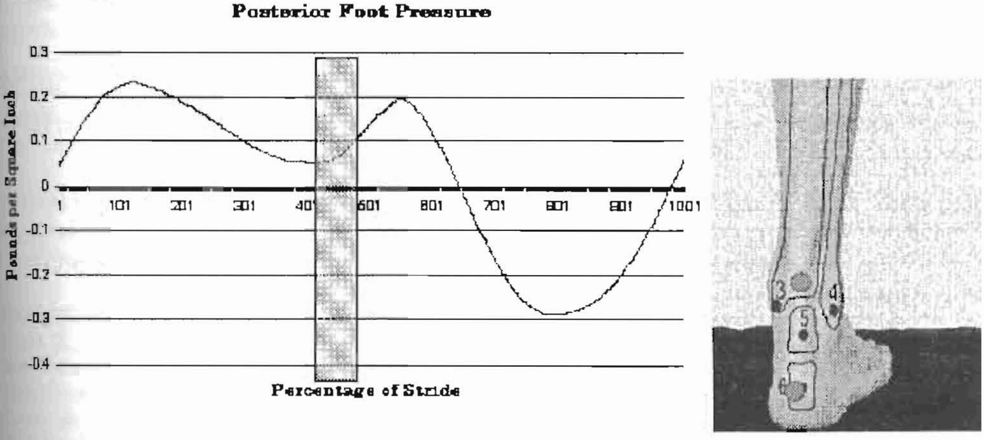

Figure 5: The average pressure value during forward ice hockey skating at the Achilles Tendon, and at the Posterior Calcaneal tuberosity sites. The shaded region identifies the termination of the foot contact phase.

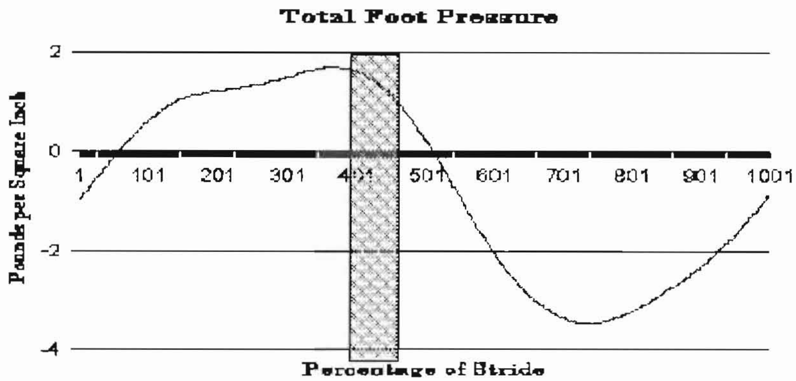

Figure 6: The average pressure value during forward ice hockey skating at the sixteen sites measured on the foot and ankle. The shaded region identifies the termination of the foot contact phase.

The results of this study have implications for the assessment of fit and comfort. Intuitively, it would seem that for a given fit and with a constant foot volume an increase in pressure in one region would be reciprocated by deficit in pressure in another region. The results show an increase in average pressure in the foot and ankle during the foot contact phase than during the swing phase. Furthermore it was found that the increase in pressure during foot contact occurred at all regions of the foot; however on the medial - lateral surfaces of the foot the average pressure during stride was less than the average pressure during the static 'neutral' weight bearing collection. The implication of these findings is that during the foot contact period or during the loading phase there is a general increase in pressure about the global surface of the foot and ankle, by inference this increase in pressure is due to a differing interaction between foot and footwear, and thus a different fit. Due to the relationship between fit and comfort, and the relationship between comfort and performance, these results highlight the inadequacy of the typical 'storeroom' static fit test that consumers use to evaluate footwear. To best assess the fit of footwear consumers should be given a trial period or should have the opportunity to test the footwear in a manner that adequately mimics the real world dynamic conditions, that the footwear is designed for.

CONCLUSION: The use of peizo resistive fabric in the measurement of pressure about the global surfaces of the foot and ankle is rather feasible. Data indicate an undulation in pressure during dynamic activity and varying degrees of 'fit' between foot and footwear during activity.

REFERENCES:

Hillmann, A., Rosenbaum, D., & Winkelmann, W. (2000). Plantar and dorsal foot loading measurements in patients after rotationplasty. Clinical Biomechanics, 15, 359-364.

Hosein, R., & Lord, M. (2000). A study of in-shoe plantar shear in normals. Clinical Biomechanics, 15, 46-53.