

“PRESSURE GRADIENT” AS A POTENTIAL INDICATOR OF PLANTAR SKIN INJURY ON THE NEUROPATHIC FOOT

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INTRODUCTION

Peak plantar pressure (PPP) during walking has been used extensively as an indicator of risk for skin breakdown in the diabetic foot. Although skin breakdown is associated with high PPP, researchers have not been able to identify a critical magnitude of PPP that adequately predicts skin breakdown in the neuropathic population. We speculate that the change in plantar pressure at the PPP location, a “peak pressure gradient, (PPG)”, is more important than the PPP because a PPG may identify a concentration of stress (a harmful vertical shearing) to the soft tissues. The purposes of this presentation are to a) describe methods for obtaining the PPG, and b) determine if the PPG at the PPP location is substantially higher in the forefoot than the rearfoot (even compared to PPP) in subjects with diabetes (DM) and a history of plantar ulcer. Skin breakdown typically is in the forefoot rather than the rearfoot despite fairly similar PPPs [1]. A much higher PPG at the PPP location in the forefoot compared to the rearfoot may partially contribute to a differential in skin breakdown location.

METHODS

The PPG at the PPP location can be calculated by

$$PPG = \max\left(\frac{\partial P}{\partial r}\right)$$

where $\frac{\partial P}{\partial r}$ (space rate of change of pressure on the plantar surface) is the directional derivative of pressure P at the PPP location on the plantar surface in any direction given by vector \vec{r} .

Plantar pressure data during walking were collected on 10 subjects (6 Males/4 Females, mean age 58.0±10.3 years, mean BMI 32.6 ±9.5 kg/m²) with DM (2 Type 1, 8 Type 2, and mean duration of DM 16.5 ± 10.0 years), PN, and a history of a plantar ulcer.

An F-scan system (Tekscan, South Boston, MA, USA) was used to collect the plantar pressure data during walking at a self-selected pace in standardized shoes with a 1-inch heel [2]. The recorded plantar pressure data were analyzed for the PPP and PPG for the forefoot and rearfoot. The PPG at the location of the PPP was calculated after a bicubic polynomial spline smoothing of the pressure data. The PPP and PPG at the PPP location for each area of interest were averaged over three steps during walking.

Analysis: A one tailed, paired t-test on the ratios of PPP and PPG between the forefoot (FF) and rearfoot (RF) was used to determine differences in PPP and PPG between the FF and RF.

Table 1: Mean PPP and PPG at Forefoot and Rearfoot

PPP FF (kPa)	PPP RF (kPa)	PPG FF (kPa/mm)	PPG RF (kPa/mm)
347.80	279.17	32.84	12.05
± 75.45	± 97.16	± 15.52	± 5.30

RESULTS AND DISCUSSION

The mean PPG was 171% higher in the FF compared to the RF in subjects with diabetes and a history of plantar ulcer while the mean PPP was only 25% higher in the FF compared to the RF (Table 1). The mean PPG FF/RF ratio (3.09) was

Table 2: Mean Ratios of Individual Forefoot to Rearfoot Values for PPP and PPG; and Results of Paired t-test Comparison

(PPP FF)/(PPP RF)	(PPG FF)/(PPG RF)	P value
1.41 ± 0.75	3.09 ± 1.54	0.001

significantly greater than the PPP FF/RF ratio (1.41) (p<0.001, Table 2). The PPG likely is much lower in the RF than the FF because of differences in soft tissue thickness and shape of the underlying bony structures. A much higher PPG at the PPP location in the FF compared to the RF may be one reason why skin breakdown typically occurs in the FF rather than the RF despite fairly similar PPPs. Because the PPG may identify harmful vertical shearing of soft tissues on the plantar foot, we propose that it is an important variable to characterize the pressure distribution on the plantar surface and to predict potential plantar skin injuries on the neuropathic foot.

CONCLUSIONS

We describe a new variable, the PPG, which may provide important information about the risk for skin breakdown. PPG is much higher in the FF compared to the RF and this may help to explain why most ulcers occur in the FF despite similar PPPs. Evenly distributed high plantar pressures likely do not cause skin breakdown. We believe that the space rate of change in plantar pressure at PPP location, the PPG, is an important variable to help identify risk for skin breakdown on the neuropathic foot, and that it deserves further investigation.

REFERENCES

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2. Mueller MJ, et al. *J Biomech*, 36, 1009-1017, 2003.

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