

PLANTAR REGIONAL PEAK PRESSURE AND MINIMAL SHEAR STRESS PROFILES IN DIABETIC AND NON-DIABETIC PATIENTS

¹ Visar Berki and ¹ Brian L. Davis

¹ The University of Akron, Akron, OH, USA

Email: vb20@zips.uakron.edu, Web: <http://www.uakron.edu/engineering/BME/>

INTRODUCTION

The measurement of plantar pressure and shear stress profiles is increasingly being applied to the problem of skin tissue breakdown and ulceration in diabetic patients. The complex nature of plantar pressure and shear stress profiles during gait presents a multitude of possibilities for their assessment. Our current objectives were to determine (i) the instantaneous regional peak pressures in diabetic and non-diabetic patients, (ii) the instantaneous regional points of minimal shear stress, and (iii) the relationship, if any, between the two data sets. If there was a significant relationship between peak pressures and low shear, this would lend support to the idea that tissue is “squeezed” radially outwards from points of peak pressure, with zones of almost no shear stress at the center of these regions. Our goal was to investigate these relationships for diabetic patients with peripheral neuropathy and non-diabetic control patients.

METHODS

Pressure and shear stress data were collected on 29 human subjects: 16 control patients (9M, 7F; Age: 47.6 ± 5.8 years; Weight: 824 N) and 13 neuropathic, diabetic patients (8M, 5F, Age: 61.6 ± 14 years, Weight: 944 N). Each subject walked barefoot across a custom built shear and pressure collection system that is aligned in the center of a 3 m. x 0.6 m. platform. The center of the walking platform contains a $40 \times 58 \times 0.17 \text{ cm}^3$ surface stress sensitive film (S3F) [1] that the subject was required to step on with the second of three steps. Four separate steps were recorded for each subject at a sampling rate of 50 Hz. Every step data set consisted of multiple 2-D arrays for pressure, medial-lateral shear, and anterior-posterior shear stress data, representing each sampled timeframe.

Each array contains pressure and shear stress data for every 1.6 mm x 1.6mm area of contact between the plantar and ground surfaces.

For every time frame, regional pressure peaks that correspond to the highest pressure in any 4.8mm by 4.8mm region of pressure values were recorded, along with their respective location coordinates. Simultaneously, shear stress coordinates were recorded, on the condition that the values corresponded to shear stress magnitudes of less than 25 Pa in all four directions (medial, lateral, anterior, and posterior). The distances between all minimal shear stress and regional peak pressure points were calculated, for all time frames.

Two sets of relationships between regional peak pressure and regional minimal shear stress points were then generated. The first set investigated each regional pressure peak, and calculated whether that peak occurred near any point that was considered as a minimal shear stress. The second relationship set investigated each regional minimal shear stress, and calculated whether that value occurred near any regional peak pressure point. Two points were considered to be nearby if they occurred within the same 4.8mm by 4.8mm neighborhood of coordinates. The final results indicated (i) the total number of regional peak pressure points, and how many of those points were near a minimal shear, and (ii) the total number of minimal shear points, and how many of those points occurred near a regional peak pressure point.

RESULTS AND DISCUSSION

For every time frame that contained pressure and shear stress data from any given patient, we observed that there were multiple instantaneous pressure peaks occurring on the plantar contact

surface. There were also numerous points of minimal shear during the same time frames. The total number of points occurring throughout the entire stance phase (multiple time frames) was summed and compared between diabetic and non-diabetic patients (Table 1). The results show that on average, diabetic patients have a higher number of regional peak pressure points (718 vs. 460) and also a higher number of minimal shear stress points (140 vs. 92) on the plantar surface. It is also evident that there were far more points of peak pressure as compared to points of minimal shear over the course of the entire stance phase. These findings are consistent with the concept that neuropathic diabetic patients have arches that flatten more than control subjects. As an arch flattens, there are concomitantly increased sites where local pressures increase. Of note is the fact that for diabetic and control subjects there was little difference in (i) the ratio of regional peak pressure points occurring near minimal shear points, and (ii) the ratio of minimal shear points occurring near regional peak pressures.

CONCLUSIONS

The current study has revealed that diabetic patients with peripheral neuropathy experience more instantaneous pressure peaks as the plantar skin surface makes contact with the ground. We believe

that this is in fact an indication of a collapse in the supporting arch structure of the foot, as is often the case in diabetic patients with foot pathologies. The increased number of peak pressure points means that there is likely a greater surface area that makes contact with the ground, which also explains the increased number of minimal shear stress points. In this scenario, both peak pressures and minimal shear stresses would be more widely distributed.

Previous studies have tried to predict shear stresses based on vertical loading parameters, given the absence of commercial plantar shear force platforms [2]. We examined our results for a possible relationship between regional peak pressure points and points of minimal shear. We conclude that we can safely predict minimal shear points with more than 84% certainty by observing the locations of peak pressures. But we cannot necessarily predict peak pressure points by observing minimal shear locations, as the occurrence rate is less than 19%.

REFERENCES

1. Stucke S, et al. *J Biomech* **45(3)**, 619-622, 2012.
2. Yavuz M, et al, *J Biomech Eng* **131(9)**, 2009.

Table 1: Means that indicate the total number of regional peak pressure and minimal shear stress points. Also shown are means indicating how many (i) pressure peaks, or (ii) minimal shear points, are close in proximity to the other value, and the respective percentage of occurrence.

	Number of Regional Peak Pressure Points (P)	P points near Minimal Shear Points (τ)	Percentage of P near τ	Number of Minimal Shear Points τ	τ , Near Regional Peak Pressure Points P	Percentage of τ near P
Control Patient Means	460	92	18.8%	94	83	86.8%
Diabetic Patient Means	718	140	17.5%	146	119	84.3%