

The Effect of Walking Speed on Peak Plantar Pressure

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Introduction: Foot ulcerations are a common problem for individuals with diabetes. Abnormal peak plantar pressures have been shown to exist at areas of tissue damage in neuropathic feet¹. Therefore, plantar pressure measurements are commonly used to diagnose and evaluate patients with diabetes. Previous studies suggest that walking speed is correlated to peak plantar pressure. Morag and Cavanagh reported elevated heel pressures associated with higher approach velocity². Drerup et al. also found a pressure increase of approximately 20% in the heel at faster walking speeds. The toe region seemed to increase as well but was not statistically significant³. Cavanagh discusses the threshold value for safe plantar pressures on neuropathic feet (200 kPa) and states that other factors such as compliance and activity level should also be considered⁴. Further research involving a range of speeds would help clarify the effect velocity has on peak plantar pressure.

Statement of Clinical Significance: Understanding the effect of gait velocity on peak plantar pressures on specific regions of the foot would clarify whether at-risk diabetic patients benefit by walking at moderate speeds in order to reduce plantar pressure.

Methodology: Ten normal subjects were recruited to walk at six different speeds (0.75, 1.00, 1.25, 1.50, 1.75 and 2.00 m/s) on a treadmill. Initially, the subjects were fit to PEDAR insoles (Novel gmbh, Munich) and a standardized shoe (xtra-depth, PW Minor, Batavia, NY). The subjects were allowed to acclimatize to each speed by walking 5-10 steps before data collection. Twenty-five steps were collected at a sampling rate of 100 Hz and then analyzed using Novel-win software. Ten steps for each foot were sectioned into five regions: the great toe (T), medial forefoot (M), central forefoot (C), lateral forefoot (L) and the heel (H). Peak pressure measurements were determined in each region and averaged over the ten steps.

Results: The peak pressure measurements varied between the five regions of the foot, with the lowest overall values occurring in the lateral forefoot and the highest values in the heel. Peak pressure and speed were linearly related in the great toe and heel regions ($R^2 = 0.98-0.99$, Figure 1a). The peak pressure in the central and medial forefoot increased as the velocity initially increased, but seemed to plateau or even decrease at the fastest speeds. Finally, the lateral forefoot demonstrated insignificant changes in peak pressure with speed. All forefoot regions were best fit to a polynomial trend line ($R^2 = 0.96-0.98$, Figure 1b). Significant differences in peak pressure ($p < .05$) as the velocity increased were determined using a repeated measures ANOVA with Fisher's PLSD tests post hoc. Overall, significant differences in peak pressure were found in the great toe, heel, central and medial forefoot. Differences found between particular speeds are expressed in Table 1.

Discussion: The foot responds to faster gait velocities by amplifying peak pressure values in the great toe and heel. The pressure in the lateral forefoot is unaffected by increased speed,

while the pressures in the central and medial forefoot only initially increase. At higher speeds, these pressure regions plateau or decrease. Based on Cavanagh's threshold value⁴ and the statistical analysis, normal subjects can walk at speeds of up to 1.25 m/s and maintain peak pressures below 200 kPa. Future research is planned to determine if the same pattern of plantar pressure as a function of speed holds true in diabetics.

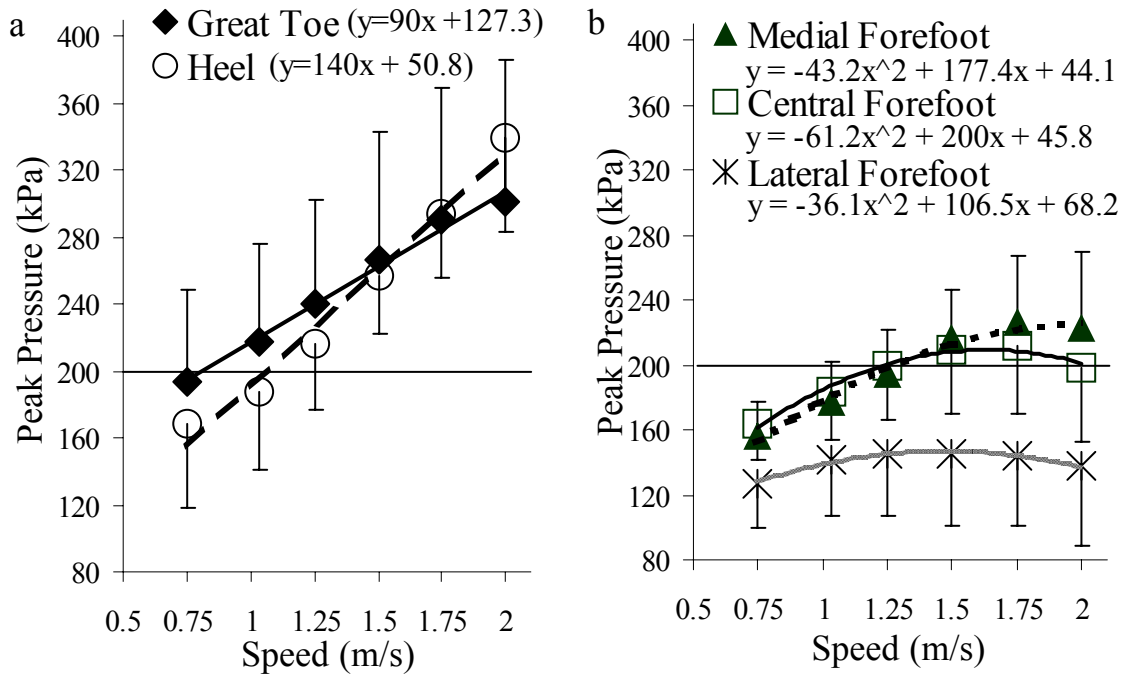


Figure 1: Mean peak pressure values for five foot regions at six speeds. Error bars are one standard deviation and equations represent the best-fit trend lines ($R^2 = 0.96-0.99$). Cavanagh's threshold value for safe plantar pressures is illustrated at 200 kPa.

Table 1: Significant differences ($p < .05$) in peak pressure for 5 foot regions at 6 speeds (m/s).

SPEED	0.75	1.03	1.25	1.5	1.75	2
0.75	-	-	C, M, H,	T, C, M, H	T, C, M, H	T, C, M, H
1.03	-	-	-	C, M, H	T, C, M, H	T, M, H
1.25	C, M, H	-	-	H	T, H	T, H
1.5	T, C, M, H	C, M, H	H	-	H	H
1.75	T, C, M, H	T, C, M, H	T, H	H	-	H

KEY: T=Great Toe, H=Heel, C=Central Forefoot, M=Medial Forefoot, L=Lateral Forefoot

References:

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3. Drerup B, Hafkemeyer U, Moller M, Wetz HH (2001) *Orthopade*, 30(3): 169-75.
4. Cavanagh PR, (2002) *Proceedings of the World Congress of Biomechanics, Calgary*.