HOW DOES SHOE UPPER DESIGN INFLUENCE PLANTAR PRESSURE DISTRIBUTION?

Howard Hillstrom, Jinsup Song, Esther Kim, and Benjamin Heilman
Gait Study Center, Temple University School of Podiatric Medicine; email: hhillstrom@tuspm.temple.edu

INTRODUCTION

The purpose of this study was to examine the immediate effects of footwear design on in-shoe plantar pressures during gait. This study is part of a larger investigation of the structural properties of Birkenstock® footwear technologies and their effect upon lower extremity function. Each of the shoe designs studied employed the identical Birkenstock footbed (ie. a deep heel cup with a 'pronounced' medial longitudinal arch support). The design differences were confined to the 'uppers' whereby the Boston (BO) was a clog, the London (LO) was a shoe, and the Arizona (AZ) was a sandal. The following research question was addressed: *Does the upper design affect shoe structure and foot function?*

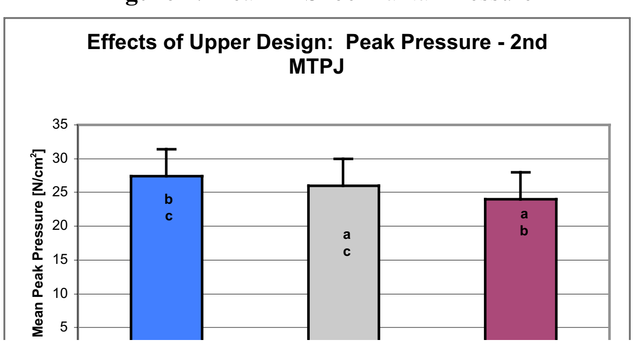
METHODS

Data was collected on 20 subjects (mean age=27) with moderate pes planus, each wearing the three shoe models described. The Novel Pedar-X system was used to measure in-shoe plantar pressures at a sampling frequency of 50 Hz. Following a 5-minute accommodation period, four trials of in-shoe plantar pressures were collected for each shoe condition while each subject walked at his or her self-selected comfortable speed. Each trial of plantar pressure data was analyzed using three separate masks (anatomical, medial-lateral, and anterior-posterior). The anatomical mask determined plantar loading as shown in Table 1. The medial-lateral mask determined plantar loading from the medial half versus lateral half of the shoe (*about its long axis*). The anterior-posterior mask determined plantar loading from the anterior half versus the posterior half of the shoe. Two parameters were calculated for each region in the aforementioned masks: peak pressure (N/cm^2) and Pressure-time integral (Ns/cm^2). Gait speed was captured with a light-based timing system. Two-way mixed effect Analysis of Co-Variance was performed, utilizing gait speed as a covariate. Post-hoc analysis consisted of the Bonferroni-Dunn test.

RESULTS AND DISCUSSION

When examining pressures from the anatomical mask the LO had the lowest peak values and AP had the highest beneath the metatarsalphalangeal joints (MTPJ). In the medial/lateral mask the LO design had the lowest medial and lateral Pressure-time integral (PTI) and Peak pressure (PP) values. LO had the lowest anterior PTI, anterior PP, and Ant/Post ratios while AP had the highest. One plausible explanation for these differences in shoe gear with identical footbeds is that load sharing was afforded by the more extensive uppers in the LO design which could effectively reduce forefoot loading.

Figure 1: Peak In-Shoe Plantar Pressure



Location	Shoe	Mean	SD	p-value	Post-Hoc
Medial Heel (N/cm^2)	AP	24.539	4.117	0.0259	b,c
	BO	26.151	4.149		a,c
	LO	23.533	4.117		a,b
Lateral Heel (N/cm^2)	AP	22.520	4.149	0.3330	
	BO	23.678	4.180		
	LO	23.713	4.149		
Medial Arch (N/cm^2)	AP	12.398	2.346	0.6718	
	BO	12.255	2.365		
	LO	12.049	2.340		
Lateral Arch (N/cm^2)	AP	15.732	2.517	0.1533	
	BO	15.373	2.536		
	LO	14.669	2.517		
1st MTPJ (N/cm^2)	AP	14.383	3.478	0.0005	c
	BO	14.398	3.510		c
	LO	17.273	3.478		a,b
2nd MTPJ (N/cm^2)	AP	27.407	3.946	0.0014	b,c
	BO	25.981	3.978		a,c
	LO	24.039	3.946		a,b
3rd MTPJ (N/cm^2)	AP	28.181	3.845	$<$ 0.0001	b,c
	BO	26.596	3.877		a,c
	LO	24108	3.845		a,b
4th MTPJ (N/cm^2)	AP	23.249	3.156	$<$ 0.0001	b,c
	BO	20.977	3.181		a,c
	LO	19.839	3.156		a,b
5th MTPJ (N/cm^2)	AP	14.433	2.087	0.2683	
	BO	14.554	2.106		
	LO	13.855	2.087		
Hallux (N/cm^2)	AP	30.450	7.519	0.1574	
	BO	27.142	7.582		
	LO	28.818	7.519		

Table 1: Peak Pressure for Each Anatomical Region

CONCLUSIONS

The shoe upper design can influence biomechanical foot function.

ACKNOWLEDGEMENTS

This study was funded by Birkenstock USA