EFFECTS OF SANDAL ARCH HEIGHT ON DYNAMIC PLANTAR PRESSURES

Jinsup Song, Howard J. Hillstrom, Esther H. Kim, and Benjamin P. Heilman
Gait Study Center, Temple University School of Podiatric Medicine

INTRODUCTION

The purpose of this study was to examine the immediate effects of sandal arch support on comfort and in-shoe plantar pressures during gait. This was based upon a postulate that the three-dimensional Birkenstock® footbed could improve foot alignment and distributed plantar pressure. The effect of a 2-month wear period on dynamic plantar pressure was also investigated in one sandal condition. This study was part of a larger investigation of the structural properties of Birkenstock® footwear technologies and their effect upon lower extremity function.

METHODS

In-shoe plantar pressures were collected on 20 healthy asymptomatic subjects (mean age of 27 and body mass index of 25.9) with moderate pes planus feet in 5 sandal conditions. All sandals incorporated the same Birkenstock® footbed technologies but had varying amount of arch support, ranging from mild to aggressive arch height. Visual analog scale (VAS) assessments were provided by subjects for both shoe comfort ratings and discomfort experienced immediately after performing activities of daily living (i.e. half flight ascent/descent of stairs, 50' timed walk at one's comfortable pace, and 50' timed walk at one's fastest possible pace). In-shoe plantar pressure and shoe comfort ratings were repeated following a 2-month wear period in the Arizona sandal. The Pedar-X system (Novel Inc, St. Paul) 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 subjects walked at their self-selected comfortable speed. Each trial of plantar pressure data was analyzed using three separate masks (anatomical, medial-lateral, and anterior-posterior). Peak pressure (PP, in N/cm^2) and Pressure-time integral (PTI, in Ns/cm^2) were calculated for each region of the masks. 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

The Arizona sandals with the soft footbed (AS) yielded the lowest PTI beneath metatarsophalangeal joints (MTPJs) 2-5, the highest overall shoe comfort (87.9%), and the fastest self-selected walking speed (see Table 1). Medial PTI was also lowest in AS while the medial/lateral PTI ratio was highest in Fulda – the sandal with the largest arch height. Anterior PTI was again lowest in AS while the anterior/posterior PTI ratio was highest in Santa Cruz – the sandal with the lowest arch height. When relating the hallucial PTI versus sandal arch height, a U-function resulted (see Figure 1), suggesting that it may be possible to optimally select footwear for specific anatomical locations in a given population or individuals.

Following a 2-month accommodation of the Arizona (AP) sandal, PTI beneath MTPJs 2-4 (see Table 2), lateral, anterior, and posterior regions all decreased as compared to the baseline. The overall comfort rating also improved from 67.8% to 85.7%. This is consistent with the postulated auto-conforming nature of the Birkenstock footbed after accommodation.

CONCLUSIONS

Significant differences were noted on plantar pressure distribution, gait speed, and shoe comfort as a function of arch support height. A significant reduction in forefoot plantar pressures and overall comfort following a 2-month wear period indicated the importance of accommodation for the classic Birkenstock footbed technology.

Table 1: Pressure Time Integral (N*sec/cm2) for forefoot regions and shoe comfort in 5 sandal conditions

Location	Shoe	Mean	SD	p-value	Post-Hoc
Hallux	SC (a)	5.5	1.1	< 0.0001	b,c
	IC (b)	4.6	1.1		a,d,e
	AS (c)	4.6	1.2		a,d,e
	AP (d)	5.4	1.1		b,c
	FU (e)	5.3	1.1		b,c
1st MTPJ	SC (a)	4.2	0.7	0.0007	d,c
	IC (b)	3.8	0.7		e
	AS (c)	3.8	0.7		a,e
	AP (d)	3.8	0.7		a,e
	FU (e)	4.2	0.7		b,c,d
2nd MTPJ	SC (a)	8.0	1.0	< 0.0001	b,c,d,e
	IC (b)	6.9	1.0		a,c,d,e
	AS (c)	6.1	1.0		a,b,d,e
	AP (d)	7.8	1.0		a,b,c,e
	FU (e)	6.5	1.0		a,b,c,d
3rd MTPJ	SC (a)	8.5	0.9	< 0.0001	b,c,d,e
	IC (b)	7.6	0.9		a,c,d,e
	AS (c)	6.4	0.9		a,b,d,e
	AP (d)	8.1	0.8		a,b,c,e
	FU (e)	7.0	0.9		a,b,c,d
4th MTPJ	SC (a)	7.4	0.9	< 0.0001	b,c,d,e
	IC (b)	6.7	0.9		a,c,e
	AS (c)	5.7	0.9		a,b,d,e
	AP (d)	6.7	0.8		a,c,e
	FU (e)	6.2	0.9		a,b,c,d
5th MTPJ	SC (a)	4.7	0.7	0.0149	b,c
	IC (b)	4.9	0.7		a,c,d,e
	AS (c)	4.4	0.7		a,b,e
	AP (d)	4.5	0.7		b,e
	FU (e)	4.7	0.7		b,c,d
Gait Speed (m/sec)	SC (a)	1.26	0.05	< 0.0001	c,d,e
	IC (b)	1.29	0.05		
	AS (c)	1.34	0.05		a
	AP (d)	1.32	0.05		a
	FU (e)	1.34	0.05		a
Overall Comfort (%)	SC (a)	60.1	27.0	< 0.0001	c
	IC (b)	79.5	20.3		e
	AS (c)	87.9	13.2		a,e
	AP (d)	67.8	51.6		
	FU (e)	58.2	26.8		b,c

Table 2: Effects of 2-month accommodation on forefoot PTI (N*sec/cm2) and shoe comfort rating

Location	Shoe	Mean	SD	p-value
Hallux	AP	5.4	1.3	0.4709
	AP2	5.2	1.4	
1st MTPJ	AP	3.8	1.1	0.0649
	AP2	4.1	1.1	
2nd MTPJ	AP	7.8	1.0	0.0052
	AP2	7.0	1.1	
3rd MTPJ	AP	8.1	1.0	0.0001
	AP2	7.2	1.0	
4th MTPJ	AP	6.7	1.0	0.0010
	AP2	5.8	1.1	
5th MTPJ	AP	4.5	0.7	0.7775
	AP2	4.5	0.7	
Gait Speed (m/sec)	AP	1.32	0.06	0.0115
	AP2	1.29	0.07	
Overall Comfort (%)	AP	67.8	21.6	0.0023
	AP2	85.7	18.5	

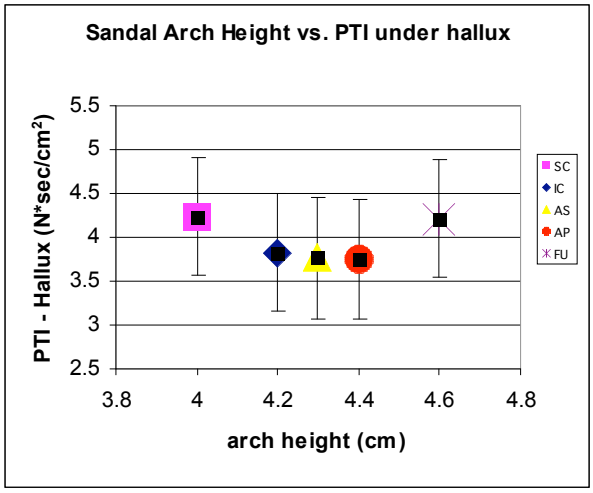

Figure 1: Sandal Arch Height versus PTI under Hallux