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Analysis of the effect of high heel shoes design components on gait ground reaction forces

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Introduction

A huge proportion of women wear high heel shoes (HHS) in a daily basis. The use of HHS disturbs the natural position of the foot, causing an alteration of gait biomechanics that may derive in musculoskeletal injuries. Several studies have already analyzed the influence of heel height on the temporal–spatial parameters of gait, joint kinematics, muscle activity, energy consumption and plantar foot pressures. However, the effect of other HHS design components have received less attention. The influence of heel width, wedge and platform in HHS gait is almost unknown. The analysis of ground reaction forces (GRF) may provide useful information about the gait performance, mainly related to the impact forces and gait stability.

Purpose of the study

The aim of the study was to analyze the influence of several HHS design components on gait GRF by means of a functional principal components analysis (FPCA).

Methods

Eight women, users of HHS and all wearing footwear of size 37 (EUR), participated in the experiment. Seven models of HHS from the same manufacturer were used. The collection was classified in 6 pairs of shoes to study the effect of heel height, heel width, and the existence of wedge or platform in gait dynamics. For each design component, a pair of shoes was selected, trying to get two models of shoes different in this parameter but similar in the other ones.

Five measurements of gait were done, for each woman wearing each model of shoes in randomized order. Gait was recorded at comfortable speed. GRF were recorded using the dynamometric platform Dinescan/IBV. With the aim to increase the effect of the footwear differences in the gait, biomechanics of the non-dominant lower limb while dual-tasking (counting backwards form 100) gait was recorded. The GRF were analyzed with respect to the percentage of the support time. A cylindrical decomposition was applied to the forces, decomposing them into: (1) vertical component, Fz(t); (2) magnitude of horizontal component, Fh (t) and (3) angular horizontal component, $\alpha(t)$, which was divided in $\cos\alpha(t)$ and $\sin\alpha(t)$.

The analysis was performed in the following steps: (i) Functional Principal Components Analysis (FPCA) of the GRF waveforms; (ii) repeated measures ANOVAs were made, being the factor the pair of shoes under comparison and the output the FPCA score of the related measurements and (iii) the marginal mean curves were reconstructed using the scores that showed significant differences, for a graphical interpretation of the results.

Results

After the FPCA 4 components were retained per waveform, explaining on average 70% variance. The results of the ANOVAs of the

FPCA score for each design component is shown in figure 1.

	WEDGE	PLATFORM	HEEL GEOMETRY WITHOUT PLATFORM	HEEL GEOMETRY WITH PLATFORM	HEEL HEIGHT WITH PLATFORM	HEEL HEIGHT WITHOUT PLATFORM
FZ1	0.003	<0.001	0.004		0.004	
FZ2		<0.001	<0.001		0.002	
FZ3	0.008	<0.001	<0.001		<0.001	<0.001
FZ4	0.002	<0.001	0.001			
FH1	0.050	0.002		<0.001	<0.001	
FH2		0.036		0.026		
FH3		0.004	<0.001		<0.001	
FH4						
COS1		0.001	<0.001	0.006	<0.001	
COS2			<0.001	0.031	0.001	
COS3						<0.001
COS4		0.049	<0.001	0.048		
SIN1		0.004				
SIN2	0.020	<0.001		0.004		
SIN3	0.002	<0.001				0.004
SIN4				0.041	0.026	

Figure 1. Values for the one way ANOVAs. The p-values shown correspond to the ANOVAS where significant differences have been found.

There were differences in the force curves with all the pairs of shoes compared in the study. Only the 4th FPCA 4 component of Fh (t) didn't show differences for any comparison. Marginal means of the FPC scores were obtained where significant differences were found. These means correspond to the output of the model fitted in each condition. The marginal mean curves were reconstructed with scores to highlight the differences in gait due to the design component under study. An example of the results is presented in the figure 2.

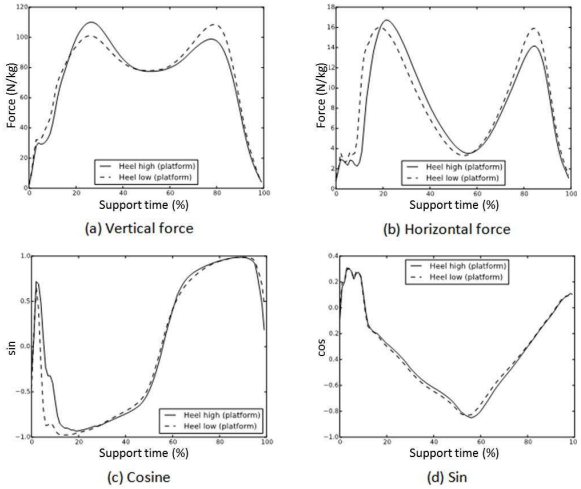

Figure 2. Marginal mean curves reconstructed for the comparison of the heel height in to shoes with platform. Solid line, higher heel; dashed line, lower heel.

Discussion and conclusion

A study was conducted in order to better understand how different design components of heel shoes alter gait biomechanics. Significant differences were found in the GRF during gait due to the effect of the 4 design components analyzed. A different behaviour in the vertical and horizontal GRF were observed in relation to each component. These foundlings may allow the association of the shoe design components to biomechanical aspects, as the impact force or gait stability.

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