

GAIT PATTERN OF WALKING ON TREADMILL WEARING NEGATIVE HEEL SHOES

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INTRODUCTION

The biomechanical and metabolic responses to human locomotion have been examined by a number of researchers. However, most of these studies are related to walking with high-heeled shoes. Studies on walking with negative heel shoe (NHS), which was called missing-heel shoes or heel-less shoes in some of the literature, are limited. Mann et al. (1976) compared tennis shoes, NHS and bare foot shod conditions, and found that there was no change in gait pattern of subjects walking in bare feet, tennis shoes, or NHS. They believed that soft tissues of the foot had absorbed any change being brought about by the shape of NHS. De Lateur et al. (1991) measured the back flexion-extension, hip flexion-extension, knee flexion-extension and ankle plantarflexion-dorsiflexion of the subjects when standing and walking with NHS, bare feet, and two levels of positive heel shoes. The results suggested that the greatest compensation for heel height occurs distally. Benz et al. (1998) reported that, walking speed was reduced significantly with the missing-heel shoes as consequence of a shorter stride length combined with an increased cadence. The walking patterns differed drastically at the ankle joint. No significant differences were found at the level of the knee and hip joints. However, in the above-mentioned literature, biomechanics data describing the gait characteristics were not published. The purpose of this study was to investigate the changes of gait pattern with wearing NHS when compared with normal low positive heel shoes (LPHS), and to provide more detailed information in this research area.

METHODS

Thirteen male subjects of mean age 23.08 yr (SD, 3.9), mean height 1.63 m (SD, 0.05) and mean body mass 50.18 kg (SD, 5.3) volunteered to participate in this study. All subjects were in an excellent state of health. Each subject has been provided informal consent according to the local ethical committee's guidelines. To assure uniformity of the testing conditions all subjects were provided with the same two kinds of shoes. Although LPHS and NHS were commercially available, they were similar in construction and material with the exception of the heel height. The LPHS (Fig. 1) had its sole tilted for 10 degrees of plantarflexion, whereas the NHS (Fig. 2) had the sole tilted for 10 degrees of dorsiflexion. Different sizes of shoes have different heel heights. In this study, only shoes of size 37 were studied. In the LPHS the heel was approximately 2 cm higher than toe, which is known as normal shoes. In contrast, in the NHS, the toe was 2 cm higher than the heel. For each subject, the order of the shoes was randomly assigned in each different test session.

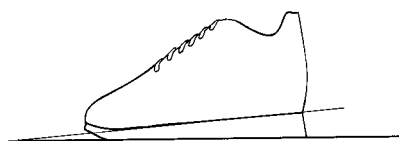


Figure 1-Lower Positive Heel Shoes



Figure 2 -Negative Heel Shoes

Before the start of each walking trial, lightweight spherical reflective markers were attached on the right side of the subject at selected anatomic positions to facilitate later video digitization. The positions included: acromion, greater trochanter, lateral epicondyle of the femur, lateral malleolus, calcaneus and head of the fifth metatarsal. Each subject was asked to wear two types of shoes and walk on a treadmill with constant speed of 1.33m/s for six minutes. For each trial, the subject's movement was recorded after she felt secure. The walking movement was filmed by a digital video camera (100Hz) positioned lateral to the subject with the lens axis perpendicular to the movement plane. The distance of the camera to the movement plane was 5m and the shutter speed was at 1/250s. For each trial, ten consecutive strides were recorded from the time point of the 1st, 4th, and 6th minutes from the starting of walk. The subjects were not aware of when exactly the data were acquired in order to minimize possible gait modifications. Since there was always a possibility of "bad" data (i.e. subject accidentally stumbled or misplaced the foot), all results were shown on the monitor and confirmed by an operator. The recorded videotapes were then digitized and analyzed a motion analysis system (APAS®) by using a human body model consisting of six points, including the toe, heel, ankle, knee, hip and the shoulder. A Butterworth low-pass filter was used to smooth the position-time data for anatomical landmarks. Differences between results were tested with paired-samples T test and the level of significant was determined at $p < 0.05$, using SPSS.

RESULTS AND DISCUSSION

The data show that wearing NHS induced significant changes in stance time, cadence, stride length and some change in maximum flexion and extension angles and the ranges of motion at hip, knee, and ankle joints respectively (Table 1).

Table 1- Statistical results of gait variables for all subjects with LPHS and NHS during treadmill walking

Parameter	LPHS		NHS		Statistical comparison	
	Mean	SD	Mean	SD	t	p
Stance time(s)	0.6277	0.0015	0.6169	0.0017	3.092	0.009
Cadence (step/min)	114.4	1.9930	116.8	2.0190	-5.363	0.000
Stride length (cm)	1.3962	0.0484	1.3669	0.0475	4.839	0.000
Max. hip flexion angle (°)	21.8677	3.2749	20.3415	3.2749	-2.489	0.028
Max. hip Ext angle (°)	-10.8208	4.0708	-11.9762	3.7477	-2.968	0.012
Hip ROM (degree) (°)	32.6885	5.1670	32.3177	4.2172	0.703	0.495
Max. knee flex angle of stance time (°)	-7.8292	2.9668	-8.2915	3.0503	0.698	0.498
Max. knee Ext angle of stance time (°)	10.8338	3.3780	9.2569	4.0068	4.252	0.001
Max. knee flex angle of swing time (°)	-55.1962	4.6166	-54.45	3.3225	-0.969	0.352
Knee Rom of swing time (°)	58.4962	4.2702	57.3638	2.7359	1.238	0.239
Knee ROM of stance time (°)	18.6631	4.6376	17.5485	4.2820	1.8666	0.087
Max. ankle PF angle of stance time (°)	-3.9554	2.0679	-9.5277	2.4104	18.713	0.000
Max. ankle DF angle of stance time (°)	23.9446	3.4063	19.1854	3.8438	11.435	0.000
Max. ankle PF angle of swing time (°)	-1.55	3.5383	-7.52	3.3973	6.6547	0.000
Ankle Rom during swing time (°)	11.1846	2.4034	9.0069	2.2497	6.83	0.000
Ankle ROM during stance time (°)	27.90	3.1906	28.7131	2.9820	-2.517	0.027

ROM=range of motion; Max.=maximum; Ext=extension; DF=dorsiflexion; PF=plantarflexion

The results support de Lateur (1991) and Benz (1998) who reported changes in cadence, stride length, and distal segment of the low extremities. The results also show differences from the findings by Mann (1976) in cadence, stride length and joint angles of ankle, knee and hip. The differences may due to the construction and material of the shoes. In Roger's study, LHS was compared with the "Earth Shoe", a kind of NHS, where the sole was tilted about 3 degree for dorsiflexion and elevation in the area of the second and third metatarsal heads. Another reason may be the difference in walking speed. In Roger's study the walking speed was not reported. The present study shows that walking wearing NHS changes the cadence, stride length and the orientation of the lower extremity, particularly the ankle joint.

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