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Short communication

In-shoe pressure distribution in "unstable" (MBT) shoes and flat-bottomed training shoes: A comparative study

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Abstract

Background: Footwear comfort in many clinical situations is dependent on the ability of the 'shoe' to redistribute plantar pressure. Offloading the metatarsal heads may be achieved by fitting an insole, but recently a new design of shoe with a curved under sole (Masai Barefoot Technology® or "MBT shoe") has been advocated. The aim of this study was to directly assess the effect of such shoes on gait pattern.
Methods: Normal subjects were recruited and asked to walk sequentially in (a) flat-soled training shoes and (b) midfoot bearing shoes (MBT shoe). Mean and peak pressures in four anatomically defined areas of the foot, and the total area of sole contact were measured electronically by an in-shoe system (Pedar Ltd., UK).
Principal results: Standing in the Masai shoes resulted in a 21% lesser peak pressure under the midfoot and an 11% lesser peak pressure under the heel in comparison to the figures found when patients wore their training shoes. There was a 76% compensatory increase in pressure under the toes. In essence there was a significant shift in pressure towards the front of the foot.

Keywords: Foot; Plantar pressure; Weight distribution; MBT shoes

1. Introduction

Shoes receive the blame for many foot deformities and symptoms. Valgus deviation develops in some toddlers after they are introduced to shoes, and the higher prevalence of foot pathology in women is linked to their increased tendency to wear high-heeled and ill-fitting shoes. Focal increases in plantar pressure may also readily be linked to plantar ulceration, stress fractures, plantar fasciitis, heel spurs, and metatarsalgia [1,2].

Previous studies have found that changing shoe design can significantly alter the plantar pressure in specific regions of the foot. A rocker sole, used in patients with diabetic neuropathy, decreases the pressure under the medial and central forefoot and toes, but increases the pressure in the rest of the foot [3,4], whereas a high-heel relieves pressure under the hind foot [1,5]. The latter may be advantageous in patients with plantar fasciitis.

The designers of the Masai Barefoot Technology shoe (MBT) have further developed the idea that footwear can have multiple effects on foot health and pathology. Based on observations of the Masai tribe who are not accustomed to wearing shoes, the MBT shoe is designed to recreate a natural uneven walking surface to reduce problems caused by today's rigid soled shoes and hard ground. Amongst many other predicted benefits, the makers of MBT shoes claim that the shoe design with an unstable rounded sole (Fig. 1) distributes plantar pressure more equally and reduces the concentration of pressure on the heels.

If these effects on pressure are found to be true, MBT shoes may offer an additional form of conservative management for a number of foot and lower limb pathologies. The aim of this study therefore, was to systematically assess the effect of the MBT shoe on plantar pressure.

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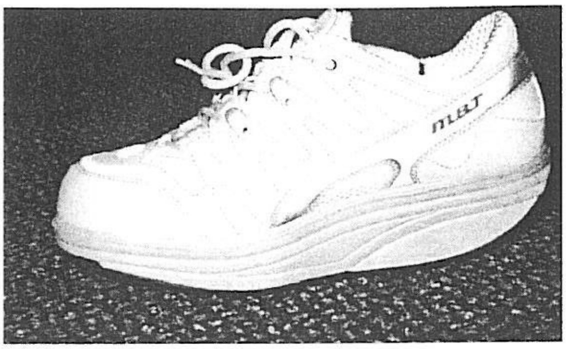

Fig. 1. MBT shoe. Note the curved sole in anterior–posterior direction.

2. Methods

2.1. Subjects

Four male and six female university students (mean age 24, range 21–39) were recruited. All of the participants were asymptomatic and had no history of foot pain or deformity. Shoe sizes ranged from 29–47 (UK 5–11).

2.2. Materials

All the participants were fitted with MBT shoes (Fig. 1) in the correct size by an experienced shoe fitter from the manufacturing company. As a control, the participants wore their own flat-bottomed sports shoe. The plantar pressure measurements were made with the PEDAR-x system (Novel Electronics, Germany). The system consists of pressure sensing insoles connected to a box which attaches around the subjects waist and transmits information to the PEDAR-x software via Bluetooth® wireless communication. The 2.5 mm width insoles contain 99 capacitive pressure sensors that produce a grid representing pressure distribution on a laptop screen. The sensors are sampled at a rate of 50 Hz.

2.3. Procedure

Prior to the experiment, the participants were gathered together with the instructor from the MBT academy who led them through a short program of dynamic stability training exercises. Only once the participants had become accustomed to the shoes, and were walking 'normally' were they taken for assessment.

The electronic insoles were fitted and calibrated in compliance with the manufacturer's guidelines. Subjects were then instructed to walk up and down the walkway in their training shoes to familiarise themselves with their surroundings and to ensure the equipment was not restrictive. The walkway was a level, consistent surface, and walking pace was whatever was comfortable for the subject to best mimic natural gait. Data were collected during three testing cycles on the walkway, then as each subject stood still on both feet for 30 s. The entire procedure was then repeated with the MBT shoes.

Table 1
Measured values for peak pressures (kPa)

Shoe	Motion	N	Minimum	Maximum	Mean	Standard deviation
Control	Walking					
	Toes	30	182.50	587.50	307.00	104.88
	Forefoot	30	212.50	420.00	296.17	59.94
	Midfoot	30	102.50	275.00	173.25	43.85
	Hindfoot	30	122.50	330.00	204.60	52.13
	Valid N	30				
MBT	Walking					
	Toes	30	202.50	617.50	327.58	95.90
	Forefoot	30	175.00	400.00	288.08	65.85
	Midfoot	30	112.50	225.00	168.40	28.76
	Hindfoot	30	130.00	307.50	208.17	44.69
	Valid N	30				
Control	Standing					
	Toes	10	0.00	87.50	42.25	25.04
	Forefoot	10	30.00	137.50	70.75	38.19
	Midfoot	10	50.00	135.00	86.25	29.35
	Hindfoot	10	60.00	262.50	129.50	61.59
	Valid N	10				
MBT	Standing					
	Toes	10	37.50	115.00	74.25	23.84
	Forefoot	10	45.00	155.00	88.75	31.34
	Midfoot	10	42.50	95.00	67.75	18.50
	Hindfoot	10	75.00	192.50	115.50	31.79
	Valid N	10				

2.4. Analyses

The acceleration and deceleration steps were excluded from analyses. Using the PEDAR software, the area of the insoles was divided up into four sections by creating "masks" that grouped sensors into anatomical areas: toes, forefoot, midfoot, and heel.

For each mask, mean pressure (kPa); average pressure over all the frames, and peak pressure (kPa); the maximum pressure that occurred in one sensor over the selected frames, were computed. The total contact area (cm^2) and the area of all loaded sensors over the insole, were also recorded. The measurements for the left and right foot were averaged together. Mean values, standard deviations and scatter-plot representations were calculated using SPSS (version 11.5) software.

3. Results

MBT shoes decreased peak pressures in the forefoot and midfoot when walking, and in the midfoot and hindfoot when standing (Table 1). Peak pressure was raised under the toes in MBT shoes when both standing and walking. The most dramatic difference was during standing, where the MBT shoes increased peak pressure under the toes by 76%, and lowered peak pressure in the midfoot and heels by 21% and 11%, respectively. Table 2 shows the results for mean

Table 2
Measured values for mean pressure (kPa) walking

Shoe	Motion	N	Minimum	Maximum	Mean	Standard deviation
Control	Walking					
	Toes	30	26.65	60.24	42.97	10.80
	Forefoot	30	41.37	73.24	56.92	8.96
	Midfoot	30	13.77	36.49	25.48	5.70
	Hindfoot	30	44.42	102.03	71.06	14.08
	Valid *N*	30				
MBT	Walking					
	Toes	30	27.57	98.30	49.93	15.05
	Forefoot	30	38.69	70.43	56.99	9.15
	Midfoot	30	11.06	32.12	21.57	5.78
	Hindfoot	30	44.47	97.54	68.23	13.96
	Valid *N*	30				
Control	Standing					
	Toes	10	0.00	20.00	5.99	6.07
	Forefoot	10	2.60	30.78	17.91	10.95
	Midfoot	10	6.07	50.00	20.03	12.37
	Hindfoot	10	31.58	95.90	62.92	20.18
	Valid *N*	10				
MBT	Standing					
	Toes	10	6.09	28.87	11.08	6.73
	Forefoot	10	6.29	36.57	26.54	8.54
	Midfoot	10	4.96	19.14	11.31	5.63
	Hindfoot	10	35.25	101.21	60.02	17.10
	Valid *N*	10				

pressure measurements. The MBT shoe decreased the mean pressure in the midfoot and hindfoot regions when both standing and walking. Again, there was a big increase in the pressure reading for the toes when the subjects were standing in the MBT shoes, with a mean pressure increase of 83%. The biggest decrease in pressure in MBT shoes was in the midfoot, with a reduction of 44% when standing and 15% when walking.

The area bearing the weight of the person standing was increased by 11.9% (from 81.7 cm^2 to 91.4 cm^2) in MBT shoes compared to the control. However, there was no difference (0.02 cm^2) in loaded area between the MBT and control shoe when walking. The most consistent finding, when both standing and walking, was a lesser pressure under the midfoot when the subjects wore their MBT shoes.

4. Discussion

This study has revealed significant differences between the plantar pressure patterns found in normal subjects wearing MBT shoes compared to those found when they were wearing training shoes. Decreases in plantar pressure were found in the posterior half of the foot, and increases under the forefoot and toes. These findings are almost directly opposite to the results of studies involving rocker-bottomed shoes [3,4,6] where pressure is found to be decreased under the toes and forefoot and increased under the midfoot and heel.

Table 3
Contact area (cm^2)

Motion	N	Minimum	Maximum	Mean	Standard deviation
Standing					
Control shoe	20	33.77	128.95	81.68	23.87
MBT shoe	20	70.50	114.85	91.40	13.62
Valid *N*	20				
Walking					
Control shoe	20	106.65	178.97	143.38	21.43
MBT shoe	20	107.05	183.42	143.36	22.38
Valid *N*	20				

The MBT shoe results had more in common with those obtained by studies on high-heeled shoes [5,7]. Nyska et al. [8], and Broch et al. [5], found that the pressure under the calcaneus decreases as heel height increases and there is forward shift of weight. A similar front-loading pattern is found in studies on barefoot plantar pressure [7].

A high-heel however, tends to load the medial side of the foot more [8] while bare feet distribute the pressure more evenly across the metatarsals [7]. Compared to bare feet or flat shoes, the contact area is also reduced in high-heels [7,8]. According to Nicolopoulos et al. [9], the average contact area of the foot when standing barefoot is 100 cm^2. This study found lower values than this in both types of shoes tested (Table 3), but the MBT produced the larger one, closest to the barefoot value. The pattern of load bearing in MBT shoes therefore does appear to more closely resemble bare foot loading (Fig. 2).

The forward shift of pressure in an MBT shoe is clearly due to the sloping design of the shoe base displacing the weight away from the heel. Lundeen et al. [10] found that pressure is decreased in the heels when walking downstairs because of the position of the foot and the fact that the heel only makes contact with the ground for a short period of time. In a similar way, the curve away from the heel in the MBT sole means that the rear foot is only briefly in contact with the surface.

The forefoot has a greater surface area than the heel and so weight redistribution onto this area may explain why the

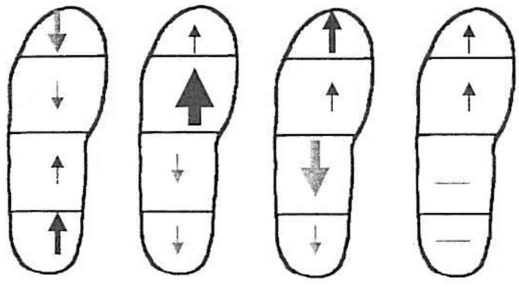

Fig. 2. Schematic representation of pressure distribution characteristics in different shoe types compared to flat-soled trainers. The size of the arrows represents the extent of the difference in pressure.