Original Article

Plantar pressure measurements of foot in Greek adult colleagues of a technological institute

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Abstract:

Problem Statement and Purpose: The current study was designed to determine the plantar pressure values and norms in feet of healthy Greek colleagues of a technological institute and to examine possible correlations between demographic data and potential foot disorders as a result of gait strategy.

Approach: 300 adults colleagues (150 women, 150men; mean age 21 years) who were found to have healthy foot according to the AOFAS (American Orthopaedic Foot and Ankle Society) clinical rating system for the ankle and foot participated in the study. Mean and maximal plantar pressures in three areas of tarsometatarsal joint were recorded during gait using a Mini-Emed pedobarographic equipment.

Results: The mean and maximal pressures recorded in the middle range of the mid-stance phase of the gait cycle were higher compared to other two regions (medial/lateral). Footprints also revealed four different patterns of pressure with this of middle-foot type presenting the highest frequency. Body mass index (BMI) was correlated only with the pressures generated in the push-off phase of gait cycle. Lastly, pressure distribution patterns did not differ between the two sexes.

Conclusions: The current research revealed that plantar pressure, of a relatively large sample (300 individuals), occurs at a high percentage in the middle region of foot among the other three regions. This finding could be used when assessing foot disorders and could help to modify the proper footwear of an individual.

Key words: pedobarography, pressure, gait, treadmill.

Introduction

Plantar pressure has been extensively examined mostly during adult walking (Alexander, Chao, & Johnson, 1990; Bennett & Duplock, 1993; Cavanagh, 1995; Duckworth, Betts, Franks, & Burke, 1982; Kanatli et al., 2008; Soames, 1985; Tuna, Yildiz, Celtik, & Kokino, 2004). These measurements of plantar pressure provide information about biomechanics of foot, ankle function during gait and indication of potential musculoskeletal and neurological disorders. The pressure distribution underneath the foot is affected by several factors such as the anatomical structure of the foot, body mass, gender and joint range of motion (Bennett & Duplock, 1993; Kellis, 2001).

Among the potential musculoskeletal disorders, metatarsalgia is a common disorder, which mainly rises as a result of repeated loadings of metatarsal heads (Golano, Viladot, Alvarez, Coughlin, & Grimes, 2006; Kanatli et al., 2008; Stokes, Stott, & Hutton, 1974; Viladot, 1973). Due to recent advancement in technology, assessment of plantar pressure and load distribution as well as different patterns of gait will provide useful informative data when managing strategies of various foot problems. (Alexander et al., 1990; Golano et al., 2006; Kanatli et al., 2008; Kellis, 2001; Luger, Nissan, Karpf, Steinberg, & Dekel, 1999; Tuna et al., 2004). The only relevant study in this field enrolled small sample and consequently could not generalize its conclusions. (Kanatli et al., 2008).

Therefore, the purpose of the current study was to examine the weight distribution pattern under the metatarsal heads and to recognize potential foot disorders among the different patterns of walking in a relatively large sample of participants.

Material & methods

Participants

300 adults (150 women- 150 men), all active colleagues from the Technological Educational Institute of Central Macedonia, participated in this 3-month study. Their mean age was 21 years old. The BMI (kg/m²) was calculated for all participants. Both feet of all participants were examined. In order to classify the foot as healthy

or not, a clinic assessment system which was developed by AOFAS was used for ankle and foot (Kitaoka et al., 1994).

Procedure-Equipment

The distribution of plantar pressure under the bare feet was measured dynamically in all participants. The EMED-SF device (Novel GmbH, Munich, Germany. 44.4 x 22.5 cm effective area, two sensors/cm² with a sampling rate at 71Hz.) was enrolled. Participants were asked to walk at their normal walking speed and touch the platform (bilateral). The average value of three successful gait cycles was then evaluated. The distribution of foot was done according to a previous relevant research by using Novel Ortho software (Kanatli et al., 2008). Particularly, the footprint was divided into seven areas. The tarsometatarsal articulation consists of three functional units or columns. For the evaluation of the pressure distribution of the forefoot, the footprint obtained from EMED system was divided into three areas as functional columns of the tarsometatarsal joint. These were the first metatarsal head, second and third metatarsal heads, fourth and fifth metatarsal heads. The other areas of examination were the heel, the mid-foot, first toe and the lesser toes. Mean and maximal pressures for each area were recorded and calculated at mid-stance and push-off phase of the gait cycle where mean pressure is the sum of forces, of all sensors in an area, divided by the contact area and maximal pressure depicts the value of a sensor with the maximum pressure, in the selected area. (Kanatli et al., 2008). For the purposes of the current paper, only one foot (left) was evaluated for further analysis.

Statistical analysis

The mean and standard deviations were obtained for all measures. Pearson correlation coefficient was used to compare the BMI and pressure distribution of the units of the forefoot. The difference between the pressure distributions of the units was estimated by applying a two-sided t-test. Correlation of the maximal pressures of the forefoot and BMI was also examined. Statistical calculations were performed with SPSS 15.0.

Results

The demographic characteristics of sex, age, height, weight and BMI averages are presented in Table 1.

All the results of mean and standard deviations of forefoot's maximum and mean pressures at mid-stance and push-off phases of the gait cycle are presented below in Table 2.

The maximal pressures of middle region presented the higher values compared to medial and lateral ones at both examined phases of gait cycle ($p < 0.05$). The same was true for mean pressures in both phases but without statistical significance. Medial and lateral region did not differ at both examined gait phases ($p > 0.05$). However there was a trend for higher values only for push-off phase when comparing medial and lateral region.

The mean BMI of all participants was 23.5 and this value classified them as normal ones. Correlation analysis between BMI and plantar pressure distribution depicted that BMI was correlated with maximal pressure values of each region and only in push-off phase [$p < 0.05$ (Table 3)].

Lastly, in table 4, are presented the four categories according to the pressure of foot in stance phase. In general, the majority of participants adopted a middle-stance type of foot pressure at which the metatarsal accepts most of the loading.

Table 1. Descriptive statistics (mean $\pm$ SD) of study population

Group	Age (years)	Mass (kg)	Height (m)	BMI (kg/m ²)
Men (n=150)	21.5 $\pm$ 4.4	75.4 $\pm$ 7.4	1.78 $\pm$ 0.9	22.9 $\pm$ 4.8
Women (n=150)	20.5 $\pm$ 3.3	54.8 $\pm$ 8.8*	1.65 $\pm$ 0.8	25.4 $\pm$ 3.0*

Data are given as mean (SD)

*Significant differences between groups ($p \leq 0.05$)

Table 2. Mean and maximal pressures under the metatarsal heads of the feet at mid-stance and push-off phases of the gait cycle

	Stance Phase		<i>p</i>	Push-off Phase		<i>p</i>
	Mean Pressure	Maximal Pressure		Mean Pressure	Maximal Pressure	
Medial Region	5.45 $\pm$ 2.1	10.84 $\pm$ 6.6		11.09 $\pm$ 4.9	28.8 $\pm$ 7.0	
Middle Region	6.95 $\pm$ 2.5	12.78 $\pm$ 4.6		18.45 $\pm$ 6.5	33.9 $\pm$ 12.4	< 0.05
Lateral Region	5.96 $\pm$ 1.8	10.11 $\pm$ 3.8		7.98 $\pm$ 2.1	24.5 $\pm$ 8.1	

Data are given as mean (SD)

*Significant differences between groups are red-highlighted ($p \leq 0.05$)

Table 3. Correlation between BMI and forefoot maximal pressure of the feet at mid-stance and push-off phases of the gait cycle (*p*)

Mid-Stance Phase	Push-off Phase
0.688	0.007
0.731	0.01
0.596	0.05

Table 4. Pressure distribution patterns of foot expressed as percentage

Middle-foot	66.5%
Medial-foot	15.6%
Lateral-foot	14.8%
Transverse arch-foot	3.1%

Discussion

When recording normal patterns of plantar pressure distributions under metatarsals heads, this would be beneficial to examine various other foot conditions. (Barnett, Bowden, & Napier, 1956; Kanatli et al., 2008; Soames, 1985; Stokes et al., 1974; Viladot, 1973; Yamamoto, Muneta, Asahina, & Furuya, 1996). This would be proper in order to prevent an individual from a foot disorder.

Plantar pressure under metatarsal heads is believed to be among the most controversial but in the meanwhile interesting topics of orthopaedics and researchers (Barnett et al., 1956; Kanatli et al., 2008; Luger et al., 1999; Soames, 1985; Tuna et al., 2004). The main issue of controversial of the above mentioned studies is which region of the foot carries the most load during gait and how would be the ideal foot according to loading values. The present results revealed that middle region accept the higher pressures both at mid-stance and push-off phases compared to other two regions (medial/lateral) and this finding comes in accordance with relevant studies and in fact reveals the absence of transverse metatarsal archn (Hughes, 1993; Hughes, Clark, Linge, & Klennerman, 1993; Kanatli et al., 2008). The highest percentage of foot-type was found in middle-stance pressure type (66.5%) and this reinforce previous studies (Duckworth et al., 1982; Hughes et al., 1993; Kanatli et al., 2008; Soames, 1985; Stokes et al., 1974). This occasion is the more frequent among others and does not denote an abnormal foot or serious pathology. Lastly, one interesting point that is revealed in our participants is that they adopted different pressures due to the phase of gait cycle. They presented the highest values of load during push-off phase rather than in mid-stance. In fact, there was found a strong correlation between high pressure values over the three regions of under-foot and BMI. This probable occurred as foot in this timing of gait (push-off phase) reacts as a lever arm and transfers the total load to the ground (Kanatli et al., 2008).

Conclusions

One of the proposals of our research to the population which participated and overall to healthy individuals, is to examine a potential foot disorder to themselves such as metatarsalgia, as all the findings support the rising of this mechanical problem with chronic complications. Probably, future anthropometric and biomechanical studies on lower extremity will shed more light on understanding the rationale of foot loading under metatarsal heads in order to prevent from potential foot disorders.

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Conflicts of interest - There are no conflicts of interest

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