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The relationship between foot pain, anthropometric variables and footwear among older people

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ABSTRACT

Objective: To verify the prevalence of pain among older people when wearing shoes, and the relationships between foot pain, high-heeled shoes and anthropometric variables.

Method: Both feet of 227 older women and 172 older men were evaluated with respect to anthropometric variables, arch index and foot posture index. The participants were also asked about the presence of foot pain while wearing high-heeled shoes. The data were analyzed using the Chi-square test, Pearson's correlation, MANOVA, multiple regression analysis, *t* test, and analysis of probability.

Findings: The prevalence of foot pain when wearing shoes was high and was associated with the female gender, however wearing high-heeled shoes was not associated with pain. The women with foot pain presented larger values for the circumferences of the metatarsal heads and the instep (after normalization with the foot length) than those without pain. The men with pain did not present different measurements from those without pain.

1. Introduction

The functional limitations from which older people suffer may be the result of foot problems. Munro and Steele (1998) and Menz and Lord (2001) identified a high prevalence of foot problems (71 and 87% respectively) among older adults, and in both cases, this was more common in women. Older women were more prone to halux valgus and plantar callus, which frequently lead to chronic painful conditions (Menz and Stephen, 2001; Menz et al., 2007).

Dhaliwal et al. (2003) reported that, in their study on 1486 older people of both genders, 34% had foot pain while Menz et al. (2006) reported that 36% of older people have debilitating foot pain. In older adults, foot pain is associated with changes in gait and balance, decreased mobility, low quality of life, and increased difficulty in activities of daily living, especially among the oldest of the older adults (Benvenuti et al., 1995; Menz and Stephen, 2001; Dhaliwal et al., 2003; Thomas et al., 2004; Keysor et al., 2005).

Footwear can also be a source of pain. With age, the width and height of the forefoot increases to a greater extent than the width and height of the hind foot, making it difficult to find appropriate shoes (Frey et al., 1995). Especially in old age, wearing inadequate shoes limits mobility and consequently impairs health, independence and quality of life (Finlay, 1995). It seems prudent that older women avoid wearing high-heeled shoes, which reduces the support base and consequently changes the weight distribution on the plantar surface of the foot, overloading the metatarsophalangeal joints and impairing balance (Tencer et al., 2004). This type of footwear may also be associated with pain because it is ineffective in the absorption of impact (Yung-Hui and Wei-Hsien, 2005) and favors esthetics to the detriment of comfort.

Corso (1998) reported that pain tolerance increases with age, which may lead to wearing tight shoes and consequent formation of calluses and foot deformities. Although many authors have found high percentages of older people wearing ill-fitting shoes (Frey et al., 1993; Burns et al., 2002; Menz and Morris, 2005), there is a lack of studies investigating the presence of pain felt when wearing shoes.

Another issue related to foot pain in older people is the extent to which changes in the anthropometric characteristics of the feet might be associated with the presence of pain. It has already been reported that flat feet and cavus feet are related to pain (Benvenuti et al., 1995; Burns et al., 2005; Badlissi et al., 2005; Staller and Tullis, 2005), however there is a need for studies investigating whether width, circumference and height may also influence foot biomechanics and shoe fit, and consequent pain.

Considering these issues, this study aimed to verify the prevalence of pain among older people when wearing shoes, and the

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relationships between foot pain, high-heeled shoes and anthropometric variables.

2. Methods

Individuals aged 60 years and over, of both genders, resident in the city of São Carlos, São Paulo, Brazil, were included in this study. Exclusion criteria were amputation of any part of the lower limbs or the use of bandages or orthoses that would prevent direct contact of the instruments with the skin. The sample was determined according to the age and gender ratios of the older population of São Carlos. Thus the sample was intentionally composed of 227 older women with a mean age of 69.6 ± 6.8 years, and 172 older men with a mean age of 69.4 ± 6.7 years. The participants were not chosen at random but according to convenience, therefore they were selected from data collection sites which were more accessible to the researchers. Data were collected at the Open University for Senior Citizens, the Health Care Unit of Universidade Federal de São Carlos and two basic health units in the city of São Carlos. Researchers were given access to the patients' registration files at each site, and called the participants for an interview.

The evaluation was carried out by two assessors in a consultation room. The participants received information about the study and signed a consent form. The present study was approved by the Ethics Committee of Universidade Federal de São Carlos, São Paulo, Brazil (approval report number 241/2006).

Firstly, the participants were asked about the presence of foot pain, pain while wearing shoes and the habit, among women, of wearing high-heeled shoes (higher than 4 cm). The full questionnaire is shown in Appendix.

The anthropometric variables studied were: foot length, width, circumference and height as described by Manfio (2001). We also assessed the first and fifth metatarsophalangeal angles, the foot arch and the foot posture. The foot arch was assessed by using the arch index (AI) as described by Cavanagh and Rodgers (1987) and the foot posture was assessed by the foot posture index (FPI) described by Redmond et al. (2006). The same assessor took all the measurements with the participant in the standing position, with equal weight distribution on both legs.

Foot length and width (of toes and metatarsal heads) were measured using a 30-cm analog caliper with 1 mm resolution. Foot length is the distance between the most prominent point in the calcaneal tuberosity region and the tip of the longest toe, along the longitudinal axis of the foot (heel–second toe). The width of the toes is the distance between the most prominent part in the medial region of the tuberosity of the distal phalange of the first toe, and the most prominent lateral region of the middle phalange of the fifth toe. The width of the metatarsal heads is the distance from the most prominent point of the medial region of the tuberosity of the first metatarsal head to the most prominent point in the lateral region of the tuberosity of the fifth metatarsal head.

The circumferences of the toes, metatarsal heads and the instep were measured by using a fiberglass tape measure with a 1-mm resolution. The circumference of the toes is the circumference of the vertical section of the foot, in a line passing through the most prominent part of the medial region of the tuberosity of the distal phalange in the first toe, and through the most prominent lateral region of the middle phalange of the fifth toe. The circumference of the metatarsal heads is the circumference of the vertical section of the foot represented by a line passing through the most prominent part of the region of the tuberosity of the first and fifth metatarsal heads. The circumference of the instep is the circumference of the vertical section of the foot in the most prominent region of the navicular bone.

The heights were measured using a portable analog height rod with a 1-mm resolution, including the heights of the first toe, the first metatarsal head and the foot curvature. The height of the first toe is the vertical distance from the floor to the upper region of the base of the distal phalange of the first toe. The height of the first metatarsal head is the vertical distance from the floor to the upper region of the first metatarsal head. The height of the foot curvature is the vertical distance from the floor to the median point of the upper region of the metatarsal body.

The joint angles were measured using a toe goniometer with a resolution of 1°. As proposed by Norkin and White (1995), the goniometer was placed on the dorsal face of the foot with its fulcrum centered on the metatarsophalangeal joint. The proximal arm of the instrument was aligned with the first metatarsus, and the distal arm with the medial line of the proximal phalange. The degrees were considered to be positive when there was valgus deviation of the first toe or varus deviation of the fifth, and to be negative when there was varus deviation of the first toe and valgus deviation of the fifth.

Footprints of both feet were then taken using a pedograph for the AI assessment. The participants were instructed to place one foot beside the pedograph and the other one on it, distributing the body weight equally on both legs. They were also instructed to remove the foot that was on the pedograph first, so as to guarantee that the full weight of the body was never on the foot being evaluated. The same procedure was repeated with the other foot.

The footprints were scanned and converted to images, which were then redrawn in AutoCAD 2005. The plantar area, with the exception of the toe area, was divided into three equal parts along the longitudinal axis of the foot, and the AI was calculated as the ratio of the area of the middle one-third of the footprint to the entire area. As suggested by Cavanagh and Rodgers (1987), an AI equal to or less than 0.21 indicates a high arch, an AI between 0.21 and 0.26 indicates a normal arch, and an AI equal to or greater than 0.26 indicates a flat or low arch. To verify the reliability of the AI calculation, the designer calculated the indexes of the right feet of 30 participants three times, and the measurement error test suggested by Bland and Altman (1996) was performed. The differences between the three attempts for each subject were less than the recommended limit for the test (repeatability $= 0.122$), indicating that it was safe to calculate the index of each footprint only once.

The participants remained upright while the postural assessment of the foot was carried out using the FPI described by Redmond et al. (2006). This index is calculated by adding up the scores in six assessment criteria: talar head palpation, supra and infra malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch and abduction/adduction of the forefoot on the rearfoot. Each criterion was scored using whole numbers from -2 to $+2$, and therefore the total score could range from -12 (indicating maximal supination) to $+12$ (indicating maximal pronation). All measurements were taken by the same assessor. A study has demonstrated good internal construct validity and fit of the FPI to the Rasch model, a useful statistical model of the uni-dimensionality (capacity to measure a single construct) and scale stability (or linearity across a range of values) of a measure (Keenan et al., 2007). They conclude that FPI is suitable for a range of clinical applications and yields high quality linear metric data. Thus, although this scoring system is not a continuous variable, it has the potential to be analyzed using parametric strategies.

Statistical analyses were performed with software from Minitab Data Analysis version 14 (Minitab Inc, State College, PA). The data were analyzed considering a significance level of 5% and using the Chi-square test, Pearson's correlation, MANOVA, multiple regression analysis, *t* test, and analysis of probability. The latter was used when there were great differences in the number of participants between the groups. In this test, means of samples drawn from the larger population were compared with the mean of the smaller population. Thus 100 samples from the larger population were chosen at random, each with the same number of participants as the smaller group. The means of the 100 samples and the mean of the smaller group were ranked. When the position occupied by the mean of the smaller group was among the five greatest ranked means or among the five smallest means, the probability of making an error in affirming that the means of the two groups were different (type I error) was less than or equal to 5% ($p \leq 0.05$) (Fisher and Van Belle, 1993).

3. Results

The presence of foot pain was reported by 115 women (50.7%) and 52 men (30.2%). With respect to pain when wearing shoes, the complaints were more frequent in the female group; at least one painful region of the foot was registered for 60.8% of this group. In the male group, only 29.6% had the same complaint. Fig. 1 shows the percentage of complaints in various regions of the foot when wearing shoes for both groups. The toes were the most affected part, followed by the metatarsophalangeal joints and the sole of the foot.

The Chi-square test, used to verify associations between gender and pain (Table 1), showed that women were more prone to pain. More specifically, significant associations were found regarding foot pain and when wearing shoes, pain in the toes, metatarsophalangeal joints, sole of the foot and heel.

One-hundred and twenty older women (52.9%) said they did not wear shoes with heels higher than 4 cm. Fifty (22.0%) rarely wore high-heeled shoes, 33 (14.5%) wore them once a week and 24 (10.6%) wore them twice a week or more. The Chi-square test was also performed in order to determine whether the presence of pain was related to the use of high-heeled shoes at least twice a week in the female group, and the results showed that there was no such relationship ($p = 0.351$).

Some of the studied anthropometric variables are dependent on foot length and should be adjusted before comparing individuals with different foot sizes. In order to identify these variables, Pearson's correlation was performed (Table 2), and it provided evidence of moderate positive correlations between foot length, widths and circumferences; and low positive correlations between foot length and height. The angles, the AI and the FPI showed no significant correlation with foot length. Thus, for the comparisons between groups, the width, circumference and height variables were substituted by variable K, described by Chouquet-Stringer and Bernard (1972) as being the value of the measurement multiplied by 100 and divided by the foot length.

When performing MANOVA in the comparison between data of the left and right feet, and analyzing the matrix of partial correlations for error, we found high positive partial correlations ($r \geq 0.6$) between the measurements of the right and left feet for all variables in both groups, except for the height of the first toe ($r = 0.56$ in the women and 0.45 in the men) and the first metatarsal head ($r = 0.57$ in the women and 0.54 in the men), which presented moderate positive correlations. Therefore, a random choice between the data of the right and the left feet was made, and the second one was selected.

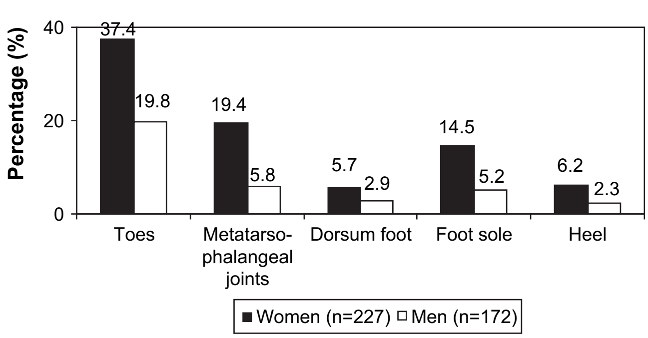

Fig. 1. Percentage of complaints in various parts of the foot when wearing shoes.

Table 1
The Chi-square test, used to verify associations between gender and pain.

	Women (%)	Men (%)	Chi-square	p-value
Foot pain	50.7	30.2	16.780	<0.001[a]
Pain when wearing shoes	60.8	29.7	38.066	<0.001[a]
In the toes	37.4	19.8	14.610	<0.001[a]
In the metatarsophalangeal joints	19.4	5.8	15.397	<0.001[a]
In the dorsum	5.7	2.9	1.806	0.179
In the foot sole	14.5	5.2	8.996	0.003[a]
In the heel	10.1	4.7	5.221	0.022[a]

[a] Association between pain and the female gender.

It was also possible to observe some high positive partial correlations among nine of the measurements in the male group and eight in the female group. The smaller F value (one-way ANOVA in the comparison between individuals with and without foot pain) and smaller effect exerted by the variable "foot pain", according to the multiple regression analysis, were considered as decision criteria for the exclusion of variables. Thus, in the male group the circumferences of the toes and of the metatarsal heads were excluded, and in the female group, the width of the metatarsal heads was excluded.

The differences between the group of women with foot pain and the group of women without pain, with respect to the anthropometric variables, were thus analyzed by a two sample t test, and the results can be seen in Table 3. The values for the following measurements were significantly larger in the women with foot pain than in those without pain: circumferences of the metatarsal heads and of the instep and the height of the first toe (in proportion to foot length).

Table 2
Pearson's correlation between foot length and the other anthropometric variables.

		Correlation coefficient	
		Women	Men
Width of the toes	L	0.586*	0.515*
	R	0.461*	0.489*
Width of the metatarsal heads	L	0.504*	0.604*
	R	0.544*	0.585*
Circumference of the toes	L	0.426*	0.521*
	R	0.385*	0.494*
Circumference of the metatarsal heads	L	0.507*	0.610*
	R	0.555*	0.613*
Circumference of the instep	L	0.511*	0.625*
	R	0.506*	0.587*
First metatarsophalangeal angle	L	−0.186*	−0.041
	R	−0.069	−0.022
Fifth metatarsophalangeal angle	L	−0.075	−0.011
	R	0.056	−0.001
Height of the first toe	L	0.103	0.147
	R	0.135*	0.285*
Height of the first metatarsal head	L	0.317*	0.402*
	R	0.263*	0.368*
Height of the curvature of the foot	L	0.281*	0.176*
	R	0.222*	0.314*
Foot posture index	L	0.070	0.090
	R	0.081	0.071
Arch index	L	−0.139*	0.101
	R	−0.088	0.032

L, left; R, right.
* p-value ≤ 0.05.

Table 3
Means and standard deviation of the anthropometric variables of the left foot in the group of women with foot pain and the group of women without pain and *p*-value of the two sample *t* test.

	Without foot pain ($n = 112$)	With foot pain ($n = 115$)	*p*-value
K width of the toes	40.30 (±2.02)	40.76 (±2.23)	0.053
K circumference of the toes	91.27 (±6.64)	91.21 (±4.96)	0.468
K circumference of the metatarsal heads	98.27 (±4.42)	99.39 (±5.55)	0.048
K circumference of the instep	97.26 (±5.03)	98.51 (±4.87)	0.029
First metatarsophalangeal angle	14.43 (±8.40)	13.30 (±8.03)	0.152
Fifth metatarsophalangeal angle	10.10 (±6.15)	9.25 (±5.22)	0.133
K height of the first toe	8.38 (±1.30)	8.80 (±1.27)	0.007
K height of the first metatarsal head	12.76 (±1.32)	12.99 (±1.40)	0.101
K height of the foot curvature	17.60 (±1.92)	17.95 (±1.84)	0.085
Foot posture index (FPI)	1.16 (±2.32)	1.34 (±2.24)	0.278

K, value of the measurement multiplied by 100 and divided by the foot length.

The mean differences between men with and without foot pain were verified by analysis of probability (Table 4). None of the variables of the men with foot pain had greater mean values than those of the men without foot pain. According to the Chi-square test, there was no association between the type of foot (normal, pes planus or pes cavus) and the presence of pain, in either the female group ($p = 0.231$) or the male group ($p = 0.773$).

4. Discussion

A survey with 7878 people aged 50 years or more revealed that women were more prone to pain in at least one part of the body than men (Thomas et al., 2004), and in the present study the presence of foot pain and pain when wearing shoes was correlated with the female gender. These findings agree with the results of one of the few epidemiological studies on the incidence of foot pain among older people, which showed that women were twice as likely to present foot pain as men (Benvenuti et al., 1995). Trials using somatic stimuli indicated that women presented lower pain thresholds for noxious stimuli than men (Berkley, 1997). Moreover, females also had more foot problems (Munro and Steele, 1998; Menz and Lord, 2001).

In the study of Manfio (2001) with young adults, men also reported fewer points of pain in the feet when wearing shoes than women. This can be explained by the esthetic standard of pointed toes generally adopted for women's footwear. Thus male shoes can be considered less harmful to foot health (Frey, 2000). However, a qualitative study conducted with women revealed that there were no differences between shoes considered "comfortable" by the subjects and those considered "uncomfortable", with respect to the esthetic characteristics (Au and Goonetilleke, 2007). They found a significant impact on the fit preferences in the toe area, metatarsophalangeal area, arch area and opening of the shoe, which coincided with the most often reported points of pain when wearing shoes: the toes, the metatarsophalangeals joints and the dorsum foot.

In Brazil, there is yet another aggravating factor. It was not until 2001 that the national shoe industry had access to the characterization of the feet of Brazilian adults, which did not fit the foreign shoe molds formerly used by manufacturers. This information was obtained from a study on the anthropometric variables of the feet of young adults (Manfio, 2001). Thus, the shoes available on the market are still not suitable for the feet of older adults, causing difficulty in finding comfortable shoes and eventually harming foot health.

The majority of the female sample (52.9%) stated that they did not wear high-heeled shoes. In a study with 1298 women with a mean age of 28.6 ± 9.0 years, only 21.7% of the sample did not wear high-heeled shoes (Manfio, 2001). Another study, carried out with 152 young women (26.2 ± 7.0 years), verified that 55.2% of the interviewees wore high-heeled shoes more than three times a week (Santos et al., 2007).

Older women seem to be less inclined to wear high-heeled shoes because of the discomfort or lack of stability. Although wearing this kind of shoe presented no association with the presence of pain in the present study, Manfio (1995) verified that 71.8% of women feel some kind of foot pain when wearing high-heeled shoes, and in the study of Santos et al. (2007), this percentage was 66.4%. It is possible that in the present study, the low percentage of women who wore high-heeled shoes at least twice a week (10.6%) limited the statistical analysis of the data, which was therefore unable to reveal the real influence of this kind of shoe on foot pain. The high heel generally decreases the support base, restricting the lateral stability of the shoe and upsetting the orthostatic balance and the dynamic balance (Tencer et al., 2004). In older people, this is aggravated by the fact that the vestibular, visual and proprioceptive systems suffer the effects of senescence. Adrian et al. (1990) evaluated the balance of women on a force platform and verified that, when wearing high-heeled shoes, they performed more poorly, especially those aged over 80. In a control case study with a group of 1371 older people, correlation was shown between the use of high-heeled shoes and risk of falls (Tencer et al., 2004).

Women with foot pain showed greater values for the circumferences of the metatarsal heads and of the instep (after normalization for foot length) than those without foot pain. In this study, foot edema was not assessed as it was not the objective of the study, however this is a condition which may explain the greater values found in older women with pain.

With respect to the men, there were no differences between the measurements of the men with foot pain and those without foot pain. The male group's anthropometry may not be among the determining factors of foot pain, as occurs in the female group.

Table 4
Means and standard deviation of the anthropometric variables of the left foot in the group of men with foot pain and the group of men without pain and *p*-value of the analysis of probability.

	Without foot pain ($n = 120$)		With foot pain ($n = 52$)		*p*-value
	Mean	SD	Mean	SD	
K width of the toes	39.2	2.4	39.4	2.2	0.47
K width of the metatarsal heads	40.3	2.3	40.4	1.8	0.38
K circumference of the instep	98.6	4.6	98.5	4.6	0.44
First metatarsophalangeal angle	11.5	6.6	12.4	7.5	0.07
Fifth metatarsophalangeal angle	8.3	4.5	8.8	5.4	0.08
K height of the first toe	8.7	1.2	8.8	1.0	0.34
K height of the first metatarsal head	13.3	1.1	13.1	1.1	0.09
K height of the foot curvature	18.8	1.9	19.0	2.3	0.13
Foot posture index (FPI)	1.0	2.4	0.7	2.0	0.16

K, value of the measurement multiplied by 100 and divided by the foot length; SD, standard deviation.

Other factors, such as foot problems, which were not examined in this study, may have a greater influence on the painful condition.

As for the foot posture assessed with the AI and the FPI, there were no differences between individuals with and without pain. However, it is still unclear whether these differences do not exist or whether the indexes used in this study were unable to detect them. Many authors (Benvenuti et al., 1995; Otsuka et al., 2003; Menz et al., 2006) have already reported that older people with pes planus are more prone to pain, therefore it is possible that the biomechanical changes caused by the flattening of the plantar arch lead to overload and joint degeneration, and consequently, to pain (Greisberg et al., 2003). The opposite situation, pes cavus, may also be a source of pain. Burns et al. (2005) investigated the relationship between high arched feet and pain, and concluded that the high plantar pressures of this kind of arch caused the pain and hampered shock absorption.

Based on the present results, it was possible to conclude that the prevalence of foot pain when wearing shoes was high, and it was associated with the female gender, however the use of high-heeled shoes was not correlated with pain. Women with foot pain had flatter feet and larger values for the circumferences of the metatarsal heads and the instep (after normalization for foot length) than those without pain. In contrast, the men with pain did not show different measurements from those without pain. This study was limited by the use of analog instruments, which are less accurate than digital ones, and by the fact that the intra-rater reliability was not assessed for each of the anthropometric measures.

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Appendix A Questionnaire

Do you currently have any problems or pain in your feet?

Do you feel any pain/discomfort (even if occasionally) in any part of your foot when wearing shoes?

For women:

Do you use high-heeled shoes (over 4 cm high)?

() never use () twice a week

() rarely () three times a week

() once a week () more than three times a week

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