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Relationship between the metatarsophalangeal joint angle and anthropometric measures and foot posture among older adults

A relação do ângulo da articulação metatarsofalangeana e de medidas antropométricas com a postura dos pés de idosos

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Abstract

Objectives: To investigate the relationship between the first metatarsophalangeal joint angle (Ang-I), the age, anthropometric measures and foot posture of older adults. **Methods:** The sample was 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 studied variables were: the width and circumference of the metatarsal heads, the height of the first metatarsal head and the dorsum of the foot, the length of the foot, the Ang-I and fifth metatarsophalangeal joint angles, the arch index and the foot posture index. The measurements were taken with analog instruments. The data were analyzed using Pearson's correlation. **Results:** There was no association between Ang-I and age or arch index, but there were positive associations between Ang-I and the width and circumference of the metatarsal heads, the foot posture index and the fifth metatarsophalangeal angle. There was a negative association between Ang-I and the height of the dorsum of the foot. **Conclusions:** Relationships were found between greater Ang-I values and greater widths and circumferences of the forefeet, greater fifth metatarsophalangeal angles and greater pronation of the feet and smaller values for the height of the dorsum of the foot.

Key words: aging; foot; hallux valgus; anthropometry.

Resumo

Objetivos: Verificar a relação entre o ângulo da articulação metatarsofalangeana I (Ang-I) e a idade, as medidas antropométricas e a postura dos pés de mulheres e homens idosos. **Métodos:** A amostra foi composta por 227 mulheres idosas, com média de idade de 69,6 anos (±6,8) e 172 homens idosos, com média de idade de 69,4 anos (±6,7). As variáveis estudadas foram: a largura e o perímetro da cabeça dos metatarsos, a altura da cabeça do metatarso I e do dorso do pé, o comprimento do pé, os ângulos articulares Ang-I e metatarsofalangeana V, o índice do arco e o índice postural do pé. As medidas foram tomadas com instrumentos analógicos. Os dados foram analisados por meio de Correlação de Pearson. **Resultados:** O Ang-I não apresentou relação com a idade e com o índice do arco, porém apresentou associação positiva com a largura e o perímetro da cabeça dos metatarsos, com o índice postural do pé e com o ângulo da articulação metatarsofalangeana V e associação negativa com a altura do dorso do pé. **Conclusões:** Foram encontradas relações entre maior Ang-I e maiores largura e perímetro de antepé, maior ângulo da articulação metatarsofalangeana V, pés mais pronados e com menor altura do dorso do pé.

Palavras-chave: envelhecimento; pé; hálux valgo; antropometria.

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Introduction

The feet need to be a firm base for the maintenance of an upright posture, being at the same time elastic and flexible enough to absorb reactive forces from the ground and to generate propulsion. They also act as sensors of the ground and take part in strategies of body balance[1]. The morphological, biomechanical, and functional changes that take place with aging may produce lesions and impairments. An example of that is the hallux valgus.

The hallux valgus consists of a lateral deviation of the hallux proximal phalanx on the first metatarsal head and is characterized by a degree greater than 9º between the first and the second metatarsals, a valgus angle greater than 15º from the first metatarsophalangeal joint and a lateral subluxation of the sesamoid bones[2]. It is common for the flexor and extensor tendons to displace themselves laterally, which makes the hallux insufficient. The lateral toes, particularly the second one, are submitted to the laterally displaced hallux and may suffer dorsal or ventral luxations, or lateral displacements. A frequent cause is congenial varus of the first metatarsal, which makes the forefoot wide. Narrow-pointed shoes and high-heels also contribute to the onset of these deformities. In a study involving 784 older adults, 37.1% had hallux valgus, a condition more commonly found among women[3].

The hallux valgus determines significant difficulties in the adaptation to shoes, generating balance problems and therefore increasing the risk of falls[4]. Moreover, this structural change in the foot implies modifications in its dynamics and punctual overload. Menz and Lord[5] observed that older adults who had hallux valgus had a slower marching speed and a shorter step. In addition to this, the pain on the feet seems to be intimately related to hallux deformities[6,7].

Other changes in the feet of older adults include bowing, pes planus, widening of the forefoot, and ungueal problems[1,8]. These morphological and postural changes may be related to the angle deformity of the hallux in older adults. Stemming from this hypothesis, this study aimed to verify the relationship between the angle of the first metatarsophalangeal joint (Ang-I) and age, the anthropometric measures and the posture of the feet in older adults.

Methods

Individuals aged 60 or over, of both sexes, residing in the city of São Carlos, SP, Brazil, were included in this study. We excluded those who had amputated any segment of the lower limbs or who made use of dressings or orthoses that might prevent the measurement instruments from having a direct contact with the skin. The sample was determined based on the older adult population of the town (20,335, according to the Instituto Brasileiro de Geografia e Estatística – Brazilian Institute of Geography and Statistics[9]) and by means of quotas of age and sex variables. Hence, it deliberately consisted of 227 older adult women, with a mean age of 69.6 years (±6.8), and 172 older adult men, with a mean age of 69.4 years (±6.7). The selection of the participants was not random, having been made out of convenience, by selecting members of the population who lived near the collection points most accessible to the researchers.

The data were collected at Universidade Aberta da Terceira Idade (Open University for Older Adults), the Health-School Unit of Universidade Federal de São Carlos, and two Basic Health Units of the São Carlos Municipality. The participants received the information about the study and signed the consent form.

The variables studied were: the anthropometric measures for width, perimeter, heights, and length of the foot described by Manfio and Ávila[10]; Ang-I and fifth metatarsophalangeal joint angles, as proposed by Norkin and White[11]; the Arch Index (AI) described by Cavanagh and Rodgers[12] and the Foot Posture Index (FPI), as described by Redmond, Crosbie and Ouvrier[13]. The materials and instruments used were: a pedigraph, a goniometer for the toes with a 1-degree resolution, an analog height gauge with a 1-millimeter resolution, an analog caliper with a 1-millimiter resolution, a fiberglass tape measure with a 1-millimeter resolution, alcohol, cotton balls, a marker, and the software AutoCad 2005.

The evaluation began with the participant barefoot and in orthostasis, distributing the weight of the body evenly onto both lower limbs. The foot length and the width of the metatarsal heads were measured with the caliper. The foot length is defined as the distance between the most prominent point in the region of the calcaneal tuberosity, up to the most prominent point in the anterior region of the tuberosity of the distal phalanx of the big toe, along the longitudinal axis of the foot (heel – 2nd toe). The width of the metatarsal heads is the distance measured from the most prominent point of the medial region of the tuberosity of the first metatarsal head up to the most prominent point of the lateral region of the tuberosity of the fifth metatarsal head[10].

The perimeter of the metatarsal heads was taken by using the fiberglass tape measure and it is defined as the perimeter of the vertical cross-section of the foot, taken along the line that passes through the most prominent part of the region of the tuberosity of the metatarsal heads (first to fifth metatarsal). The heights (of the head of the first metatarsal and of the dorsum of the foot) were measured with an analog height gauge. The height of the first metatarsal head is the vertical distance measured from the foot support plane up to the upper region of

the first metatarsal head. The height of the dorsum of the foot is the vertical distance between the foot support plane and the most prominent region of the navicular bone[10].

The measurements of the joint angles were taken with a toe goniometer that was placed onto the dorsum of the foot with the axis centered on the metatarsophalangeal joint. The proximal arm of the instrument was aligned with the first metatarsal and the distal arm with the medial line of the proximal phalanx[11]. The degrees that represented valgus of the first toe and varus of the fifth were considered as positive; negative degrees were those that represented varus of the first toe and valgus of the fifth one.

All measures were taken by the same examiner, who ensured the instruments exerted the least possible pressure on the skin. Before the measurements took place, the instruments were sanitized with cotton and a 70% alcohol solution, and the anatomical landmarks of the foot were marked so that the measures were always taken from the same place.

With the evaluated patient still in orthostasis, the postural evaluation of the foot was carried out by means of the FPI, already validated for older adults[14]. This instrument consists of the sum of six evaluation criteria scored with whole numbers from -2 to +2 and therefore the test can have a minimum score of -12, indicating maximum supination; and a maximum score of +12, indicating maximum pronation. The criteria are as follows: (1) talar head palpation, considering that the most medially palpable talar head scores positive points, and most laterally, negative points; (2) comparison between the upper and lower curvatures of the lateral malleolus, considering that if the infra-malleolar curvature was more convex than the supra, that would score positive points, otherwise, negative points; (3) evaluation of the position of the calcaneal frontal plane, considering that the calcaneal eversion scores positive points, and its inversion, negative points; (4) evaluation of the talonavicular joint region which, when convex scores positive points, and when concave, negative points; (5) height and congruence of the longitudinal arch, which scores positive points when it is low and flattened out and negative points otherwise; and (6) the alignment of the forefoot over the rearfoot (posterior view), which scores positive points when there is an abduction of the forefoot over the rearfoot, and negative points when the opposite situation is observed.

The footprints of the right and left foot were taken using the pedigraph, so that the AI – already validated for older adults[14] – could be calculated later. The footprints were taken by the same examiner. The participant was instructed to place one foot next to the pedigraph and place the other foot onto the device, placing the weight of the body evenly on both legs. They were also instructed to remove the foot that was on the pedigraph first to ensure that the weight was never placed only on the foot being tested. The same procedure was repeated for the other foot.

The footprints were scanned and converted into images that were later refined by an experienced designer with the aid of the AutoCad 2005 software. The plantar area, except for the digital area, was divided into three equal parts along the longitudinal axis of the foot, and the AI is the ratio between the mid-third area and the total area. Greater values correspond to flatter feet, and lower values to high arch feet.

In order to verify the reliability of the AI calculation, the designer calculated the indexes of the right and left feet of 30 older adults three times, and then applied the replicability test, as suggested by Bland and Altman[15]. The differences between the measurements of each subject were smaller than the limit set by the test (replicability=0.122), indicating that it was safe to make only one calculation per participant.

The data were analyzed by means of Pearson's correlation, and the level of significance was set at 5%. As observed by Keenan et al.[16], although the data obtained from the FPI are not continuous, they have the potential to be analyzed by using parametric strategies.

The perimeter, length, and height variables depend on the foot length, and therefore had to be adjusted to this variable so that they could become comparable in the study of individuals with different foot sizes. In that sense, the *k* variable described by Chouquet-Stringer and Bernard[17] was used as the measure multiplied by 100 and divided by the length of the foot.

The present study is in accordance with the ethical standards put forward by Resolution 196/96 of the Conselho Nacional de Saúde (National Health Council) and was approved by the Research Ethics Committee of Universidade Federal de São Carlos, under protocol number 241/2006.

Results

Table 1 displays the means and standard deviations of the variables studied in the male and female groups. The left Ang-I of the female group was, on average 13.9º (±8.2) and on the right foot, 12.0º (±8.3). Table 2 shows the results of Pearson's correlation as applied to the variables of the female group. Ang-I maintained a positive, medium-intensity association with the ratio of width and the perimeter of the metatarsal heads/foot length and with the fifth metatarsophalangeal joint angle. Weak and negative relationships were observed with the height of the 1st right metatarsal head and the height of the dorsum for the right foot (in its proportions with the foot length). Weak and positive relationships were observed with the right FPI and with its sixth evaluation criterion, i.e. the alignment of the forefoot, indicating that higher Ang-I values are linked to more abducted forefeet. As for age, only the measures of the right feet had a positive and weak correlation with this variable.

Table 1. Means and standard deviations of the variables studied in the female and male groups.

	Women		Men	
Variables	Left foot	Right foot	Left foot	Right foot
Foot length (cm)	24.0 (±1.1)	24.0 (±1.1)	25.9 (±1.4)	25.9 (±1.2)
Perimeter of the metatarsal heads (cm)	23.7 (±1.3)	23.8 (±1.3)	25.5 (±1.5)	25.5 (±1.4)
Width of the metatarsal heads (cm)	9.9 (±0.6)	9.9 (±0.6)	10.5 (±0.7)	10.5 (±0.7)
Height of the first metatarsal head (cm)	3.1 (±0.3)	3.1 (±0.3)	3.4 (±0.3)	3.4 (±0.3)
Height of the dorsum of the foot (cm)	5.7 (±0.6)	5.7 (±0.6)	6.5 (±0.6)	6.6 (±0.6)
First metatarsophalangeal angle (º)	13.9 (±8.2)	12.0 (±8.3)	11.8 (±6.9)	10.0 (±6.5)
Fifth metatarsophalangeal angle (º)	9.7 (±5.7)	9.7 (±6.5)	8.4 (±4.8)	8.2 (±4.7)
Arch Index	0.23 (±0.05)	0.24 (±0.05)	0.22 (±0.05)	0.23 (±0.05)
Foot Posture Index (FPI)	1.3 (±2.3)	1.1 (±2.4)	0.9 (±2.3)	0.8 (±2.4)
3rd scoring criterion (FPI)	0.1 (±0.6)	0.0 (±0.6)	0.0 (±0.5)	0.0 (±0.5)
4th scoring criterion (FPI)	0.4 (±0.7)	0.3 (±0.7)	0.3 (±0.8)	0.2 (±0.8)
6th scoring criterion (FPI)	0.3 (±0.7)	0.3 (±0.7)	0.2 (±0.7)	0.2 (±0.7)

Table 2. Pearson's correlation between the values for Ang-I and the other variables studied in the female group.

Women			
Variables		Correlation coefficient	p-value
Age	L	0.092	0.165
	R	**0.133**	**0.045**
K Width of the metatarsal heads	L	**0.560**	**<0.001**
	R	**0.443**	**<0.001**
K Perimeter of the metatarsal heads	L	**0.426**	**<0.001**
	R	**0.320**	**<0.001**
K Height of the first metatarsal head	L	0.005	0.938
	R	**-0.141**	**0.034**
K Height of the dorsum of the foot	L	-0.010	0.880
	R	**-0.150**	**0.024**
Fifth metatarsophalangeal angle	L	**0.471**	**<0.001**
	R	**0.347**	**<0.001**
Arch Index	L	0.049	0.458
	R	0.054	0.420
Foot Posture Index (FPI)	L	0.075	0.262
	R	**0.175**	**0.008**
3rd scoring criterion (FPI)	L	0.086	0.197
	R	0.057	0.395
4th scoring criterion (FPI)	L	-0.038	0.564
	R	0.113	0.090
6th scoring criterion (FPI)	L	**0.133**	**0.045**
	R	**0.175**	**0.008**

K=value of the measurement multiplied by 100 and divided by the foot length; L=left; R=right.

Table 3. Pearson's correlation between the values for Ang-I and the other variables studied in the male group.

Men			
Variables		Correlation coefficient	p-value
Age	L	0.050	0.513
	R	-0.023	0.764
K Width of the metatarsal heads	L	**0.347**	**<0.001**
	R	**0.331**	**<0.001**
K Perimeter of the metatarsal heads	L	**0.229**	**0.003**
	R	**0.263**	**0.001**
K Height of the first metatarsal head	L	-0.094	0.219
	R	0.023	0.761
K Height of the dorsum of the foot	L	**-0.171**	**0.025**
	R	**-0.153**	**0.046**
Fifth metatarsophalangeal angle	L	**0.394**	**<0.001**
	R	**0.366**	**<0.001**
Arch Index	L	0.071	0.352
	R	0.025	0.744
Foot Posture Index (FPI)	L	**0.337**	**<0.001**
	R	**0.313**	**<0.001**
3rd scoring criterion (FPI)	L	**0.211**	**0.005**
	R	**0.184**	**0.016**
4th scoring criterion (FPI)	L	**0.240**	**0.001**
	R	**0.212**	**0.005**
6th scoring criterion (FPI)	L	**0.327**	**<0.001**
	R	**0.312**	**<0.001**

K=value of the measurement multiplied by 100 and divided by the foot length; L=left; R=right.

The men had a mean of 11.8º (±6.9) in the left Ang-I, and of 10.0º (±6.5) in the right Ang-I. Among the several variables analyzed by Pearson's correlation, only the height of the 1st metatarsal head/foot length, the AI, and the age did not evidence any association with Ang-I (Table 3). Positive, medium-intensity correlations were established between Ang-I and the foot width/foot length ratio, the angle of the fifth metatarsophalangeal joint, the FPI, and the forefoot alignment (sixth criterion of the FPI). Positive and weak relationships were found between Ang-I and the foot perimeter, and the 3rd and 4th criteria of the FPI. The height for the dorsum of the foot had a weak negative correlation with Ang-I.

Discussion

Ang-I was weakly associated with age only in the female group, and even so only in relation to the measurements of the

right foot. Perhaps the limited age span being studied (older adults only) prevented us from verifying that association. Mafart[18] already reported that the prevalence of the hallux valgus increases with age, which would justify a possible association. Nevertheless, it is necessary to highlight that the diagnosis of hallux valgus does not depend on a single joint angle, as investigated in this study.

Ang-I maintained a positive correlation with the width and the perimeter of the metatarsal heads (in their proportions with the foot length) and with the angle of the 5th metatarsophalangeal joint. Lamur et al.[19] also noted an association between the hallux valgus and wider forefeet, perhaps due to the lateral exostosis of the first metatarsal head, common in hallux valgus cases. The angle of the fifth metatarsophalangeal joint, that may characterize the fifth varus toe, often seems to be a consequence of the hallux valgus, as well as the luxation of the central toes and the periostitis of the second and third metatarsal bones[20].

The AI did not have an association with Ang-I. Saragas and Becker[21] did not find differences in the incidence of flat feet among women with and without hallux valgus. Some authors agree that flat feet exert very little influence on the genesis of the hallux valgus due to the great difference between the incidence and the weak coincidence of both deformities[22-25].

A positive correlation was found between Ang-I and some of the criteria of the FPI. This finding suggests that older adults who had a greater angle in the first metatarsophalangeal joint also had more proned feet. Kilmartin and Wallace[26], Komeda et al.[27] and Nery[28] also observed this association, reinforcing the idea that the valgus of the rearfoot also prones the 1st metatarsal and the hallux, forcing it to lean on its medial face in the propulsion phase of gait, resulting in a valgus force that acts on the hallux[29]. Besides the valgus of the rearfoot, the proned foot is accompanied by the internal rotation and the medial displacement of the talus and of the navicular, which are responsible for the reduction in the height of the dorsum of the foot, which may explain the negative association found between Ang-I and the foot dorsal height.

The Pearson correlations between the anthropometric variables and Ang-I had different results according to the laterality. In the female group, the differences between the correlation coefficients of the left and right sides were of about 0.1 and in the male group they were even smaller. This finding may be due to the natural variation between the right and left sides. In the cases in which the correlations were weak (correlation coefficient <0.2), they were only significant on one of the sides ($p \leq 0.05$) because in these cases the coefficient neared the cut-off value for $\alpha \leq 0.05$.

The main limitation detected in this study was the fact that the measurements were taken on different periods of the day, which might interfere with the volume of the foot, especially in individuals with vascular problems. Moreover, the use of analog instruments, less precise than their digital counterparts, may have represented a limitation, even though these are the resources most commonly used in clinical activity.

Based on the results obtained, it is possible to conclude that Ang-I did not show a relationship with age or with the AI, although it did show a positive association with the width and the perimeter of the metatarsal heads, as well as with the FPI and with the angle of the fifth metatarsophalangeal joint; conversely, it was negatively associated with the height of the dorsum of the foot. Such findings reinforce the hypothesis that the hallux valgus does not occur in isolation, but takes part in the morphological changes of the feet of older adults, which may in turn originate pain, difficulty to find adequate to shoes, and gait problems. Therefore, the evaluation of the feet should be part of the older adult patient's physical therapy treatment, as it will provide a more thorough functional diagnosis, particularly concerning disorders affecting body balance, as well as those related to pain disabilities.

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