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Study of the metatarsal formula in patient with primary metatarsalgia☆

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ABSTRACT

Objectives: The aims of this study were (i) to ascertain the prevalence of different types of metatarsal formula among patients with primary metatarsalgia; (ii) to compare the variable of "shortening of the first metatarsal in relation to the second" (I/II) between the metatarsalgia and control groups; and (iii) to analyze the intra and interobserver concordance by means of Morton's transverse line method and Hardy and Clapham's arc method.

Methods: A cross-sectional observational study was conducted on 56 patients by means of radiographs on their 112 ft, of which 56 were in the metatarsalgia group and 56 in the control group. The evaluations were done between December 2012 and June 2013. The measurements were made by three third-year orthopedics residents with prior training in the methods used, and a template was used.

Results: There was no concordance between the two methods, as shown by Bland–Altman plots, although the intraclass correlation coefficients showed that the intra and interobserver reproducibility was high using the transverse line method (0.78 and 0.85) and moderate using the arc method (0.73 and 0.60). Comparison between the groups showed that there was a statistical difference ($p \leq 0.05$) such that there was greater shortening of the first metatarsal (3.39 mm) in the control group than in the metatarsalgia group (2.14 mm). In the patients with primary metatarsalgia, the *index minus* metatarsal formula was more prevalent according to the transverse line method (62.5%) and the *zero plus* type according to the arc method (71.4%).

Conclusion: In the present study, it was observed that the metatarsal formula prevalences depended on the measurement method. In both groups, shortening of the first metatarsal predominated. There was no intra or interobserver concordance in either of the two proposed methods.

☆ Work developed in the Orthopedics Service, Santa Casa da Misericórdia de Santos, Santos, SP, Brazil.

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Estudo da fórmula metatarsal em pacientes com metatarsalgia primária

Palavras-chave:
Metatarsalgia
Ossos do metatarso
Reprodutibilidade dos testes

RESUMO

Objetivos: Verificar a prevalência dos tipos de fórmula metatarsal (FM) em pacientes com metatarsalgia primária (MP); comparar a variável "encurtamento do primeiro metatarso em relação ao segundo" (I/II) entre os grupos metatarsalgia (GM) e controle (GC); analisar a concordância intra e interobservadores pelos métodos das linhas transversais (MLT) de Morton e dos arcos (MA) de Hardy e Clapham.

Métodos: Estudo observacional transversal em 56 pacientes por meio de radiografias dos 112 pés, 56 do GM e 56 do GC avaliados entre dezembro de 2012 e junho de 2013. As mensurações foram feitas por três residentes do terceiro ano em ortopedia, com treinamento prévio dos métodos e uso de template.

Resultados: Não houve concordância em nenhum dos dois métodos verificados pelos gráficos de Bland–Altman, apesar de o coeficiente de correlação intraclasses apresentar uma alta reprodutibilidade intra e interobservadores pelo MLT (0,78 e 0,85) e moderada pelo MA (0,73 e 0,60). Na comparação entre os grupos, observou-se diferença estatística ($p \leq 0,05$) com um encurtamento do primeiro metatarso (3,39 mm) maior no GC em relação ao GM (2,14 mm). Nos pacientes com MP, a FM tipo *index minus* foi mais prevalente pelo MLT (62,5%) e o tipo *zero plus* pelo MA (71,4%).

Conclusão: Foi observado que a prevalência da FM depende do método de mensuração. Em ambos os grupos houve predomínio do encurtamento do primeiro metatarso. Não houve concordância intra e interobservadores em nenhum dos métodos propostos.

Introduction

Metatarsalgia, characterized by pain in the plantar region of the forefoot under the metatarsal heads, is one of the most frequent complaints in clinical practice among conditions affecting the feet.[1,2] Nearly 80% of the normal population present some form of pain in the metatarsal region over their lifetime.[3] The main etiological factors are biomechanical alterations, which make up 92% of the total.[4] These can be classified as primary, secondary and iatrogenic. Primary metatarsalgia alterations are related to the anatomy of the metatarsals and their relationships, which can lead to mechanical overload on the affected metatarsus and may evolve with pain and plantar callosities. In some cases, these consequences may become incapacitating.[1,5]

The presence of a short first metatarsus, known as Morton's toe, is considered by many authors to be a contributing factor for the development of primary metatarsalgia.[1,3,6] The relationship among the lengths of the metatarsals is defined as the metatarsal formula.[3,7] Although this tool is used both for diagnostic investigation and for guidance toward treatment, the choice of the measurement method and their results are matters of controversy in the literature. The methods most cited are Morton's transverse line (MTL) and Hardy and Clapham's arc method (AM).[8–10]

One crucial aspect in interpreting diagnostic tests is that the observers' measurements should be coherent, so that the results will be reproducible. This is the concept of precision, which is necessary for the validation of the method and its usefulness in clinical practice.[11]

The objectives of the present study were to observe the prevalence of the types of metatarsal formula among patients with primary metatarsalgia; compare the variable of "shortening of the first metatarsus in relation to the second" between the metatarsalgia group (MG) and the control group (CG); and analyze the intra and inter-observer agreement through the MTL and AM methods.

Methods

This was a cross-sectional observational study on 56 patients (112 ft), over the age of 18 years and all female, who were divided into 28 patients (56 ft) in the MG and 28 (56 ft) in the CG.

The MG consisted of patients with painful symptoms in the region of the metatarsal heads, who had been diagnosed as presenting primary metatarsalgia due to mechanical overload. The CG was composed of patients with plantar fasciitis, who presented pain in the hindfoot region.

Patients were excluded if they presented deformities that compromised the forefoot, midfoot or hindfoot; a personal history of previous surgery or trauma to the feet; or personal histories of diabetes mellitus, rheumatological diseases, vascular diseases or neuropathies.

This study was approved by the research ethics committee (Platform Brazil procedural no. 152078 of November 30, 2012) and all participants signed a free and informed consent statement.

Procedures

Three medical residents in orthopedics who were in their third year of specialization and under the supervision of the principal investigator evaluated all the patients with complaints of pain in their feet who went through the outpatient service of our department between December 2012 and June 2013.

The volunteers underwent simple radiography on both feet in the upright standing position, in true dorsoplantar view with a cranial angle of 15°, at real size.[12]

Reproducibility

To assess interobserver reliability, all the radiographic images were measured using the MTL and AM separately by three observers.

To assess intraobserver reliability, one of the observers was randomly chosen to perform the measurements again, eight weeks after the first evaluation.

All three observers received prior training on the measurement methods. To help the evaluation and make it more reliable and reproducible, an illustrative and explanatory model for both methods was attached beside the registration form (Fig. 1).

Morton's transverse line method of measurement was applied schematically: 1 – set up a line over the diaphyseal axis of the second metatarsal; 2 – draw a transverse line perpendicular to the apex of the head of the first metatarsal; 3 – draw a transverse line perpendicular to the apex of the head of the second metatarsal; 4 – measure the distance between these two transverse lines in millimeters. Hardy and Clapham's arc method was also applied schematically: 1 – set up a line over the diaphyseal axis of the second metatarsal; 2 – mark the center of the arcs at the intersection of this line with another line that touches the most medial point of talonavicular and the most lateral point of calcaneocuboid; 3 – draw an arc that touches the apex of the head of the first metatarsal; 4 – draw an arc that touches the apex of the head of the second metatarsal; 5 – measure the distance between these two arcs in millimeters.[6–9]

Statistical analysis

Based on a pilot study performed previously and considering the variable of "relative difference in the length between the first and second metatarsals" (I/II), the sample size was defined as 28 patients per group, with a power of 80% and significance level of 0.05.

The descriptive analysis was presented as the mean and standard deviation of the variables analyzed. To evaluate intra and interobserver reliability, the interclass correlation coefficient (ICC) was applied and classified as: minimal (≤0.25), low (between 0.26 and 0.49), moderate (between 0.50 and 0.69), high (between 0.70 and 0.89) or very high (≥0.90).[13]

Single-factor analysis of variance was used to compare the CG and the MG regarding the variable I/II.

To observe the prevalences of the types of metatarsal formula, Viladot's classification[3,14] as modified by Mancuso et al.[15] was used, considering two types: values lower than −0.5 mm were classified as index minus and positive values as zero plus.

Table 1 – Relative difference in length between the first and second metatarsals.

Observer	Method	Mean (SD)
A	Transverse lines	−2.77 mm (2.90)
	Arc	0.04 mm (2.90)
B	Transverse lines	−2.72 mm (2.87)
	Arc	0.42 mm (2.88)
C	Transverse lines	−2.47 mm (3.04)
	Arc	−0.88 mm (2.94)

mm, millimeters; SD, standard deviation.

Table 2 – Comparison of the interobserver agreement analysis between the transverse line method and the arc method.

Method	ICC	CI	*p*
Transverse lines	0.85	[0.81; 0.89]	0.104
Arc	0.60	[0.50; 0.69]	0.001[a]

ICC, intraclass correlation coefficient; CI, confidence interval; *p*, significance level of the analysis of variance in blocks.
[a] $p \leq 0.05$.

Results

The descriptive data and the statistical analysis results were as follows:

Table 1 shows the mean and standard deviation (SD) of the measurements on the variable I/II using both the MTL and the AM by all three observers.

Table 2 demonstrates that the MTL presented higher ICC and lower CI, in comparison with the AM, while in analysis of variance divided into blocks, the AM presented a significant difference ($p \leq 0.05$), which demonstrated disagreement between the observers.

The Bonferroni method shown in Table 3 demonstrated that the means of observers A and B differed ($p \leq 0.05$) from the mean of observer C, using the AM.

Figs. 2 and 3 present the results from the Bland–Altman plots, which indicated that there was no agreement among the observers, using either the MTL or the AM.

Table 3 – Statistical analysis on the comparisons between observers, two by two.

Observers compared	*p*
C–A	0.001[a]
C–B	0.002[a]
B–A	0.296

p, significance level.
[a] $p \leq 0.05$.

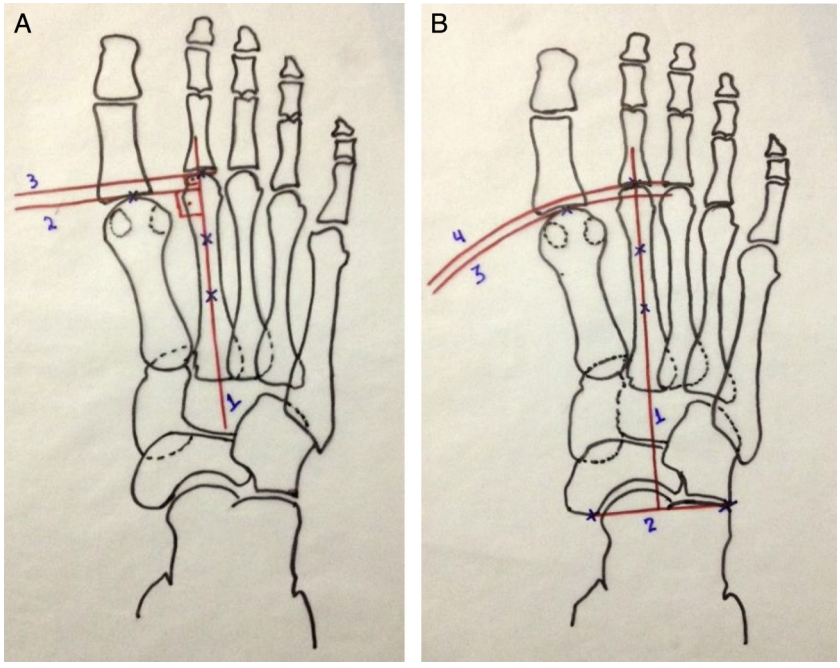

Fig. 1 – Previous training and template for measurements using Morton's transverse line method (A) and Hardy and Clapham's arc method (B).

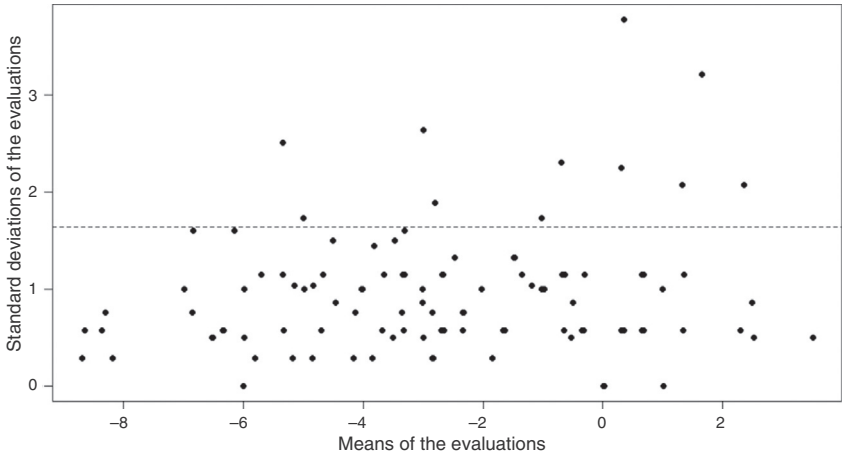

Fig. 2 – Interobserver evaluation using the transverse line method.

Table 4 presents the descriptive measurements on the variable I/II, according to the MTL and AM, made by observer A at two different times.

Table 4 – Relative difference in length between the first and second metatarsals.

Evaluations	Method	Mean (SD)
1st time	Transverse lines	−2.77 mm (2.90)
	Arc	0.04 mm (2.90)
2nd time	Transverse lines	−2.57 mm (2.80)
	Arc	0.06 mm (2.77)

SD, standard deviation; mm, millimeters.

Table 5 demonstrates that the MTL obtained a higher ICC and lower CI than the AM did. The Student *t* test indicated that there was agreement between the evaluations using the two methods.

Table 5 – Comparison analysis on intraobserver agreement.

Method	ICC	CI	*p*
Transverse lines	0.78	[0.70; 0.84]	0.275
Arc	0.73	[0.64; 0.81]	0.909

ICC, intraclass correlation coefficient; CI, confidence interval; *p*, significance level of the Student *t* test analysis.
[a] $p \leq 0.05$.

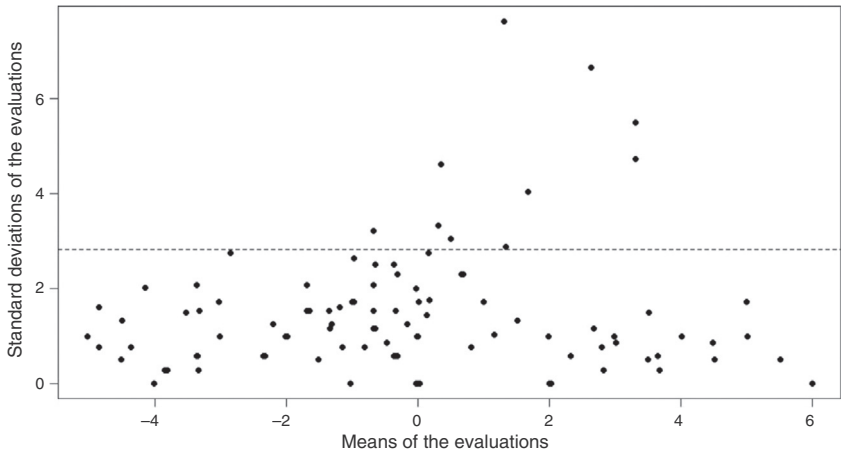

Fig. 3 – Interobserver evaluation using the arc method.

Figs. 4 and 5 indicate that there was no agreement between the evaluations using either the MTL or the AM.

Comparisons between the groups were made using the first measurements from observer A, by means of the MTL.

The mean value of the descriptive measurements on the variable I/II in the MG was −2.14 mm (SD = 3.05) and in the CG it was −3.39 mm (SD = 2.63) (Fig. 6).

The result from inferential analysis to compare the CG and the MG regarding the variable I/II was used in a single-factor mixed model of variance. This indicated that there was a difference ($p \leq 0.05$) between the means of the CG and MG.

Table 6 shows a descriptive comparison between the MTL and AM regarding the prevalences of types of metatarsal formula in the CG and MG. The MG showed higher prevalence of

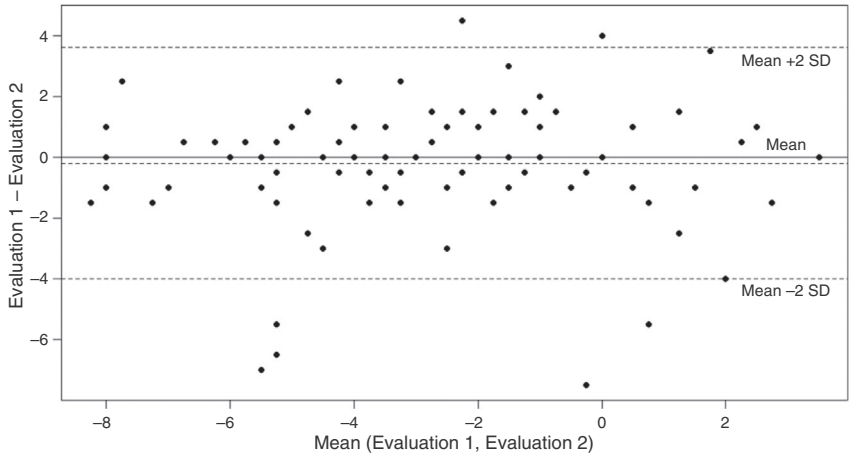

Fig. 4 – Intraobserver evaluation using the transverse line method.

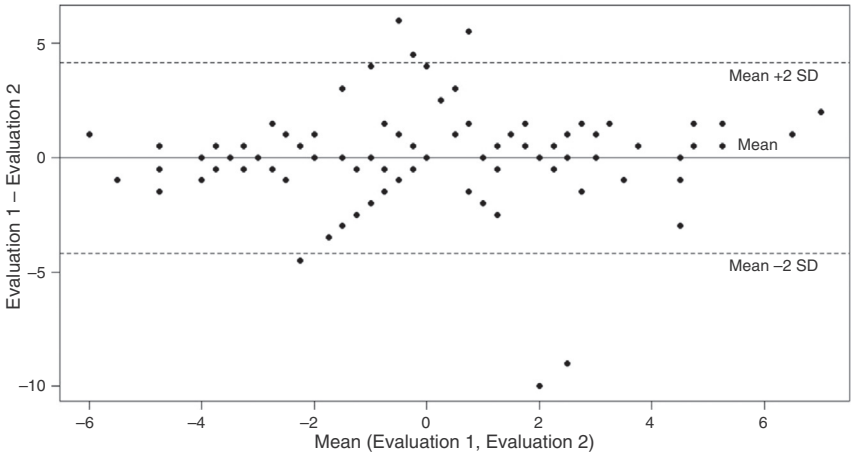

Fig. 5 – Intraobserver evaluation using the arc method.

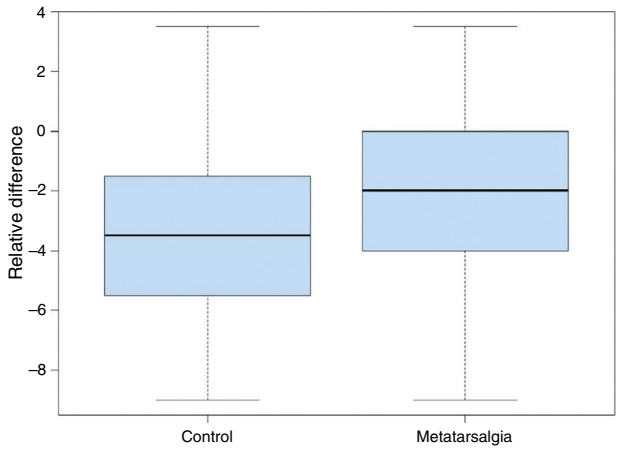

Fig. 6 – Distribution of the variable of "relative difference of the length between the first and second metatarsal", according to each group.

Table 6 – Prevalence of the types of metatarsal formula in the general sample and in the groups.

Method	Metatarsal formula	Metatarsalgia group	Control group
Transverse lines	Index minus	62.5%	85.7%
	Zero plus	37.5%	14.3%
Arc	Index minus	28.6%	53.6%
	Zero plus	71.4%	46.4%

feet with the index minus type of metatarsal formula (62.50%) according to the MTL, while the zero plus type of metatarsal formula was more prevalent according to the AM (71.43%). The CG presented higher prevalence of the index minus type of metatarsal formula (85.71%) according to the MTL, and also according to the AM (53.57%).

Discussion

The length relationships between the metatarsals, more commonly known as the metatarsal formula, is a matter of controversy in the literature with regard to both the choice of method for measurement and the association of this condition with the development of several disorders that compromise the forefoot, such as primary metatarsalgia.[7,10]

The results from the present study showed that measurement of the metatarsal formula through the transverse line method is related to higher prevalence of feet with a second metatarsal longer than the first (index minus). The same was observed by Morton,[6] who correlated this type of foot as a contributing factor for the development of primary metatarsalgia. This concept has been established by several authors.[1,3,5] However, when the same method was used for the control group, even greater prevalence of the index minus type of foot was observed, as also seen by Barroco et al.[12] among 332 normal feet in their study. In comparing the means of the numerical variable of "relative difference between the length of the first and second metatarsals", a significant difference was observed ($p \leq 0.05$). However, this finding was the inverse of the conceptual hypothesis, with greater shortening of the first metatarsal in the control group than in the metatarsalgia group. This result, combined with data in the literature,[12] contradicts the "Morton's toe" theory and demonstrates that feet with shortening of the first metatarsal or with an index minus type of metatarsal formula measured through the transverse line method are in fact the most prevalent type of feet among the general population.

The present study found that the prevalences of different types of metatarsal formula among patients with primary metatarsalgia depend on the measurement method. Unlike in the transverse line method, the most prevalent type of metatarsal formula observed through the arc method is the zero plus formula, as observed by Hardy and Clapham and other authors.[9,16,17] This phenomenon possibly occurs due to technical differences between the measurements: when patients with a high intermetatarsal angle (greater than 9°) are evaluated, there is a relative decrease in the length of the first metatarsal as measured through Morton's transverse line method. However, when patients whose feet do not present deformities are evaluated, as was the case in the present study, in which the patients presented a normal intermetatarsal angle (between 0° and 8°), there is a relative increase in the length of the first metatarsal when measured through Hardy and Clapham's arc method.[15]

Several ways to measure metatarsal length have been described in the literature, such as anatomopathological assessments on the feet of cadavers,[18] clinical parameters,[19] lateral-view radiography,[20] tomography[21] and computer-based measurement,[22] even for surgical planning.[23] However, the manual radiographic method of measuring the relative length of Morton's transverse lines and Hardy and Clapham's arcs are the methods most cited and used as diagnostic instruments.[7,9,10]

In the present study, the evaluations made by the third-year orthopedic residents, who had received previous training and used a template, did not present intra and interobserver agreement using either method. The transverse line method presented a greater correlation coefficient than that of the arc method, possibly due to the simplicity of the technique, since the arc method has one additional step. This step comprises an additional line that is drawn on the Chopart joint, and this was considered by the observers to be the disagreement factor. However, in another study, none of the methods presented agreement according to the Bland and Altman method.[24] When the mean values from the intra and interobserver evaluations were paired and plotted with their standard deviations and agreement limits, instead of finding results near the zero line of equality, the results were very discrepant. This demonstrates the lack of agreement and reproducibility of the methods and, thus, puts their use in clinical practice into question.

The reproducibility of a test indicates the precision of the method and determines its validity and use in clinical practice.[11] The Bland and Altman statistical method is the methodology most used to analyze the agreement between two methods, the agreement between the evaluations of two or more observers using the same method, or even the agreement between the evaluations of the same observer at different times, for the same method. Use

of the correlation coefficients in isolation is inappropriate because this may bring incomplete information and inadequate interpretations.[25,26]

A diagnostic technique should present precision and reproducibility, with consistency over different observations and little variability. However, the techniques proposed to assess the metatarsal formula cannot be compared or standardized, precisely because the current subjective criteria present great intra and interobserver variability.

Different methods for measuring the length of the metatarsals have the potential to give rise to different results, with potential consequences for surgical planning. In the light of the current results, surgical treatment based only on this radiographic parameter is, to say the least, questionable. Clinical examination must be the priority in recommending any metatarsal osteotomy and should be complemented by other parameters, such as assessment of the instability of the first ray and anatomical alterations of the metatarsals in the coronal plane.

Conclusion

It was observed that the prevalence of the metatarsal formula depends on the measurement method. In cases of primary metatarsalgia, the index minus type is related to Morton's method, while the zero plus type is related to Hardy and Clapham's method.

In comparing the CG and the MG using Morton's transverse line method, there was predominance of shortening of the first metatarsal in both groups.

The methods for measuring the metatarsal formula applied in the present study did not show any intra or interobserver agreement.

Conflicts of interest

The authors declare no conflicts of interest.

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