Interobserver Agreement of the Static Methods of Evaluating the Types of Footprint in Runners*

Concordância interobservadores dos métodos estáticos de avaliação dos tipos de pisada em praticantes de corrida

Rafael Rocha Macedo[1,2] Thiago Kazunori Neves Kanashiro[1] Gustavo Henrique Ramalho de Mattos[1] Alexandre Alcaide[3] Luciano Miller Reis Rodrigues[2] Eiffel Tsuyoshi Dobashi[1]

[1] Hospital IFOR - Rede D'Or São Luiz, São Bernardo do Campo, SP, Brazil
[2] Discipline of Orthopedics and Traumatology, Faculdade de Medicina do ABC, Santo André, SP, Brazil
[3] Clínica de Ortopedia e Recueração Desportiva, Santo André, SP, Brazil

Address for correspondence Rafael da Rocha Macedo, MD, Rua Piranhas, 50, apto 104, Torre 1, Santo André, SP, 09050-080, Brazil (e-mail: rrochamacedo@yahoo.com.br).

Rev Bras Ortop 2020;55(4):490–496.

Abstract

Objective To evaluate the accuracy of interobserver diagnostic methods of the type of footprint among running athletes using three evaluation methods: physical examination, podoscopy, and baropodometry compared with radiographic measurement of Meary angles and calcaneal pitch.

Methods This is a cross-sectional study of athletes who practice running. The inclusion criteria were: individuals with minimum age of 18 years and maximum age of 65, male or female, healthy and without comorbidities that interfere with running performance; regular practitioners who run at least twice a week; body mass index between 18.5 and 29.99 Kg/m^2; acceptance of the written informed consent form (WICF). The non-inclusion criteria included: presence of previous or active injuries that compromise sports activity; previous foot surgeries; obesity. Forty patients were selected, 29 (72.5%) male and 11 (27.5%) female, whose mean age was 39 years (minimum 19 years and maximum 61 years). The body mass index (BMI) of the 40 patients ranged from 21.00 to 29.99 kg/m^2 (mean 25.48 kg/m^2 with standard deviation of 2.39 kg/m^2 and a median of 25.50 kg/m^2). We excluded those with values above 29.99. Running frequency ranged from 2 to 5 times per week (average 3.13 times per week, with standard deviation of 0.79 times per week and median of 3 times per week). Physical examination, podoscopy, and baropodometry were performed, and their evaluation was made by 4 examiners. Additionally, the results were compared with the radiographic classification of the footprint type obtained by measuring the Meary angles and the calcaneal pitch.

Keywords
► foot
► moderate running
► physical examination

* *Study conducted at Orthopedics and Sports Recovery Clinic, Santo André, SP, Brazil.*

received February 6, 2019
accepted September 13, 2019

DOI https://doi.org/10.1055/s-0039-3402464.
ISSN 0102-3616.

Results The interobserver agreement of these parameters was verified by the weighted Kappa agreement index, in which we obtained a significant agreement between the participants considering physical examination, podoscopy, and baropodometry, and according to the Kappa index. The agreement was marginal when comparing the results of the three methods with the radiographic angular classification.

Conclusion We obtained excellent agreement among observers when considering physical examination, podoscopy, and baropodometry for the diagnosis of the footprint type among runners. However, when comparing the results obtained with the radiographic measurements, the agreement for the diagnosis of footprint type was low.

Resumo

Objetivo Avaliar a acurácia dos métodos de diagnóstico interobservadores do tipo de pisada em atletas corredores utilizando três métodos de avaliação: exame físico, podoscopia e baropodometria comparando com a medida radiográfica dos ângulos de Meary e *pitch* do calcâneo.

Métodos Trata-se de estudo transversal de atletas que praticam corrida. Os critérios de inclusão foram: indivídulos com idade mínima de 18 anos e máxima de 65 anos de ambos os sexos; indivídulos hígidos, sem comorbidades que interfiram no desempenho da corrida; praticantes regulares que realizam corrida ao menos duas vezes na semana; índice de massa corpórea entre 18,5 e 29,99 Kg/m^2; aceitação dos termos de consentimento livre e esclarecido (TCLE). Os critérios de não inclusão compreenderam: presença de lesões prévias ou ativas que comprometam a atividade esportiva; cirurgias prévias dos pés; obesidade. Foram selecionados 40 pacientes, sendo 29 (72,5%) do sexo masculino e 11 (27,5%) do sexo feminino cuja média das idades foi de 39 anos (mínimo de 19 anos e máximo de 61 anos). O índice de massa corpórea (IMC) dos 40 pacientes variou de 21,00 a 29,99 Kg/m^2 (média de 25,48 Kg/m^2 com desvio-padrão de 2,39 Kg/m^2 e mediana de 25,50 Kg/m^2). Excluímos os que apresentaram valor superior a 29,99 Kg/m^2. A frequência de corrida variou de 2 a 5 vezes por semana (média de 3,13 vezes por semana com desvio-padrão de 0,79 vezes por semana e mediana de 3 vezes por semana). Foram realizados exame físico, podoscopia e baropodometria, e sua avaliação foi feita por quatro examinadores; além disso, os resultados foram comparados com a classificação radiográfica do tipo de pisada obtida através da mensuração dos ângulos de Meary e *pitch* do calcâneo.

Resultados A concordância interobservadores destes parâmetros foi verificada pelo índice de concordância de Kappa ponderado, segundo o qual obtivemos uma concordância significante entre os participantes, levando-se em consideração o exame físico, podoscopia e baropodometria e de acordo com o índice Kappa. A concordância foi marginal quando comparados os resultados dos três métodos com a classificação angular radiográfica.

Conclusão Obtivemos uma concordância excelente entre os observadores ao considerarmos o exame físico, a podoscopia e a baropodometria para o diagnóstico do tipo pisada em corredores. Porém, quando comparados os resultados obtidos com as medidas radiográficas, a concordância para o diagnóstico do tipo da pisada foi baixa.

Palavras-chave
- pé
- corrida moderada
- exame físico

Introduction

Running, as a physical activity, has gained prominence over the last few years for its easy accessibility and low cost. This sport also gives its practitioners great independence as it is an individual sport. It also has noticeable benefits such as improved cardiorespiratory quality and muscle tone.[1]

Despite the highlighted benefits, we found an occurrence of 79% lower limb injuries, especially on the feet and knees, among continuous running practitioners.[2]

To improve performance and body endurance, the practice of this sport requires fostering appropriate scientific information, so that its perfect practice can be developed.[3]

Considering specifically the foot, this body segment of body-to-ground contact is provided with a rich amount of skin receptors, exteroceptors, and proprioception. This helps with balance and adjusts body posture during standing position.[4]

Three types of foot pattern are described concerning the configuration of the medial arch (flat, concave, and normal foot) with four types of footprints (neutral, supine, prone, and markedly prone), and such variations are individual.[5,6]

Clinical analysis of footprints in runners should be performed through a detailed physical examination of the feet helped by podoscopy and baropodometry.

Podoscopy is used to study the contact area of the feet in relation to the ground under direct vision,[7] while electronic baropodometry aims to measure and compare the pressures distributed in different areas of the plantar region of the foot in a static position or during gait.[8]

Several authors have used these resources to assess clinical foot problems in order to identify abnormalities to adequately provide changes in plantar pressure distribution. They are also seen as safe methods that help planning and choosing the right foot therapy.[9]

Another widely used feature is the feet radiograph with load, which aims to assess changes in alignment and joint spaces, being also possible to promote the analysis of the characteristics of the medial arch of the foot, as well as to classify the type of footstep through angular measurements.[10]

When a critical analysis of the literature considering the binomial composed by running and the different methods of complementary diagnosis, we found a reduced number of articles. Therefore, the present study was performed with the primary objective of verifying interobserver agreement considering orthopedic physical examination of the foot, podoscopy, and baropodometry and, secondarily, to make a comparison of the results with the radiographic classification obtained by measuring the Meary angles and calcaneal pitch on profile radiographs with load.

Materials and Methods

The present study was submitted to the research ethics committee of Plataforma Brazil under CAAE 97161218.5.0000.5625 and approved for completion in accordance with the opinion 2.946.418.

This is a cross-sectional study that aims to evaluate interobserver agreement by analyzing the characteristics of the static footprint of athletes who practice running and comparing the results with those of the radiographic classification.

The inclusion criteria for study participants were:

1) Minimum age of 18 years and a maximum of 65 years, either male or female.
2) Healthy patients without comorbidities that interfere with running performance.
3) Regular practitioners who run at least twice a week.
4) Body mass index (BMI) between 18.5 and 29.99 kg/m^2 (normal weight and overweight)
5) Accepting the terms and signing the written informed consent form (WICF).

The proposal for patient participation was made in a personal interview, when the researchers explained the importance and purpose of the study, making sure, later, of the correct and total understanding of the subject, in order to avoid irregularity in the consent process. It is noteworthy that the refusal to accept and sign the WICF, or the withdrawal of the consent, could occur at any time, without causing consequences of any kind to the individual.

The non-inclusion criteria comprised:

1) Patients with previous or active injuries that compromise sports activity, such as peripheral, degenerative neuropathies, trauma sequelae, local or systemic inflammatory diseases, etc.
2) Previous foot surgeries.
3) Runners with BMI above 30.00 Kg/m^2.

Forty patients were then selected, 29 (72.5%) male and 11 (27.5%) female, whose average age was 39 years (minimum 19 years and maximum 61 years).

The BMI of the 40 patients ranged from 21.00 to 29.99 Kg/m^2 (mean of 25.48 Kg/m^2 with standard deviation of 2.39 Kg/m^2 and median of 25.50 Kg/m^2). We excluded those with values above 30.00 Kg/m^2.

Running frequency ranged from 2 to 5 times per week (average 3.13 times per week with standard deviation of 0.79 times per week and median of 3 times per week).

We elaborated a care protocol in which some variables considered important by the researchers were contemplated. Three evaluation parameters were selected: physical examination, podoscopy and baropodometry.

1. Clinical Evaluation Method:

1.1 Static inspection of the foot and ankle with the patient on a 1 meter high flat platform, with the individual in orthostatic position according to previous markings on the ground, in order to standardize the position for the examination, the examiners positioned one at a time, all at the same angle for the analysis, to minimize errors due to the angle taken in the verification act. The following parameters were analyzed on physical examination:

- Hindfoot position - this measurement was performed in the orthostatic position, from the posterior view where the hindfoot and ankle axes were found as follows: to trace the hindfoot axis, the clinical center of the calcaneus and the center of the ankle were located for tracing a straight line. From the center of the ankle to the tricipital mass, a second straight line was drawn. Their crossing was assessed using a goniometer to find the measure in degrees of this variable (neutral, cavus or valgus).
- Plantar vault height - we used the non-quantitative inspection method, in which we classify the foot as flat, neutral, or hollow by directly viewing the plantar vault height. It is an observational method that consists of visualizing the inner portion of the midfoot, in which three situations can be found: flat foot (all midfoot supported on the platform), neutral foot (medial region with partial support of the medial arch on the platform), or hollow foot (midfoot totally without platform support).

2. Podoscopic evaluation method:

All patients underwent the podoscopy exam, and were observed by the four examiners individually, who diagnosed bipodal static support of the feet in three categories: neutral, pronated, or supinated.

We used the Valente classification, in which, for a neutral step, the width of the isthmus would correspond to less than half of the total width of the forefoot. If the width of the isthmus were to exceed half the width of the forefoot, the diagnosis would be a flat foot. If the width of the isthmus was less than 1/3, then hollow foot would be diagnosed.

All patients were examined in front and back orthostasis, respecting the same preestablished position with marks on the appliance to avoid misleading or involuntary positioning.

3. Baropodometric evaluation method:

The volunteers were also subjected to a static baropodometry of examination, using a FOOTWORK Arkipelago (Arkipelago, São Paulo, SP, Brazil) device, with 2,704 sensors with a maximum pressure of $100\,N/cm^2$ by sensor. The electrical signals were captured and sent to a computer that generated an image that was analyzed by the observers, thus defining the type of footprints for each corridor.

4. Radiographic evaluation method

The volunteers performed a profile incidence radiograph of the feet with load to measure the Meary angles and calcaneal pitch, previously made by one of the examiners, and checked by a second one; according to such angles, they arrived at the diagnosis for each step, as follow: pronated with pitch less than 10 degrees and Meary smaller than -4 degrees; supinated with pitch greater than 30 degrees and Meary greater $+4$ degrees; neutral (normal in the literature) with pitch 10 to 30 degrees and Meary -4 to $+4$ degrees, according to the angular classification already established in the literature.[11] The methods for measurement are described in ►**Figure 1**.

Statistical Analysis

Initially, all variables were analyzed descriptively. For quantitative variables, this analysis was performed by observing the minimum and maximum values and calculating means, standard deviations and medians. For the qualitative variables, the absolute and relative frequencies were calculated.

Agreement between observers was assessed using the weighted Kappa agreement coefficient (κ),[12] whose interpretation is:

$\kappa > 0.75$ excellent agreement
$0.4 \leq \kappa \leq 0.75$ good agreement
$0 \leq \kappa \leq 0.4$ marginal agreement

Results

We evaluated 40 patients aged 19 to 61 years (mean 39 years, with standard deviation 10.68 years, and median 39.50 years). Twenty-nine (72.5%) patients were male.

The BMI of the 40 patients ranged from 21.00 to 29.99 kg/m^2 (mean 25.48 kg/m^2, with standard deviation of 2.39 kg/m^2, and a median of 25.50 kg/m^2).

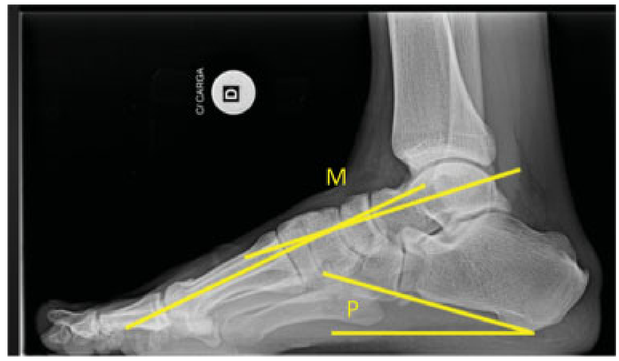

Fig. 1 Measurements of Meary angles (M) and calcaneal pitch (P).

Running frequency ranged from two to five times per week (average 3.13 times per week, with standard deviation of 0.79 times per week, and median of three times per week).

The calcaneal pitch observed on radiography ranged from 12° to 34° (mean 22.70°, with standard deviation 5.54°, and median 22.00°).

In ►**Figure 2** we present the frequency distribution of the 40 patients according to the radiological classification.

Evaluations of these 40 patients were performed through the physical examination, podoscopy and baropodometry, by four observers. In ►**Table 1** we present these reviews.

In ►**Table 2** we present the weighted Kappa agreement coefficient among the four observers in the physical exam. From these values we can conclude that observer 2 has excellent agreement with observers 1 and 3, and among the other observers we have good agreement.

In ►**Table 3** we present the weighted Kappa agreement coefficient among the four observers in podoscopy. From these values we can conclude that there was a good agreement among all observers when compared to each other.

In ►**Table 4** we present the weighted Kappa agreement coefficient among the four observers in baropodometry. From these values we can conclude that observer 1 shows good agreement with observers 2, 3 and 4. Observer 2 shows excellent agreement with observer 3, and good agreement

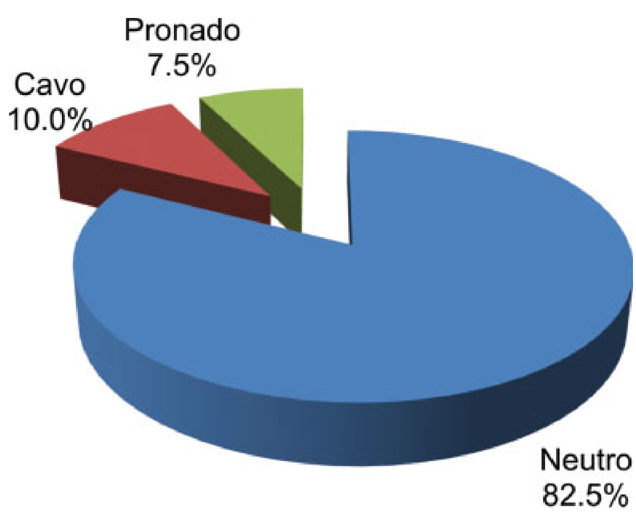

Fig. 2 Relative frequencies of 40 patients according to radiological classification.

Table 1 Absolute and relative frequencies of evaluations of the four observers, according to the physical examination, podoscopy and baropodometry

		Observer							
		1		2		3		4	
Test		n	%	n	%	n	%	n	%
Physical	Neutral	19	47.5	17	42.5	18	45.0	22	55.0
	Cavus	6	15.0	5	12.5	7	17.5	7	17.5
	Pronated	15	37.5	18	45.0	15	37.5	11	27.5
Podoscopy	Neutral	25	62.5	31	77.5	18	45.0	19	47.5
	Cavus	8	20.0	5	12.5	12	30.0	7	17.5
	Pronated	7	17.5	4	10.0	10	25.0	14	35.0
Baropodometry	Neutral	17	42.5	22	55.0	18	45.0	18	45.0
	Cavus	15	37.5	13	32.5	15	37.5	13	32.5
	Pronated	8	20.0	5	12.5	7	17.5	9	22.5

with observer 4, and observer 3 shows excellent agreement with observer 4.

In ►**Table 5** we present the weighted Kappa agreement coefficient among the four observers in radiography. From these values we can conclude that the observers present marginal agreement between the examinations performed and the radiography.

Discussion

Due to the increase in the number of runners, the interest of the professionals who perform the postural diagnosis has been growing. Using methods such as baropodometry, these professionals are able to perform quantitative analyzes in order to better understand the mechanisms that govern gait and running, thus providing injury prevention.[13] The comparison between the data provided by physical examination, podoscopy, baropodometry with radiography with load, through angular measurement, has been already studied in the literature.[14] However, there are few studies showing the effectiveness of the analysis of certain methods that diagnose different types of foot or footprint. For this purpose, we find the report of Buldt et al.,[15] who classified, in their study, foot types through anthropometric measurements associated with baropodometry, showing the pressure differences of this segment between the different types of footprints.

In the present study, we evaluated 40 runners and numerically observed a lower sample of individuals with flat feet,

Table 2 Weighted Kappa index value and respective 95% confidence interval of the four observers in relation to the physical examination

	Observer		
Observer	2	3	4
1	0.78	0.73	0.70
	(0.65; 0.93)	(0.56; 0.89)	(0.53; 0.87)
2		0.77	0.61
		(0.65; 0.90)	(0.44; 0.78)
3			0.69
			(0.52; 0.86)

Table 3 Weighted Kappa index value and respective 95% confidence interval of the four observers in relation to podoscopy

	Observer		
Observer	2	3	4
1	0.50	0.65	0.56
	(0.26; 0.74)	(0.47; 0.83)	(0.37; 0.75)
2		0.45	0.41
		(0.23; 0.67)	(0.20; 0.61)
3			0.70
			(0.56; 0.85)

Table 4 Weighted Kappa index value and respective 95% confidence interval of the four observers in relation to baropodometry

	Observer		
Observer	2	3	4
1	0.71	0.74	0.70
	(0.56; 0.86)	(0.60; 0.88)	(0.55; 0.86)
2		0.84	0.74
		(0.71; 0.97)	(0.59; 0.89)
3			0.81
			(0.69; 0.94)

Table 5 Weighted Kappa index value and respective 95% confidence interval for the four observers in relation to radiography

	Test		
Observer	Physical	Podoscopy	Baropodometry
1	0.23	0.18	0.19
	(-0.02; 0.48)	(-0.16; 0.52)	(-0.11; 0.49)
2	0.15	0.00	0.00
	(-0.10; 0.40)	(-0.50; 0.49)	(-0.37; 0.34)
3	0.15	0.13	0.00
	(-0.13;0.43)	(-0.19; 0.46)	(-0.32; 0.29)
4	0.25	0.15	0.13
	(0.03; 0.46)	(-0.14; 0.45)	(-0.21; 0.48)

which corroborates the literature data,[15] with most individuals having a neutral footstep.

When we analyzed the interobserver Kappa coefficient by physical examination, we noticed excellent agreement between researchers 1, 2, and 3. To try to interpret this result, the observers were exposed, and it was inferred that the lower expertise of examiner 4 could have influenced the interpretation of the variables studied, although a previous explanation has been given as to how the different analyzes should be performed. Considering podoscopy, we observed a good agreement among observers for the diagnosis of foot type. Looking at the baropodometry method alone, we found that there was excellent agreement among most observers.

Surprisingly, when we used radiographic measurements to classify foot type according to Meary angles and calcaneal pitch, and compared the results obtained through physical examination, podoscopy, and baropodometry, we observed an agreement, according to the Kappa coefficient, marginal.

The result presented is extremely interesting, leading us to reflect on the diagnosis of foot type using only an isolated method such as baropodometry. We noted in the work of Ward et al.[16] that baropodometry as an isolated diagnostic method has low reproducibility and applicability.[17] However, in the present study, considering the sum of the information from the physical examination, and of podoscopy and baropodometry, we obtained a very appropriate agreement between the observers. But, when we compared all the methods used with the results of the radiographic angular measurements, we observed a significant discrepancy in the results; thus, we imagine that there may be an intrinsic difficulty in categorizing the different types of feet by measurements of calcaneal pitch and Meary angle because there would be a very wide range of values obtained for the flat foot and the hollow foot, causing overestimation of neutral feet. Perhaps if another method of radiographic classification could be applied, a more accurate diagnosis of foot type could be achieved, expecting, thus, an improvement in the agreement rates of the methods used with the radiographic classification.

The second possibility for discussion is due to the importance of performing a radiograph with load for the diagnosis of foot type through angular measurement, with other methods, such as physical examination, podoscopy, and baropodometry, counting for complement to the diagnosis.

Another advantage that the use of radiography could provide would be to clear up the errors of a potentially misclassification categorization, which could result in the inappropriate use of a certain type of footwear or insole, causing biomechanical injury, and consequently, lesions.

We believe that our work presents some aspects that should be improved considering the continuity of this research project. Despite the results obtained, there would be a need to expand the sample so that a more robust result could be obtained. For this, an enlarged sample, based on the results of previous sample calculation, and the study of different categories, such as studying separately the gender involved, and narrowing down the age groups, could provide more detailed information about the runners. In addition, we did not evaluate individuals dynamically, which may modify the results, as there is a change in the type of footprint along the normal phases of gait, and these positions may be variable between people.

Conclusion

We obtained excellent agreement among observers when considering physical examination, podoscopy, and baropodometry for the diagnosis of runners' footprint type. However, when comparing the results obtained from the physical examination, baropodometry, and podoscopy with the radiographic measurements, the agreement for the diagnosis of the footstep type was low.

Conflicts of interest
The authors have no conflict of interests to declare.

References

1 Neto J Junior, Pastre CM, Monteiro HL. Alterações posturais em atletas brasileiros do sexo masculino que participaram de provas de potência muscular em competições internacionais. Rev Bras Med Esporte 2004;10(03):195–198
2 Lun V, Meeuwisse WH, Stergiou P, Stefanyshyn D. Relation between running injury and static lower limb alignment in recreational runners. Br J Sports Med 2004;38(05):576–580
3 Mutti D. Futsal da iniciação ao alto nível. 2a ed. São Paulo: Phorte; 2003
4 Mattos HM, Pryzsiezny WL. Análise baropodométrica da influência podal na postura. Rev Ter Man Fisioter Manip 2004;3(01): 240–246
5 Guimarães GV, Freitas HF, Silva PR, Teixeira LR. Pés: devemos avaliá-los ao praticar atividade físico-esportiva? Rev Bras Med Esporte 2000;6(02):57–59
6 Nigg BM, Khan A, Fisher V, Stefanyshyn D. Effect of shoe insert construction on foot and leg movement. Med Sci Sports Exerc 1998;30(04):550–555
7 Mansour E, Yaacoub JJ, Bakouny Z, Assi A, Ghanem I. A podoscopic and descriptive study of foot deformities in patients with Down syndrome. Orthop Traumatol Surg Res 2017;103(01): 123–127
8 Libotte M. Podoscopíe électronique. Encyclopédie médico-chirurgicale: Kinésithérapie rééducation fonctionnelle. Paris: Elsevier; 2000

9 Stebbins JA, Harrington ME, Giacomozzi C, Thompson N, Zavatsky A, Theologis TN. Assessment of sub-division of plantar pressure measurement in children. Gait Posture 2005;22(04):372–376

10 Leite NM, Faloppa F. Propedêutica ortopédica e traumatológica. Porto Alegre: Atmed; 2013

11 Coughlin MJ, Mann RA, Saltzman CL. Surgery of the foot and ankle. 8th ed. Philadelphia: Mosby-Elsevier; 2007

12 Rosner BA. Fundamentals of biostatistics. 4th ed. Belmont: Duxbury Press; 1995

13 Yang DJ, Park SK, Kim JH, Heo JW, Lee YS, Uhm YH. Effect of changes in postural alignment on foot pressure and walking ability of stroke patients. J Phys Ther Sci 2015;27(09):2943–2945

14 Robinson CC, Balbinot LF, Silva MF, Achaval M, Zaro MA. Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. J Diabetes Sci Technol 2013;7(05):1113–1121

15 Buldt AK, Forghany S, Landorf KB, Levinger P, Murley GS, Menz HB. Foot posture is associated with plantar pressure during gait: A comparison of normal, planus and cavus feet. Gait Posture 2018; 62:235–240

16 Ward ED, Phillips RD, Patterson PE, Werkhoven GJ. 1998 William J. Stickel Gold Award. The effects of extrinsic muscle forces on the forefoot-to-rearfoot loading relationship in vitro. Tibia and Achilles tendon. J Am Podiatr Med Assoc 1998;88 (10):471–482

17 Baumfeld D, Baumfeld T, da Rocha RL, et al. Reliability of baropodometry on the evaluation of plantar load distribution: a transversal study. BioMed Res Int 2017;2017:5925137