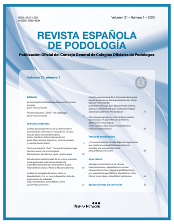

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Observational study of the plantar fat pad distension in healthy patients in sitting position, bipodal and monopodal standing

Estudio observacional de la distensión de la grasa plantar en pacientes sanos en sedestación, carga bipodal y monopodal

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Keywords:

Plantar fat, distention, sitting, standing, monopodal standing, Clarke angle, Chippaux-Smirack index, Staheli index.

Abstract

Introduction: This work aimed at studying the variation of the distention of plantar fat in sitting, bipodal and monopodal standing, and to relate these changes with the footprint and the posture of the foot.

Patients and methods: 14 healthy adults participated in the study. Their plantar footprint was scanned in bipodal standing, monopodal standing, and seated. In these footprints, the Clarke angle, Chippaux-Smirack index, Staheli index, forefoot width, itsmo width, and heel width, were measured. And these measures were compared between the three weightbearing conditions.

Results: For the Clarke angle, the Chippaux-Smirack index and the Staheli index, significant differences were observed in all measurements, except the comparison between sitting and bipodal standing in the Staheli index. The correlations in the bipodal-monopodal modality were all strong ($r > 0.8$). For the forefoot, isthmus and heel widths in all three positions, we obtained statistically significant differences in all measurements. Direct strong correlation between FPI and Clarke angle in monopodal weightbearing ($r = 0.69$) was obtained, and strong inverse correlation between FPI and Staheli angle in bipodal weightbearing.

Conclusions: The study results suggest that there were changes in the plantar footprint in the different weightbearing conditions as the load increased.

Palabras clave:

Grasa plantar y distensión, sedestación, carga bipodal, carga monopodal, ángulo de Clarke, índice de Chippaus-Smirack, índice Staheli.

Resumen

Introducción: Este trabajo se planteó con el objetivo de estudiar la variación de la distensión de la grasa plantar en sedestación, carga bipodal y monopodal, y relacionar estos cambios con la huella plantar y la postura del pie.

Pacientes y métodos: Participaron en el estudio 14 adultos sanos a los que se les escaneó la huella plantar en carga bipodal, en carga monopodal y en sedestación. En estas huellas se midieron el ángulo de Clarke, índice de Chippaux-Smirack, índice de Staheli, anchura del antepié, anchura del itsmo y anchura del talón, y se compararon estas medidas entre las tres situaciones de carga.

Resultados: Para el ángulo de Clarke, el índice de Chippaux-Smirack y el índice de Staheli se observaron diferencias significativas en todas las mediciones, excepto la comparación entre sedestación y bipedestación bipodal en el índice de Staheli. Las correlaciones en la modalidad bipodal-monopodal fueron todas fuertes ($r > 0.8$). Para las anchuras del antepié, del istmo y del talón en las tres posiciones, obtuvimos diferencias estadísticamente significativas en todas las mediciones. Se obtuvo correlación fuerte directa entre FPI y ángulo de Clarke en carga monopodal ($r = 0.69$), y correlación fuerte inversa entre FPI y ángulo de Staheli en carga bipodal.

Conclusiones: Los resultados del estudio sugieren que existen cambios en la huella plantar en las diferentes posiciones. Se observan cambios en la misma, a medida que aumenta la carga.

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INTRODUCTION

The heel is the part of the foot that contacts the ground first and therefore the first to receive the reaction forces [1.] When it comes into contact with the ground, the forces it supports are approximately 85-110 % of the body weight, reaching 250 % when running[2]. In a male of 70 kilograms, the heel area has an average of 23 cm^2, and the pressure it can reach is 3.3 kg/cm^2. This pressure can raise maximums in some areas of 5 Kg/cm2 and even double during running[3]. In addition, it is estimated that there are about 721 heel shocks per kilometer during the ride[4].

The plantar fat pad (PFP) covers from the calcaneous[5] to the metatarsal zone[6], functioning as a shock absorber[5]. It plays an important role in the support of body weight and allows the gait to occur without pain. This is mainly due to its structure composed of fat cells encapsulated in reticulated fibroelastic structures 6. Deterioration of the plantar fat pad plays an important role in the pathogenesis of both metatarsalgias[7] and heel pain[8].

Metatarsalgia and painful heel syndrome are common pathologies of daily occurrence in practice, and in many cases their origin and diagnosis is controversial[5,9]. There are current studies about the loss of the plantar fat pad as a result of metatarsalgias or painful heel syndrome[4,8-11]. The studies focus mainly on observing changes in thickness and their properties[1,3,4,8-12].

In a study carried out in Australia of the prevalence and correlation of foot pain in a population where 3206 people were randomly chosen, 3.6 % had heel pain[13], and American studies indicate that up to 7 to 10 % of adults suffer from talar pain[14].

Diabetic patients are a population group we must take into account for keeping properties of the plantar fat pad in correct conditions. Heel pressure ulcers are the second most common location of this type of injury[15].

Knowledge of changes in the width of plantar fat through the footprint on healthy subjects can provide us with normal data that would then be used for preventive purposes on different groups of patients (diabetics, patients with neurological impairment, patients with heel pain, etc.). Determining these changes through the footprint is a simple and economical method, applicable in any situation by pedigraphy.

That is why we are considering a research to study the possible changes that occur in the plantar footprint on healthy patients, both in sitting position and in monopodal and bipodal standing. In addition, the foot posture will be used to check the correlation between the different types of feet and the behavior of the fat pad located under the sole of the foot.

The objectives of our research were to study the variation of the strain of plantar fat in sitting position, bipodal and monopodal standing; analyze clarke's angle modification, Chippaux-Smirack index, Staheli index in sitting position, bipodal and monopodal standing; and determine the relationship between plantar footprint changes and foot posture.

PATIENTS AND METHODS

This can be defined as a descriptive, cross-sectional and observational study, framed within a pilot study[16]. The overall sample of the study is composed of 14 people (7 men and 7 women) ranging in age between 24.43 ± 2.22 and 24.86 ± 2.8 years respectively, of whom we have taken as a sample the plantar footprint of the right foot. Study participants went to the Clinical Area of Podiatry of the University of Seville for a period from July 2014 to September 2014, where they were informed and given an informed consent document with the objectives and possible risks of this investigation. This study meets all bioethical human research requirements according to the Helsinki Declaration, which was approved by the Directorate of the Clinical Area of Podiatry of the University of Seville.

As an inclusion criteria, healthy patients between the ages of 18 and 40 years. The age limit was set as 40 years because from this age it is estimated that PFP[6] begins to deteriorate. And the exclusion criteria were patients with rheumatoid arthritis, diabetes, neuropathy or vascular disorder, presence of any dermal alteration that could alter the image of the footprint, patients with hiperlaxaty ligament syndrome, prior history of osteoarticular foot surgery, people with stability problems, and requiring orthopedic devices.

The variables we have considered to take into account in the study are: age, weight, sex, height, body mass index, Foot Posture Index (FPI), Clarke angle, Chippaux-Smirack index, Staheli index, forefoot width, isthmus width and heel width. Foot Posture Index or Postural Foot Index (PPI) is a diagnostic clinical tool whose purpose is to quantify the degree of neutral, pronate or supined position of the foot. It is a simple method of scoring various foot posture factors by a simple and quantifiable result[17]. The score is between -12 and + 12. Values around 0 will match a neutral foot, with those of a pronated foot approaching +12, and a supinated foot at -12.

The digital plantar scanner CbsScanFoot model EDP-G2-A was used for obtaining the footprint, guaranteeing its intra and interobserver reliability for the recording of the plantar footprint the work of Papuga et al.[18].

Each patient took the print in different positions:

a) In bipodal standing: Patient in bipedal position, with his eyes in front and with his arms relaxed, respecting his angle and base of gait, so that obtaining the footprint is the most real to his position in static (Figure 1).
b) In monopodal stading: Patient in bipedal position, looking ahead, and clutching to maintain his stability on side railings. To obtain the footprint, the patient is asked to flex the left knee so that only the right foot is contacted with the ground (Figure 2).
c) In sitting postion: Patient sitting in a chair with its back attached to the back, arms in position of about 90º, so that hands are placed on the thigh, with the knees flexing, in a relaxed position and with the foot at a right angle relative to the floor of the scanner (Figure 3).

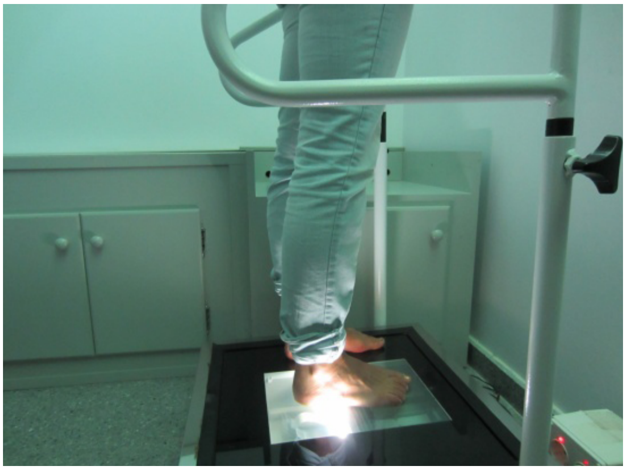

Figure 1. Obtaining bipodal load footprint.

Figure 2. Obtaining monopodal load footprint.

Once the plantar footprints were obtained, variables were measured on them. To carry out this task, AutoCAD® program was used, and we proceed to the calculations of the different measurements with it: Clarke angle, Chippaux-Smirack index, Staheli index, forefoot width, width of the isthmus and heel width.

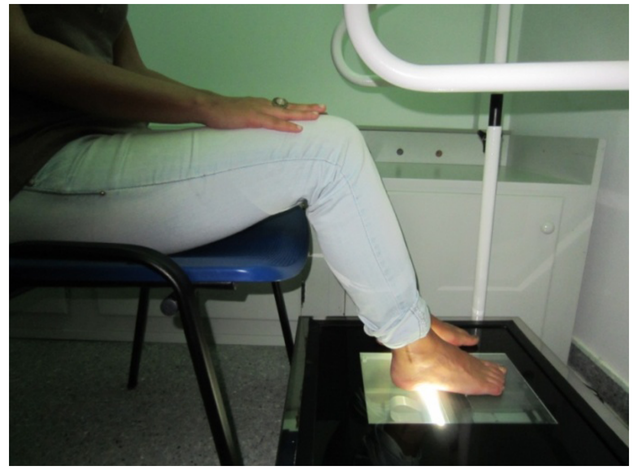

Figure 3. Obtaining sitting position footprint.

The statistical analysis was performed with the SPSS version 18 statistical package for Windows. Total sample is described taking into account age, sex, BMI and IPP. Measurements taken on the footprint are described in both bipodal and monopodal standing. The Shapiro-Wilks test was used to determinate the normality of the sample. The student t test were performed for comparing the different measurements and their position and the variables: angle of Clarke, index of Chippaux-Smirrack, index of Staheli, forefoot width, width of the isthmus, width of the heel. To study possible correlations between variables, Pearson correlation coefficient was used.

RESULTS

The sample studied consisted of 14 people, 7 men and 7 women, with the average age of 24.43 ± 2.22 and 24.86 ± 2.8 years respectively. The average BMI of the people studied was 22.50 ± 2.79.

With regard to the FPI, the average for pronators subjects was 7.5 ± 1.08, 1 for neutrals and -2 ± 1 for supinators. Table I shows the descriptive statistic of the variables studied for each position.

Table I. Descriptive statistics of the variables in the three positions

	Bipodal standing	Monopodal standing	Sitting position
	Mean ± SD	Mean ± SD	Mean ± SD
Clarke angle	56,4 ± 6,47	53,41 ± 7,47	73,35 ± 5,97
Chippaux-Smirack index	20,56 ± 6,48	24,86 ± 7,77	16,47 ± 4,32
Staheli index	0,36 ± 0,12	0,43 ± 0,15	0,31 ± 0,08
Forefoot width	9,13 ± 0,57	9,23 ± 0,64	8,82 ± 0,58
Istmmus width	1,89 ± 0,67	2,31 ± 0,81	1,44 ± 0,35
Heel width	5,05 ± 0,53	5,22 ± 0,51	4,55 ± 0,41

SD: Standard deviation.

Table II. T-Student and Pearson coefficient in the variables Clarke angle, Chippaux-Smirrack index and Staheli index

	Clarke Angle		Chippaux-Smirrack index		Staheli index	
	p	r	p	r	p	r
Bipodal-Monopodal	0,02	0,83	<0,01	0,89	<0,05	0,89
Monopodal-Sitting	<0,01	0,17	<0,05	-0,13	0,02	-0,10
Sitting-Bipodal	<0,01	0,38	0,05	0,10	0,19	0,11

Table III. T-Student and Pearson coefficient in the variables forefoot width, isthmus width, heel width

	Forefoot width		Isthmus width		Heel width	
	p	r	p	r	p	r
Bipodal-Monopodal	0,02	0,98	<0,01	0,91	<0,02	0,95
Monopodal-Sitting	0,001	0,96	<0,03	-0,02	<0,01	0,79
Sitting-Bipodal	0,001	0,98	0,03	0,18	<0,01	0,89

Table IV. FPI correlation with Clarke angle, Chippaux-Smirrack index and Staheli index in their different positions

Pearson correlation	Bipodal stadning	Monopodal standing	Sitting position
FPI and Clarke Angle	0,52	0,69	0,36
FPI and Chippaux-Smirrack index	-0,12	-0,11	-0,45
FPI and Staheli index	-0,76	-0,12	-0,47

Subsequently, t-Student was applied for related samples to determine whether there were significant differences between the variables studied for each position, as well as Pearson's coefficient to study the correlation between them (Table II and III).

For Clarke's angle at different positions, we observe significant differences in all measurements ($p<0.05$). In relation to correlations in the bipodal-monopodal position, a strong relationship was found ($r = 0.83$).

In the Chippaux-Smirrack index we had statistically significant differences at all measurements ($p<0.05$). With regard to correlations in the bipodal-monopodal modality, a strong relationship was found ($r = 0.89$).

In the Staheli index in the different positions we obtained statistically significant differences ($p<0.05$), except the comparison between sitting position and bipodal standing. In relation to correlations in the bipodal-monopodal modality, a strong relationship was found ($r = 0.89$).

For forefoot, isthmus and heel widths in the different positions, we obtained statistically significant differences at all measurements ($p<0.05$). Regarding the Pearson coefficient, values were very high for the forefoot and backfoot width, among all positions; for the width of isthmus the value was high when comparing bipodal and monopodal.

When analyzing correlation between the FPI and Clarke's angle, The Chippaux-Smirrack index, and the Staheli index in every studied position, we observed that there was a strong direct correlation between FPI and Clarke's angle in monopod load (r x 0.69). On the other hand, we observed strong inverse correlation between FPI and Staheli angle in bipodal load (Table IV).

Finally, the percentage of variation was calculated with respect to the studied variables between the monopodal and bipodal position (Table V).

DISCUSSION

Recording variations in the plantar footprint in relation to the patient's position can be a way to determine whether the patient can develop foot pathologies. Metatarsalgias and painful heel are common pathologies of consultation, which origin is sometimes unknown[5,9]. Being able to determine whether plantar fat has lost its buffering characteristics would help to understand the origin of these pathologies[4,8-11].

Determining the plantar footprint using a scanner is a quick method to computerize the footprint and use digital media for measurement. The studies focus mainly on observing the changes in thickness and its properties and in this way it is easy to carry it out[1,3,4,8-12].

It was observed that there was an increase in forefoot and heel width values as load increased. In the forensic study carried out by Reel et al.[19] whose objective was to estimate the height of people from anthropometric measurements of

Table V. Variation of percentages between bipodal and monopodal standing

	Bipodal standing	Monopodal standing	Difference	%
Clarke angle	56,4°	53,41°	2,99°	-5,30 %
Chippaux-Smirrack index	20,56 %	24,86 %	-4,3 %	20,91 %
Staheli index	0,36 %	0,43 %	-0,07 %	19,44 %
Forefoot width	9,13 cm	9,23cm	-0,10 cm	1,09 %
Isthmus width	1,89 cm	2,31cm	-0,42 cm	22,22 %
Heel width	5,05 cm	5,22 cm	-0,17 cm	3,36 %

the foot, pedigraphies were performed in static and dynamic and the width of the forefoot and heel was calculated, obtaining an average of 93.22-7.39 mm and 49.68-5.33 mm respectively. In relation to the values of our study, we observed that values increased as the load increased and, furthermore, those obtained in monopodal standing resembled those obtained by Reel in dynamics, so we can interpret the expansion of the foot in monopodal position and dynamic are similar, being able to study how it would behave standing in dynamic by observing him in monopodal standing.

As for the angle of Clarke, means obtained in our study were 73.35 ± 0.08° in sitting position, 56.4 ± 6.47° in bipodal standing and 53.41 ± 7.47° in monopodal standing. In this way, we observe that arc flattening occurred as load increases, which corroborates our hypothesis, thus varying the footprint in the different positions. According to the classifications of Bavor and Horawa (1974) and Jawroski (1987) 0-29° would be a flattened foot, 30-50° would be a normal foot and from 50° would be associated with a cavo foot[20].

In the study of Shiang et al.[21] where different predictor parameters of arc height were evaluated, footprints were obtained by pressure platform and bipodal standing. In relation to Clarke's angle, they had an average of 46.29 ± 9.75°. If we compare them with the data from our study, we observed that our average was approximately higher than 10°, which may be due to the use of the platform used in the study of Shiang et al.[21] was composed of sensors that at very low pressures such as the that occur in the marginal areas of the footprint, does not record them giving a image of footprint more cava than the one recorded by the scanner used by us, so its values of Clarke's angle are going to be lower.

The study carried out by López et al.[22] studied the footprints of young football players and non-players. Prints were obtained through pedigraphy, and always in bipodal standing. Regarding Clarke's angle on the right foot, it was 47.8 ± 9.8°. We could consider the variations of this data are mainly associated with the difference in the use of pedigraphy instead of electronic podiscope, since as collected from fascione et al.[23] the data collected with various techniques demonstrated differences, so the interchangeable use of the values obtained from the different methods of obtaining the footprint is not recommended. Despite this, there are fewer differences when we compare our data with those of López et al.[22] than with those of Shiang et al.[21], which confirms the idea that the footprint registered by platforms may not be real.

Regarding the index of Chippaux-Smirracklas averages obtained in our study were in sitting position 16.47 x 4.32 %, in bipodal load 20.56 x 6.48 %, and in monopod load 24.86-7.77 %. As with Clarke's angle, as the charge increases, the footprint flattens and changes. The Chippaux-Smirrack index was also evaluated in the work carried out by López et al.[22]. Means obtained were 31 ± 9.5 %. Chippaux-Smirrack index was also evaluated in Shiang et al. study[21] with means of 68 ± 21 %. As in the Angle of Clarke our data are not comparable to those of other studies where different fingerprinting instruments have been used.

In our study, we obtained Staheli index values of 0.31 ± 0.08 % in sitting position, 0.36 ± 0.12 % in bipodal load, and 0.43 ± 0.15 % in monopodal load. In the work of Shiang et al.[21] Staheli index it was also used as an arc predictor, obtaining an average of 0.82 ± 0.24 %. It can also be said, as in the case of Clarke's angle or Chippaux-Smirrack index, that the data obtained are not comparable when using different fingerprinting methods.

It is significant that in both Shiang's study and ours, mean values obtained indicate footprints of cave feet according to normal values, so we consider whether there is currently a tendency of elevation of the arc physiologically by various factors.

When applying the t-student for dependent samples, we find that there was a significant statistical difference in each position ($p<0.05$) at both the Angle of Clarke and in the Index of Chippaux-Smirrack and that of Staheli, except in the latter in the comparison between sitting and bipodal position ($p=0.188$). This indicates that the expansion of the soft parts was significant when it came to dynamics.

When applying the t-Student at all measurements of forefoot, isthmus, and heel width in the different positions, significant differences ($p<0.05$) were observed, as well as strong correlations in the three measurements in their different positions, except in the width of the isthmus in the sitting modalities.

A strong direct correlation was observed between the FPI variables and Clarke angle, except in sitting position. As we have already mentioned, Clarke's angle indirectly measures the height of the internal longitudinal arc[24], and the height and congruence of the arc is one of the parameters used by the FPI. That is why we can say that the calculation of Clarke's angle, from obtaining the bipodal or monopodal standing footprint, was correlated with the FPI.

Therefore we could say about the 3 different options, that the one that can best predict the height of the arch, since it is more reliable in correlation to the FPI, is the angle of Clarke, as long as we obtain the plantar footprints in bipodal or monopodal load.

From the data obtained, we can calculate the percentage of modification that variables suffer as load increased. An increase (1.09 %) was observed in the width of the forefoot because by increasing the load the plantar fat expanded. In this section lies the importance of it when it comes to developing metatarsalgia. A non-variation of the expansion of the same or, conversely, an exaggerated expansion would increase pressure peaks at the metatarsal level. On this subject we can contrast the studies of Waldecker[10] y Abouaesha et al[25]. The first one concluded in his work that there was no association between a decrease in the thickness of PFP, and metatarsalgias, neither with the intensity nor frequency of them. The second one concluded that there was a strong inverse relationship between the thickness of the PFP and dynamic foot pressure measurements. We would be more in favor of the latter because pathologies can appear in the metatarsal area if we do not keep the plantar fat in proper condition. This would be as a result of the loss of cushioning capacity.

At the level of the isthmus an increase was observed 22 %, being the structure that suffered the greatest variation, because as a support structure, it will be more requested as we increase the load widening.

The width of the heel also increased (3.36 %), due to the importance of the expansion of plantar fat. With regard to this and as at the metatarsal level the malfunction of this structure at this level could generate pathologies8. It could also be explained that there is a further increase in expansion at the heel level (3.36 %) than the forefoot (1.09), mainly due to the different thickness of the structures at this level. At the metatarsal level it is estimated to be between 0.5 and 1.5 mm[9,10,26] and at heel level between 1.5 and 1.8 mm[27-29]. This shows the shocking role so important that the heel has in the heel contact phase and the more propulsive function that the forefoot buffer in the take-off phase.

The results of the study suggest that there are changes in the plantar footprint in the different positions. Changes are observed, as the load is the result of the behavior of musculoskeletal structures and PFP. With regard to the latter, the study, when using young and healthy people, has tried to present the behavior that it manifests within normality.

The limitations of this work were the low size of the sample and the healthy young patients used for the study. Subsequent studies would be interesting to compare these behaviors with those of population groups in which PFP may be affected (diabetics, neuropathy, vascular disorders) or with elderly population groups, in which PFP begins to degenerate. Such a comparison could also bring reality closer to whether changes in PFP correlate with various pathologies (metatarsalgia, ulceration, talalgia).

Another aspect that is interesting and that will be included in future studies is to compare the behavior of the foot at the prono-supinatory level, being able to use parameters such as the Helbing line, which would allow us to observe the degrees of pronation of the backfoot, and whether these have a greater or lesser impact on the changes to the plantar footprint.

In conclusion, we have determined that plantar fat at heel level undergoes an expansion 0.17 cm, the forefoot 0.10 cm and isthmus 0.42 cm; Clarke's angle also decreases by 2.99º, the Chippaux-Smirrack index increases by 4.3 % and Staheli's rate increases by 0.07 %, all of them go from a bipodal to monopodal load state. When comparing the FPI with the observed variations, we highlight the correlation between that parameter with Clarke's angle in monopodal load. This is due to 71.4 % of the subjects were pronators and being at maximum load (monopodal) the angle reflected that pronation. This is not the same with the Staheli or Chippaux-Smirrack indexes, as these variables are obtained from the relationship between the isthmus and heel or forefoot respectively and those widths do not have to be modified when proning.

CONFLICT OF INTEREST

The authors do not present any conflict of interest.

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