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ORIGINAL ARTICLE

Correlation Between Plantar Fascia Thickness and Other Variables in Women Diagnosed with Plantar Fasciopathy

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Abstract

Objectives: The objective of this study was to explore the relationship between plantar fascia (PF) thickness and various factors including pain, function, anthropometric parameters, and other variables in women diagnosed with plantar fasciopathy.Methods: A total of 37 feet from female patients were randomly selected for this investigation. Utilizing ultrasound, the thickness of the PF was meticulously measured. Subsequently, the correlation between PF thickness and several factors such as pain intensity, functional impairment, height, age, weight, biconvexity of the plantar fascia, duration of the disease, recurrence of plantar fasciopathy, and daily activity levels were analyzed.Results: The findings of this study unveiled a significant positive correlation between PF thickness and several parameters. Specifically, there was a notable correlation with pain intensity, where increased thickness corresponded to heightened pain levels. Additionally, PF thickness exhibited positive associations with height, age, and weight, indicating that these anthropometric factors may influence PF thickness. Moreover, the biconvexity of the plantar fascia, disease duration, and recurrence of plantar fasciopathy showed correlations with PF thickness, suggesting potential implications for disease progression and management. Furthermore, the study identified a relationship between PF thickness and daily activity levels, underscoring the impact of physical exertion on PF health. Notably, the presence of hyperemia

in the plantar fascia, as determined by power Doppler ultrasound, also showed a correlation with PF thickness, highlighting potential vascular implications in plantar fasciopathy.
Conclusion: In conclusion, this study provides valuable insights into the multifaceted relationship between PF thickness and various clinical parameters in women with plantar fasciopathy. Understanding these correlations may aid in the development of more targeted and effective management strategies for this debilitating condition.

Introduction

It is estimated that 10% of the population experiences heel pain at some point in their lives, although there are few available data from high-quality epidemiological studies (1). Plantar fasciitis is the most common cause of heel pain in the United States and affects more than 2 million people per year. Its high prevalence in the U.S. (approximately 4% to 7%) results in an annual expenditure of $284 million on treatments (2). The incidence of plantar fasciitis is higher among people aged 40 to 60, with a female-to-male predominance of 2:1 (1,3). Plantar fasciitis accounts for 25% of all foot injuries in athletes, among whom it is also the most frequent cause of heel pain (4).

Typically, pain can be reproduced by palpating the inferomedial tubercle of the calcaneus at the site of insertion of the plantar fascia (PF) into the heel bone. Passive dorsiflexion of the foot and toes can reproduce the pain. The Windlass or Jack test specifically involves actively reproducing the pain by passively dorsiflexing the first metatarsophalangeal joint, and is positive if pain is elicited (5).

The PF is characterized as a fibrous aponeurotic thickening that plays a fundamental role in the static support of the longitudinal arch of the foot, while also absorbing loads associated with weight-bearing and physical activity (6). In anatomical nomenclature, only the term "plantar aponeurosis" is used, classifying it within the chapter of "fasciae". Nevertheless, various anatomy books describe the structure interchangeably as "plantar fascia" and "plantar aponeurosis". It is relevant to note that the term "aponeurosis" refers to a tissue with a unidirectional arrangement of its collagen fibers, while "fascia" represents a structure with multidirectional fibers (7).

Plantar fasciitis is caused by the degeneration of the PF as a result of repetitive microtears due to trauma or repeated overloading, rather than a primary inflammatory reaction (8), hence the term plantar fasciosis has been coined in the literature and more recently plantar fasciopathy. The exact cause of plantar fasciosis is currently unknown, although it is believed to be

multifactorial, with abnormal biomechanics and delayed collagen healing of the fascia as possible contributors (9).

Risk factors include excessive foot pronation or flat feet, high arches, Achilles tendon or gastrocnemius muscle tightness, leg length discrepancy, obesity, overtraining, prolonged standing or walking, and improper gait (10–13). Most patients seek treatment within the first year and, in the vast majority of cases, the pain resolves within the first year. Multiple treatments have been proposed in the medical literature, and most specialists opt to initiate conservative treatment, which is effective in 70-80% of cases. The most commonly used approaches are physiotherapy, plantar orthotics, gastrocnemius stretching, and corticosteroid injections (12).

Studies have shown similar accuracy and effectiveness of musculoskeletal ultrasound in morphological evaluation and diagnosis of plantar fasciitis compared to magnetic resonance imaging (14) and even better following other references (15). Ultrasound is generally preferred due to its certain advantages over magnetic resonance imaging, such as its non-invasiveness, lower cost, and good patient tolerance. Ultrasound has reported thickening of the PF and tissue abnormalities, hypoechoic changes, perifascial fluid accumulations, and subcalcaneal bone spurs (14,15).

A consistent clinical association has been found between higher body mass index and plantar fasciopathy. This association may differ between patients classified as athletes or non-athletes (16).

It appears that healthy men and women have similar PF thickness. However, as plantar fasciopathy develops, men tend to develop thicker plantar fasciae than women, which could have implications for the treatment chosen by the therapist (17).

Mild intrafascial or perifascial hyperemia may occur with plantar fasciitis, but most individuals will not show increased soft tissue vascularity when evaluated with routine Doppler ultrasound. Health professionals treating plantar fasciitis should not consider a positive Doppler signal as essential for the diagnosis of the condition, but rather as a feature that may help refine the treatment plan for an individual patient (18).

The aim of this study is to demonstrate the correlation between PF thickness data measured by ultrasound and other variables measured in the study.

Materials and Methods

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Study Design and Patients

All subjects needed to meet the inclusion criteria: 1) patients had to be adult women. Additionally, 2) they also had to present symptoms compatible with plantar fasciopathy and a 3) PF thickness greater than 0.4 centimeters as described by McMillan et al. (19), and 4) accept their participation in the study.
Exclusion criteria were 1) systemic diseases or non-podiatric morpho-functional alterations that may have an impact on the ankle and foot and could lead to significant clinical discrepancies in lower limbs, 2) evident clinical asymmetries, or scoliosis, 3) having received any treatment (medical, orthopedic, and/or invasive) on the foot in the last three months, 4) plantar fasciopathy associated with another condition such as nerve entrapment, and 5) patient difficulties in understanding the instructions to follow during treatment.

To be included, patients had to be adult women. Additionally, they also had to present symptoms compatible with plantar fasciopathy and a PF thickness greater than 0.4 centimeters as described by McMillan et al. and accept their participation in the study.
Exclusion criteria were systemic diseases or non-podiatric morpho-functional alterations that may have an impact on the ankle and foot and could lead to significant clinical discrepancies in lower limbs, evident clinical asymmetries, or scoliosis, having received any treatment (medical, orthopedic, and/or invasive) on the foot in the last three months, plantar fasciopathy associated with another condition such as nerve entrapment, and patient difficulties in understanding the instructions to follow during treatment.

All patients underwent a clinical evaluation and an ultrasound evaluation. The clinical evaluation was based on a visual analog scale (VAS) (20) (0-10) and the Foot Function Index (FFI) (21,22), which evaluates function on a scale of 0 to 100. Subjects were also classified as sedentary, active, or athletes based on their daily physical activity according to their subjective perception, as well as whether the disease appeared for the first time, was a recurrence, or was chronic (23). Weight and height, the presence of vascularization in the PF visualized with ultrasound (24) at the time of the initial evaluation, and the biconvex (25) or flattened shape of the PF were also evaluated.

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Our clinical trial was conducted in strict accordance with the ethical principles established in the Declaration of Helsinki of 1964, with special emphasis on its most recent revisions in the 2013 version, which ensure the protection and respect of participants in medical research. Ethical approval was granted by the Research Ethics Committee of our center, under protocol number 2093-N-21. All participants provided voluntary informed consent before being included in the study, and they were assured of the confidentiality and security of their clinical and radiological data.

The clinical trial was conducted on a sample of 37 female patients diagnosed with plantar fasciitis, who volunteered to participate in the research. These patients presented characteristic symptoms of this condition, such as acute pain when taking the first steps after rest or getting up from prolonged sitting. Additionally, they reported tenderness to touch in the proximal PF area, and indicated that the pain intensified throughout the day.

The initial diagnosis was based on the evaluation of clinical symptoms, which were confirmed by ultrasound using a high-resolution device, specifically the Alpinion Ecube 9, equipped with a linear transducer of 6 to 12 MHz (Figure 1). This diagnostic method provided detailed images that allowed for an accurate assessment of the condition of the PF in an objective manner (Figure 2 and 3).

Statistical Analysis

A regression analysis was performed relating the thickness of the PF measured by ultrasound to the rest of the variables analyzed in the study to estimate the coefficients of the linear equation. $P < 0.05$ was considered statistically significant.

Results

The average age of the patients was 48.5 ± 13.8 years. The mean pain score on the EVA scale was 7.027 ± 1.292. The function score on the FFI scale was 63.374 ± 17.564 points. The mean thickness of the PF was 6.019 millimeters ± 1.396. The mean body weight was 68.026 ± 6.688 kilograms, and height was 162.189 ± 6.055 centimeters. In 16 subjects, the disease appeared for the first time, in 7 it was a recurrence, and in 11 it was considered chronic. 13 subjects were sedentary, 15 were active, and 8 were athletes. The mean duration of the disease in months was 9.513 ± 6.593. 19 patients had received previous treatment, and 17 had not. 3 presented biconvexity of the PF, and 34 did not (table 1).

With an accuracy of 60.8%, the statistically significant predictors of increased PF thickness, from highest to lowest, were: pain measured on the EVA scale, height in centimeters, dysfunction measured with the FFI scale, age measured in years, body mass, biconvexity or lack thereof of the PF, duration of the disease in months, classification as chronic, recurrence, or first occurrence of plantar fasciopathy, and physical activity.

Greater pain measured on the EVA scale was associated with a greater thickness of the PF. Greater dysfunction, as well as taller height, older age, and higher body mass, were also associated with thicker PF. Patients with biconvexity had greater thickness of the PF than those without. Patients classified as having a recurrence of the disease had greater thickness than those experiencing it for the first time. Additionally, longer duration of the pathology was associated with greater thickness, as well as higher levels of physical activity (table 2).

Discussion

Prognostic factors in plantar fasciopathy are frequently analyzed to provide insight into the extent to which patients will benefit from different treatment modalities. The thickness of the PF is of particular interest as it is a prominent and common manifestation of plantar fasciopathy and can be quantitatively evaluated. Additionally, it has been studied that the thickness of the PF is a valid objective measure to assess the effectiveness of new or existing treatment protocols (26).

In healthy individuals, the thickness of the PF is closely correlated with age, height, weight, body mass index, and walking activity in the general population, and our descriptive study conducted in women diagnosed with plantar fasciopathy shows that there are no differences in thickness among affected patients. (27).Similarly, in our study, as the thickness of the PF increased, patients experienced more pain. Changes in PF thickness serve as a valid objective measure to assess the efficacy of new or existing treatment protocols, and generally, as PF thickness increases, patients experience more pain (28).

Moreover, as the thickness of the PF increased, patients also exhibited more dysfunction as indicated by higher scores on the FFI scale. This relationship has been previously studied by other authors, with conflicting conclusions in various works (29,30).In our study, a greater thickness of the PF measured by ultrasound was associated with a longer duration of the disease. That is, with a longer disease duration, there was a greater thickness of the PF. However, no literature was found to compare this data with other scientific studies. PF thickness has been positively associated with higher body mass and height. In our study, these two variables also showed a positive correlation (31).The biconvexity of the PF is a condition that has been rarely studied, in which the structure presents an oval appearance. In our study, patients whose fasciae were

classified as biconvex had a greater thickness of the PF. Patients who were older had a greater thickness of the PF in our study. It has been studied that the thickness of the PF in healthy subjects is greater in older patients, so the results of our article are consistent (32).In our study, patients were classified as sedentary, active, or athletes, according to their self-perception. Female athlete patients with the disease had a greater thickness of the PF, a relationship that has been studied in the non-diseased population, reaching the same conclusion (31), although there is literature that does not show a relationship (33). Further studies on this matter are necessary, both in diseased and non-diseased populations.

When including patients in the study, they were classified based on whether it was their first occurrence, a recurrence, or a chronic condition. Patients who had a recurrence of the disease had a greater thickness of the PF measured by ultrasound in this study. The classification of heel pain as chronic presents heterogeneity in the literature, with some classifying it as chronic when it lasts more than one month, others when it persists for more than three months, and others for more than six months (34). In our case, we classified patients as chronic if they had a duration of more than six months. Likewise, in our study, the presence of vascularity in the PF visualized by ultrasound at the time of the initial evaluation showed no correlation with the thickness of the PF. Intrafascial or perifascial hyperemia may appear in plantar fasciopathy, but this fact must be studied and correlated with other variables in future studies.

The appearance of hyperemia in tendinopathy has been widely studied, appearing in advanced phases of the disease and not in initial phases, such as the tendon dysrepair phase or the degenerative tendinopathy phase, according to J L Cook's classification (35). There are authors who consider the PF a specialized tendon, and the appearance of hyperemia probably has a similar etiopathogenesis, but it is a fact that must be studied in future studies (23). In plantar fasciosis the authors' experience is that the hyperemia observed by power doppler can appear at any phase, both in initial phases and in advanced phasesWhen collecting data for the study, patients were asked whether they had undergone previous treatment or not. Having undergone previous treatment showed no significant changes in the thickness of the PF. This seems to support what has been shown in previous studies that treatments reduce the thickness of the PF but do not reach normal values (36).

Our study was conducted only on female patients suffering from the disease, diagnosed according to the criteria explained previously in this article. The difference in PF thickness between asymptomatic men and women has been studied by other authors, with it being thicker in men (0.42 mm) according to Pascual Huerta et al. (37), and similar according to other authors (27,38).

It should probably be taken into account that in women, since they have lower height and lower body mass on average than men, their thickness of the PF measured by ultrasound to diagnose the disease may be lower. More studies should be done in the future differentiating the thickness of the PF in subjects with plantar fasciopathy between men and women.

The presence or absence of subcalcaneal spur was not considered in our descriptive study. The relationship between subcalcaneal spur and heel pain has been confirmed by multiple meta-analyses. However, a subpopulation of individuals with a spur is completely asymptomatic (39).

The sample size of our study is small, highlighting the importance of conducting additional research with larger samples of the population affected by plantar fasciitis. It is essential to expand the scope of research to include both men and women in future studies, which will allow us to obtain a more comprehensive and representative view of the disease.

By expanding the sample to a more diverse population, we can more accurately evaluate whether the findings and conclusions of our study are extrapolatable to the general population. Additionally, it will be crucial to investigate possible differences in the presentation of plantar fasciitis between men and women, which could have significant implications for the diagnosis and treatment of the disease.

Subsequent studies could include comparative analyses between groups of men and women to determine if there are disparities in the prevalence, severity, or response to treatment of plantar fasciitis. These analyses will help identify possible gender-specific risk factors and develop more personalized and effective treatment approaches.

Furthermore, it may be important to consider the inclusion of more demographic and clinical variables in future studies to obtain a more complete understanding of the factors that influence the development and progression of plantar fasciopathy.

In summary, additional studies with larger and more diversified samples are needed to validate and expand the findings of our initial study. By doing so, we will be better equipped to understand the true nature of plantar fasciitis and improve healthcare and management of this prevalent condition.

Conclusions.

There were significant findings indicating a correlation between pain intensity and PF thickness, with thicker measurements corresponding to higher reported pain levels. Also, more dysfunction was shown in patients with higher measurement of PF. Moreover, the study revealed positive

links between PF thickness and anthropometric factors such as height, age, and weight, suggesting a potential influence of these variables on PF thickness in women suffering plantar fasciopathy. Additionally, observations pointed to correlations between PF thickness and factors like the biconvexity of the PF, disease duration and recurrence of plantar fasciopathy, hinting at implications for disease progression and management strategies.

Furthermore, the research highlighted a connection between PF thickness and daily activity levels, emphasizing the impact of physical activity on PF thickening. Noteworthy was the correlation found between the presence of biconvexity in the PF, as identified through ultrasound examination and PF thickness, which shows a relationship little studied in the scientific literature

Abbreviations

PF Plantar fascia
FFI Foot Funtion Index
VAS Visual Analog Scale
SD Standard Deviation
ICC Intraclass correlation coefficient
SEM Standard error of measurement
MDC Minimal change detectable
CI Confidence Interval

Declarations

Ethics approval and consent to participate

Ethical approval was granted by the Research Ethics Committee of Hospital Universitario de Nuestra Señora de Valme, under protocol number 2093-N-21. The ethical and human criteria established in the Declaration of Helsinki were followed. Informed signed consent was obtained from all study participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author contributions
RMS: Conceptualization, writing and measurement. RMD: Measurement Methodology. AGC: Methodology and design. AGC: Data curation: RMD: original draft preparation. JMCL: writing—reviewing and editing. All the authors have read and approved the final manuscript.

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Figure 1. Researcher with linear probe on foot for measurement of plantar fascia.

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Figure 2. Plantar fascia thickness measurement area.

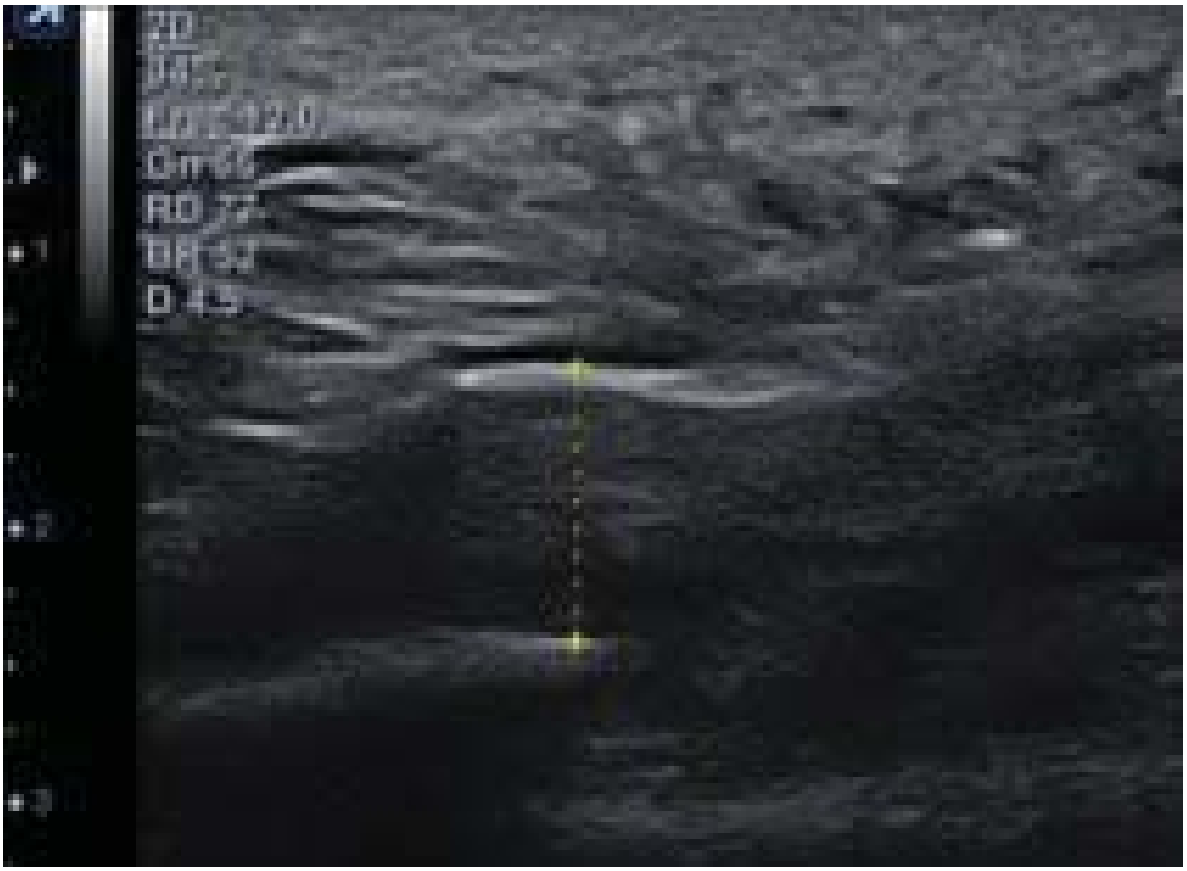

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Figure 3. Plantar fascia with normal morphology (a) (b) and plantar fascia with biconvex morphology (c) (d). From Fleischer AE, Albright RH, Crews RT, Kelil T, Wrobel JS. Prognostic Value of Diagnostic Sonography in Patients With Plantar Fasciitis. J Ultrasound Med. 2015. (1)

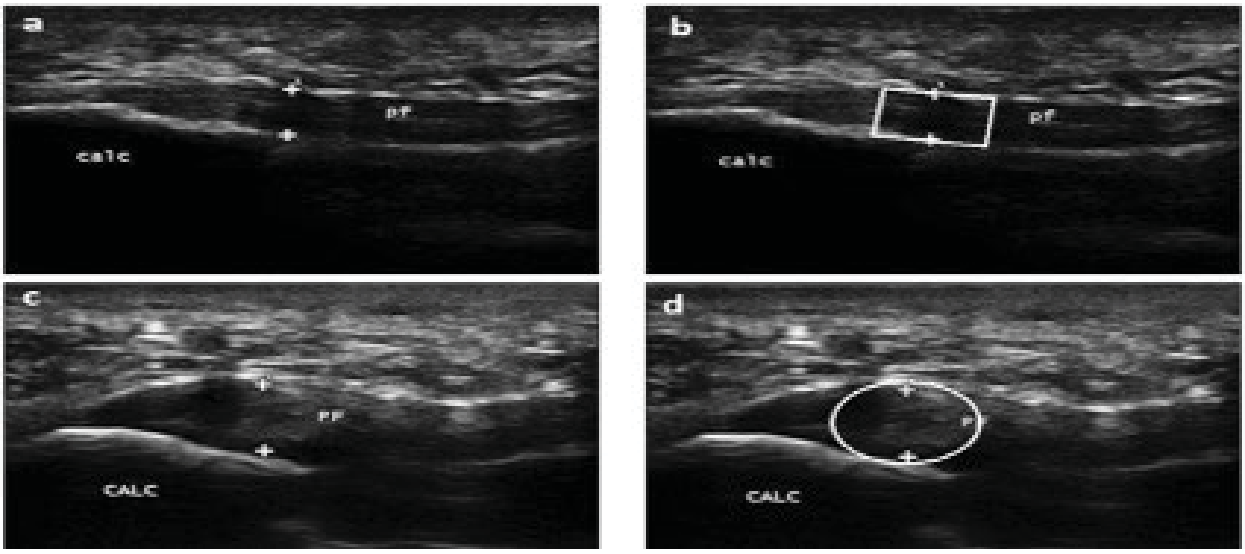

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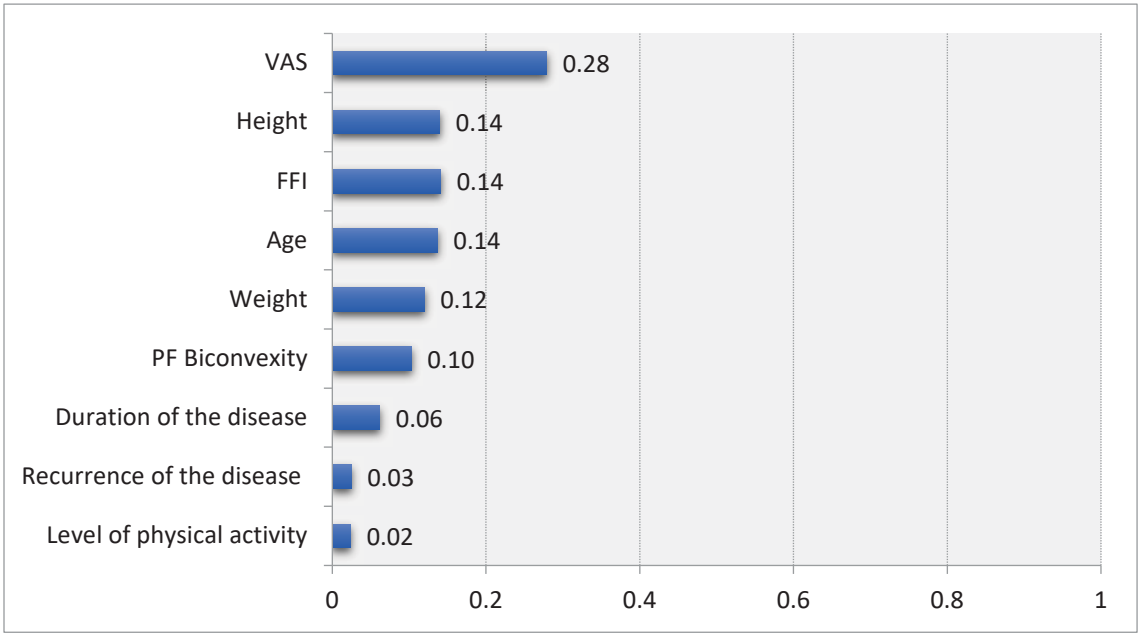
Table 1. Summary anthropometric measurements.

	N	Mean	SD	Minimum	Maximum
Age (Years)	37	13.8	18.86	23	77
FFI (Scores)	37	63.374	17.564	26.08	94.68
VAS (Scores)	37	7.027	1.292	4	9
Weight (kg)	37	68.026	6.688	57	84
Heigth (cm)	37	162.189	6.055	148	179
Duration of the Disease (months)	37	9,513	6.593	1	31

Abbreviations: **SD** = Standard Deviation; **FFI** = Foot Function Index.

Table 2. Statistically significant predictors.



Abbreviations: **VAS** = Visual Analogic Scale; **FFI** = Foot Function Index; **PF** = Plantar Fascia. On the ordinate axis are the variables and on the abscissa the importance of the predictor. The importance of the predictor is shown as a ratio, with 0 being not at all important and 1 being the most important.