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Relationship between tightness of the posterior muscles of the lower limb and plantar fasciitis

ABSTRACT

BACKGROUND: The aim of this study was to determine whether tightness of the posterior muscles of the lower extremity was associated with plantar fasciitis.

METHODS: One hundred lower limbs of 100 subjects, 50 with plantar fasciitis and 50 matching controls were recruited. Hamstring and calf muscles were evaluated through the straight leg elevation test, popliteal angle test, and ankle dorsiflexion (knee extended and with the knee flexed). All variables were compared between the two groups. In addition, ROC curves, sensitivity, and specificity of the muscle contraction tests were also calculated to determine their potential predictive powers.

RESULTS: Differences between the two groups for the tests used to assess muscular shortening were significant ($P<0.001$) in all cases. The straight leg elevation test and ankle dorsiflexion with the knee extended presented respective sensitivities of 94% and 100% and specificities of 82% and 96% as diagnostic tests for the participants in this study.

CONCLUSION: Tightness of the posterior muscles of the lower limb was present in the plantar fasciitis patients, but not in the unaffected participants.

CLINICAL RELEVANCE: The results of this study suggest that therapists who are going to employ a stretching protocol for treatment of plantar fasciitis should look for both hamstring as well as triceps surae tightness by means of including examination of the posterior muscles of the lower extremity in the examination protocol of plantar fasciitis. Also, stretching exercises programs could be recommended for treatment of

plantar fasciitis, focusing on stretching the entire course of triceps surae and hamstrings, apart from an adequate tissue-specific plantar fascia-stretching protocol.

LEVEL OF EVIDENCE: Level III. Case control study. Prognostic studies investigating the effect of a patient characteristic on the outcome of disease.

KEYWORDS: Plantar Fasciitis; Hamstring Muscles; Triceps Surae; Tightness; Sleep Posture.

INTRODUCTION

Plantar fasciitis (PF) is a pathological condition whose ætiology is multifactorial. Some of the risk factors involved are: sport or physical exercise,[13] overweight,[22] age,[14] gender,[30] prolonged standing,[19] increased subtalar pronation accompanying pes cavus or flat feet,[15] and limited ankle dorsiflexion.[30] There has been few studies about the relationship between tightness of the posterior lower limb muscles and PF, and most of them can be interpreted in terms of some retraction of the posterior muscles of the leg or thigh being present in cases of PF.[8,14]

The posture that the individual adopts during sleep could also influence the contracture of these muscles, as has been demonstrated in studies of patients who have spent long time bed-ridden.[10] A supine position fosters permanent plantar flexion of the ankle due to the weight of the bedding, and this would tend to retract the triceps surae. Similarly, a prone position requires plantarflexion of the ankle, thus contracting the posterior leg muscles.

A great variety of therapeutic regimens has been described and is widely used as valid treatments for plantar fasciitis. Among these, it is included dietetic measures in subjects with overweight; pharmacologic treatment, as oral non-steroidal anti-inflammatory or steroidal injections; orthotics, as foot orthoses or night splints; physical therapy, as cryotherapy, ultrasound, laser or tapes; and surgical procedures as partial or total release of the plantar fascia. In addition, stretching programs mean an important conservative treatment for plantar fasciitis, since they might be acting directly upon some risk factors, as shortness of posterior musculature of the lower limb.[33] The results of various studies suggest that tightness of the posterior muscles of the lower limb could be involved in plantar fasciitis etiology, and that stretching programs have beneficial effects on this pathology.[7, 9, 12, 18, 20, 32] The main objective of this study was to determine whether there existed tightness of the posterior lower limb muscles in PF participants compared to matched controls without this condition. The null hypothesis is that there is no difference between the PF group and the control group either in the variables that measure the contraction of the posterior muscular chain of the lower extremity.

MATERIAL AND METHODS

Subjects

One hundred subjects, 34 men and 66 women, aged 48.40 ± 15.16 years, and with BMI 28.89 ± 4.54, took part in this study. Tightness of hamstrings and calf muscles were measured. The participants were patients attending the Orthopaedic Service of the Clinical Podiatry Area of the University of Seville (Spain) who satisfied the criteria for inclusion and gave their written informed consent to voluntarily participate in the study.

The required sample size was calculated using the software G*Power 3.1.3, assuming an α error of 5% and a β error of 5% to estimate the difference between two independent samples using one-tailed tests and with a large effect size (d > 0.8). The result was that a minimum of 35 cases per group were necessary. The work was carried out between October 2009 and March 2011, and was approved by the Research Ethics Committee of the University of Seville.

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The study participants were assigned to two groups, one of individuals with PF (case group) and the other of individuals without PF (control group). The inclusion criterion for the case group participants was a diagnosis of plantar fasciitis according to the following clinical manifestations: pain in the distal-internal region of the plantar surface of the heel, with possible radiation towards the medial edge and to the rest of the sole of the foot; pain increment when the patient took their first steps in the morning and after prolonged standing; pain increment with direct pressure on the antero-internal region of the heel; and pain increment with repeated pressure on the same area when the toes dorsiflexed passively.[1, 3, 29] Patients who served as the control group attended the center for elimination of hyperkeratosis or treatment of nail disorders. Inclusion criteria for the control group were to be similarly matched in age, sex, lower limb side and BMI with the case group subjects. Exclusion criteria for both groups were: osteoarticular pathology in the hip, knee, or ankle that caused pain or restricted movement; neuromuscular disease; disorders related to heel pain, such as subcalcaneal bursitis, Achilles tendon bursitis, Haglund's exostosis, or fracture of the calcaneus; and history of recent trauma in the lower limbs or elective surgery in those with. Specifically, subjects were excluded from the case group if they had been treated for PF with muscle stretching exercises or night splints, or who reported some direct trauma as being the origin of the plantar pain. Data were finally collected for 50 patients with PF and 50 controls.

In cases where PF was unilateral, the affected limb was the one measured. In cases where PF was bilateral, only the more affected limb was included, or, if both were affected equally, a coin toss was used to select the limb to measure at random.

Procedure

The straight leg elevation test (SLET), popliteal angle (PA), ankle dorsiflexion with the knee extended (ADFKE), and ankle dorsiflexion with the knee flexed (ADFKF) were measured in the participants (figure 1a to 1d). The SLET determines specifically the stiffness of the elastic component of the hamstring muscle.[25] It was performed with the patient laying supine on the examination table, hip and knee in neutral position. The leg was elevated gradually, with the knee extended, until feeling discomfort due to tension in the posterior aspect of the thigh, or until the examiner observed the contralateral limb beginning to rise. At that time, a two-arm goniometer was used to measure the angle formed between the lower limb and the examination table. The centre of the goniometer was placed on the greater trochanter of the femur, one arm parallel to the lateral bisectrix of the thigh, and the other arm parallel to the examination table. An angle of 80 degrees was considered normal.[11, 17, 24]

The PA provides another test of the degree of elasticity of the hamstrings muscles. The participant was laying supine on the examination table, hip and knee flexed at 90 degrees. Knee was extended gradually until the participant referred to discomfort, due to firm resistance, in the posterior aspect of the thigh. At that time the angle formed by the lateral bisection of the thigh and the lateral bisection of the leg was measured. The centre of the goniometer was placed on the lateral aspect of the knee, coinciding with the axis of rotation. One arm was positioned parallel to the lateral bisection of the thigh, and the other was directed towards the lateral malleolus. The residual knee flexion angle was measured as the degrees lacking from null extension, which is 180 degrees. The normal range was considered to be 0–15 degrees,[25] while values of 16 to 34 degrees corresponded to moderate hamstring contracture, and values greater than or equal to 35 degrees corresponded to severe contracture.

Ankle dorsiflexion was measured with the knee extended and with the knee flexed at 90 degrees. The participant was laying in supine on the examination table and the subtalar joint in neutral position. The goniometer was placed with the fixed arm parallel to the lateral bisection of the leg and the mobile arm parallel to the fifth metatarsal. At least, ten degrees had to be obtained to consider the ankle dorsiflexion with the knee extended as normal, and 15 degrees with the knee flexed. [21, 31]

The final value of each variable measured with the goniometer was obtained by the mean of three repeated measurements. Measurements were always made by the same researcher (YAB).

Data analysis

Data were analyzed using the SPSS software package (SPSS Science, Chicago, Illinois). To analyze the intraobserver reliability of the quantitative variables, the intra-class correlation coefficient (3,1) was calculated. Twelve participants were selected at random (six from each group), and three measurements were made of these variables, with a one-week period between each measurement.

The *Kolmogorov-Smirnov* test applied to the data from the quantitative variables showed the distribution to be non-normal, so comparisons and correlations were made using the non-parametric *Mann-Whitney U-test* and *Spearman's rho*, respectively. The effect size for comparisons was calculated by means of *Cohen's d* using the formula: (Mean 1 – Mean 2)/([SD1 + SD2]/2), where the value of d is positive if the difference between the means is in the predicted sense. This parameter classifies the effect size into small if $d = 0.20$, medium if $d = 0.50$, and large if d is greater than or equal to 0.80.

Correlation between the quantitative variables using *Spearman's rho* was also calculated, with a two-tailed test of significance. The effect size for correlations was considered small if $\rho = 0.10$, medium if $\rho = 0.30$, and large if $\rho \geq 0.50$.

The method of ROC curves was used to evaluate the diagnostic power of the ADFKE and SLET variables, determining the area under the curve and the cut-off points. From these curves, sensitivity, specificity, and positive and negative predictive powers were calculated, together with their corresponding 95% confidence intervals.

Differences were considered statistically significant when $p < 0.05$.

RESULTS

The study sample consisted of 100 participants, 34 men and 66 women. Bilateral PF was present in 22 participants and unilateral PF in 28 participants in the case group. Individuals were assigned to the control group by pair matching. Nevertheless, it was verified that there were no differences between groups regarding age and BMI (BMI in control group 28.18 ± 4.16, BMI in PF group 29.59 ± 4.83, *p* = 0.124; Age in control group 48.62 ± 15.40, age in PF group 48.18 ± 15.07, *p* = 0.886).

The results for the intra-class correlation coefficient showed good intraobserver reliability in the quantitative variable measurement procedure. In particular, for SLET, the correlation coefficient was 0.96 (*95% CI*: 0.834–0.990); for PA, 0.99 (*95% CI*: 0.990–0.999); for ADFKE 0.99 (*95% CI*: 0.972–0.999); and for ADFKF 0.95 (*95% CI*: 0.795–0.997).

The comparison of the values of SLET, PA, ADFKE, and ADFKF between the two groups showed statistically significant differences in all cases. Mean, standard deviations, 95% confidence intervals, medians, and interquartile ranges for the two groups are shown in Table 1, together with *Cohen's d* and the p-value for comparisons.

Table 2 lists the values of *Spearman's rho* for the correlations between the four quantitative variables together with an indication of the corresponding significance levels. As it can be observed, the two variables that measure the contracture of the hamstring musculature are strongly correlated, as also are the two variables that measure the retraction of the posterior muscles of the leg. Therefore, in the study of ROC curves and predictive powers, sensitivity, and specificity, only one of each of these two pairs of variables was used. Straight leg elevation test was chosen because it was found to be referred more often in the literature, and ADFKF because it involves the assessment of all of the triceps surae muscular bellies (ankle dorsiflexion with the knee flexed only evaluates the soleus).

Figure 2 shows the ROC curve for SLET. The area under the curve is 0.982 (*p* < 0.001; *95% CI*: 0.964–1). Seventy degrees was considered to be the cut-off in this test. Although the normal value of the angle is considered to be 80 degrees,[11, 17, 24] the value of 70 degrees yielded better sensitivity and specificity, and has been also advocated by some authors as the normal value,[2, 13] that is, individuals with values less than or equal to 70 degrees would give a positive test result. Sensitivity was found to be 94% (0.94; *95% CI*: 0.872–1); specificity 82% (0.82; *95% CI*: 0.711–0.928); positive predictive power 83.9% (0.839; *95% CI*: 0.742–0.938); and negative predictive power 93.2% (0.932; *95% CI*: 0.856–1).

Figure 3 shows the ROC curve for ADFKE. The area under the curve is 0.999 ($p <$ 0.001; *95% CI*: 0.997–1). Ten degrees was considered to be the cut-off in this test. This is considered to be the limit of normality for ankle dorsiflexion with the knee extended,[24, 31] that is, individuals with values less than or equal to ten degrees would give a positive test result. Sensitivity was found to be 100%; specificity 96% (0.96; *95% CI*: 0.904–1); positive predictive power 96.2% (0.962; *95% CI*: 0.909–1); and negative predictive power 100%.

DISCUSSION

Before discussing the results, the authors would like to clarify that this study design does not allow establishing any cause-effect relationship since it does not provide data on temporal relationships between PF and the variables measured, by means of comparing cohorts. It is therefore important to stress that, while the factors studied in the present seem to be associated with the development of this pathology, they are not the only ones involved.

The relationship between PF and contracture of the posterior muscles of the lower extremity has previously been studied. Rome et al.[28] found no statistically significant differences (p = 0.39) between a control group and a group with PF with respect to limited ankle dorsiflexion. Taunton et al.[30] retrospectively reviewed 267 cases of PF, of which only 43 (16%) had excessive contracture of the gastrocnemius–soleus complex. Irving et al.[14] reported a case-control study which included ankle dorsiflexion as a variable. The results showed the PF group to present greater values of this angle than the control group.

On the other hand, most current evidence suggests that tight gastrocnemious is an etiologic factor for PF. Kliber et al.[16] studied 43 athletes' feet with PF; they observed that 37 of them showed a decreased range of ankle dorsiflexion in the affected limb compared with the non-afected one. Riddle et al.[26] observed significant differences ($p<0.001$) in the limitation of ankle dorsiflexion in a PF group compared with a control group. Patel and Digiovanni,[23] examined 254 patients with PF and found that 83% had limited ankle dorsiflexion, 57% had an isolated contracture of the gastrocnemius, 26% had a contracture of the gastrocnemius-soleus complex, and 17% did not have a dorsiflexion limitation. These authors observed an equinus contracture in 83% of acute cases, and 82% of chronic cases. An isolated contracture of the gastrocnemius was found in 60% of acute, and 52% of chronic cases. A gastrocnemius-soleus complex contracture was noted in 23% of acute cases, and 30% of chronic cases. Digiovanni et al.[6] carried out a clinical trial in which the patients were randomly assigned to one of two groups: One group received instructions for a plantar fascia tissue-stretching program, and the other group for an Achilles tendon-stretching program for eight weeks. Both groups reported an overall reduction in pain, although a greater improvement was noted in those patients who follow the plantar fascia tissue-stretching. However, these authors reported long-term benefits of both stretching protocols,[7] and they found no significant differences between the groups in the two-year followup.

These results suggest that shortness of the posterior muscles of the leg plays an important role in the development of PF, although this is not the only etiologic factor. Harty et al.[12] observed a significant contracture of the hamstrings muscles in a group of subjects with PF compared with a control group. Domínguez et al.[8] observed a limited ankle dorsiflexion and knee extension in most of the PF subjects, which would confirm contracture of triceps surae and hamstrings. Labovitz et al.[14] found that patients with hamstring tightness were about 8.7 times as likely to experience PF in the corresponding foot compared with patients without hamstring tightness. The results of the above mentioned studies support the functional deficit of the plantar fascia caused by hamstring shortening. That is, tight hamstrings could increase knee flexion, which in turn would induce prolonged forefoot loading and would engage the windlass mechanism. Also, when tight posterior leg muscle group exists, ankle range of motion is limited and it may be compensated by excessive pronation of the subtalar joint, causing tension on the plantar fascia.

The ROC curves for the SLET and ADFKE showed high specificity and sensitivity, i.e., subjects with contracture of the posterior leg muscles are more likely to develop PF. Despite this close relationship, these tests cannot be used for the diagnosis of PF. This would have required a cohort study with prospective followup of subjects with shortening of these muscles to verify whether or not they eventually develop PF. Nonetheless, in the authors' opinion, the present results could serve as a basis for future investigations.

Regarding to the fact that the sleeping posture could also influence the contracture of these muscles, some references to the impact that sleeping posture might have on the musculature of the calf were found.[4, 10] Bowers et al.[5] suggested that, during the hours of sleep in a prone or supine position, the foot assumes a plantarflexed posture, which could lead to contracture of the gastrocnemius muscle. The prolonged stays in bed in a supine position of ICU patients caused equinnus feet.[10] The authors believe that a prone/supine sleep posture may also contribute to contracture of the calf muscles and plantar fascia by maintaining the foot in a plantarflexed posture, and thus be a factor influencing the development of PF, but this subject requires further research.

A practical application of the present results could be for the therapist to include examination of the posterior muscles of the lower extremity in the examination protocol of PF patients. Also, stretching exercises programs could be recommended for treatment of PF, focusing on stretching the entire course of triceps surae and hamstrings. It could be introduced together with other preventive measures such as rest or use of physiological footwear and foot orthoses.

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LEGENDS

Table 1. Comparison of variables SLET, PA, ADFKE, ADFKF and PFI between the

two groups. IR: interquartile range.

Table 2. Correlations between the four quantitative variables studied. ** Significant at the 0.01 level (two-tailed).

Figure 1a. Measurement of the straight leg elevation test.

Figure 1b. Measurement of the popliteal angle test.

Figure 1c. Measurement of the ankle dorsiflexion with the knee extended.

Figure 1d. Measurement of the ankle dorsiflexion with the knee flexed.

Figure 2. The ROC curve for the straight leg elevation test. Vertical axis: sensitivity; Horizontal axis: 1 - specificity.

Figure 3. The ROC curve for the ankle dorsiflexion with knee extended. Vertical axis: sensitivity; Horizontal axis: 1 - specificity.

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In cases where PF was unilateral, the affected limb was the one measured. In cases where PF was bilateral, only the more affected limb was included, or, if both were affected equally, a coin toss was used to select the limb to measure at random.

Procedure

The straight leg elevation test (SLET), popliteal angle (PA), ankle dorsiflexion with the knee extended (ADFKE), and ankle dorsiflexion with the knee flexed (ADFKF) were measured in the participants (figure 1a to 1d). The SLET determines specifically the stiffness of the elastic component of the hamstring muscle.[25] It was performed with the patient laying supine on the examination table, hip and knee in neutral position. The leg was elevated gradually, with the knee extended, until feeling discomfort due to tension in the posterior aspect of the thigh, or until the examiner observed the contralateral limb beginning to rise. At that time, a two-arm goniometer was used to measure the angle formed between the lower limb and the examination table. The centre of the goniometer was placed on the greater trochanter of the femur, one arm parallel to the lateral bisectrix of the thigh, and the other arm parallel to the examination table. An angle of 80 degrees was considered normal.[11, 17, 24]

The PA provides another test of the degree of elasticity of the hamstrings muscles. The participant was laying supine on the examination table, hip and knee flexed at 90 degrees. Knee was extended gradually until the participant referred to discomfort, due to firm resistance, in the posterior aspect of the thigh. At that time the angle formed by the lateral bisection of the thigh and the lateral bisection of the leg was measured. The centre of the goniometer was placed on the lateral aspect of the knee, coinciding with the axis of rotation. One arm was positioned parallel to the lateral bisection of the thigh, and the other was directed towards the lateral malleolus. The residual knee flexion angle was measured as the degrees lacking from null extension, which is 180 degrees. The normal range was considered to be 0–15 degrees,[25] while values of 16 to 34 degrees corresponded to moderate hamstring contracture, and values greater than or equal to 35 degrees corresponded to severe contracture.

Ankle dorsiflexion was measured with the knee extended and with the knee flexed at 90 degrees. The participant was laying in supine on the examination table and the subtalar joint in neutral position. The goniometer was placed with the fixed arm parallel to the lateral bisection of the leg and the mobile arm parallel to the fifth metatarsal. At least, ten degrees had to be obtained to consider the ankle dorsiflexion with the knee extended as normal, and 15 degrees with the knee flexed. [21, 31]

The final value of each variable measured with the goniometer was obtained by the mean of three repeated measurements. Measurements were always made by the same researcher (YAB).

Data analysis

Data were analyzed using the SPSS software package (SPSS Science, Chicago, Illinois). To analyze the intraobserver reliability of the quantitative variables, the intra-class correlation coefficient (3,1) was calculated. Twelve participants were selected at random (six from each group), and three measurements were made of these variables, with a one-week period between each measurement.

The *Kolmogorov-Smirnov* test applied to the data from the quantitative variables showed the distribution to be non-normal, so comparisons and correlations were made using the non-parametric *Mann-Whitney U-test* and *Spearman's rho*, respectively. The effect size for comparisons was calculated by means of *Cohen's d* using the formula: (Mean 1 – Mean 2)/([SD1 + SD2]/2), where the value of d is positive if the difference between the means is in the predicted sense. This parameter classifies the effect size into small if $d = 0.20$, medium if $d = 0.50$, and large if d is greater than or equal to 0.80.

Correlation between the quantitative variables using *Spearman's rho* was also calculated, with a two-tailed test of significance. The effect size for correlations was considered small if $\rho = 0.10$, medium if $\rho = 0.30$, and large if $\rho \geq 0.50$.

The method of ROC curves was used to evaluate the diagnostic power of the ADFKE and SLET variables, determining the area under the curve and the cut-off points. From these curves, sensitivity, specificity, and positive and negative predictive powers were calculated, together with their corresponding 95% confidence intervals.

Differences were considered statistically significant when $p < 0.05$.

RESULTS

The study sample consisted of 100 participants, 34 men and 66 women. Bilateral PF was present in 22 participants and unilateral PF in 28 participants in the case group. Individuals were assigned to the control group by pair matching. Nevertheless, it was verified that there were no differences between groups regarding age and BMI (BMI in control group 28.18 ± 4.16, BMI in PF group 29.59 ± 4.83, $p = 0.124$; Age in control group 48.62 ± 15.40, age in PF group 48.18 ± 15.07, $p = 0.886$).

The results for the intra-class correlation coefficient showed good intraobserver reliability in the quantitative variable measurement procedure. In particular, for SLET, the correlation coefficient was 0.96 (*95% CI*: 0.834–0.990); for PA, 0.99 (*95% CI*: 0.990–0.999); for ADFKE 0.99 (*95% CI*: 0.972–0.999); and for ADFKF 0.95 (*95% CI*: 0.795–0.997).

The comparison of the values of SLET, PA, ADFKE, and ADFKF between the two groups showed statistically significant differences in all cases. Mean, standard deviations, 95% confidence intervals, medians, and interquartile ranges for the two groups are shown in Table 1, together with *Cohen's d* and the p-value for comparisons.

Table 2 lists the values of *Spearman's rho* for the correlations between the four quantitative variables together with an indication of the corresponding significance levels. As it can be observed, the two variables that measure the contracture of the hamstring musculature are strongly correlated, as also are the two variables that measure the retraction of the posterior muscles of the leg. Therefore, in the study of ROC curves and predictive powers, sensitivity, and specificity, only one of each of these two pairs of variables was used. Straight leg elevation test was chosen because it was found to be referred more often in the literature, and ADFKF because it involves the assessment of all of the triceps surae muscular bellies (ankle dorsiflexion with the knee flexed only evaluates the soleus).

Figure 2 shows the ROC curve for SLET. The area under the curve is 0.982 ($p < 0.001$; *95% CI*: 0.964–1). Seventy degrees was considered to be the cut-off in this test. Although the normal value of the angle is considered to be 80 degrees,[11, 17, 24] the value of 70 degrees yielded better sensitivity and specificity, and has been also advocated by some authors as the normal value,[2, 13] that is, individuals with values less than or equal to 70 degrees would give a positive test result. Sensitivity was found to be 94% (0.94; *95% CI*: 0.872–1); specificity 82% (0.82; *95% CI*: 0.711–0.928); positive predictive power 83.9% (0.839; *95% CI*: 0.742–0.938); and negative predictive power 93.2% (0.932; *95% CI*: 0.856–1).

Figure 3 shows the ROC curve for ADFKE. The area under the curve is 0.999 ($p < 0.001$; *95% CI*: 0.997–1). Ten degrees was considered to be the cut-off in this test. This is considered to be the limit of normality for ankle dorsiflexion with the knee extended,[24, 31] that is, individuals with values less than or equal to ten degrees would give a positive test result. Sensitivity was found to be 100%; specificity 96% (0.96; *95% CI*: 0.904–1); positive predictive power 96.2% (0.962; *95% CI*: 0.909–1); and negative predictive power 100%.

DISCUSSION

Before discussing the results, the authors would like to clarify that this study design does not allow establishing any cause-effect relationship since it does not provide data on temporal relationships between PF and the variables measured, by means of comparing cohorts. It is therefore important to stress that, while the factors studied in the present seem to be associated with the development of this pathology, they are not the only ones involved.

The relationship between PF and contracture of the posterior muscles of the lower extremity has previously been studied. Rome et al.[28] found no statistically significant differences (p = 0.39) between a control group and a group with PF with respect to limited ankle dorsiflexion. Taunton et al.[30] retrospectively reviewed 267 cases of PF, of which only 43 (16%) had excessive contracture of the gastrocnemius–soleus complex. Irving et al.[14] reported a case-control study which included ankle dorsiflexion as a variable. The results showed the PF group to present greater values of this angle than the control group.

On the other hand, most current evidence suggests that tight gastrocnemious is an etiologic factor for PF. Kliber et al.[16] studied 43 athletes' feet with PF; they observed that 37 of them showed a decreased range of ankle dorsiflexion in the affected limb compared with the non-afected one. Riddle et al.[26] observed significant differences (p<0.001) in the limitation of ankle dorsiflexion in a PF group compared with a control group. Patel and Digiovanni,[23] examined 254 patients with PF and found that 83% had limited ankle dorsiflexion, 57% had an isolated contracture of the gastrocnemius, 26% had a contracture of the gastrocnemius-soleus complex, and 17% did not have a dorsiflexion limitation. These authors observed an equinus contracture in 83% of acute cases, and 82% of chronic cases. An isolated contracture of the gastrocnemius was found in 60% of acute, and 52% of chronic cases. A gastrocnemius-soleus complex contracture was noted in 23% of acute cases, and 30% of chronic cases. Digiovanni et al.[6] carried out a clinical trial in which the patients were randomly assigned to one of two groups: One group received instructions for a plantar fascia tissue-stretching program, and the other group for an Achilles tendon-stretching program for eight weeks. Both groups reported an overall reduction in pain, although a greater improvement was noted in those patients who follow the plantar fascia tissue-stretching. However, these authors reported long-term benefits of both stretching protocols,[7] and they found no significant differences between the groups in the two-year followup. These results suggest that shortness of the posterior muscles of the leg plays an important role in the development of PF, although this is not the only etiologic factor. Harty et al.[12] observed a significant contracture of the hamstrings muscles in a group of subjects with PF compared with a control group. Domínguez et al.[8] observed a limited ankle dorsiflexion and knee extension in most of the PF subjects, which would confirm contracture of triceps surae and hamstrings. Labovitz et al.[14] found that patients with hamstring tightness were about 8.7 times as likely to experience PF in the corresponding foot compared with patients without hamstring tightness. The results of the above mentioned studies support the functional deficit of the plantar fascia caused by hamstring shortening. That is, tight hamstrings could increase knee flexion, which in turn would induce prolonged forefoot loading and would engage the windlass mechanism. Also, when tight posterior leg muscle group exists, ankle range of motion is limited and it may be compensated by excessive pronation of the subtalar joint, causing tension on the plantar fascia.

The ROC curves for the SLET and ADFKE showed high specificity and sensitivity, i.e., subjects with contracture of the posterior leg muscles are more likely to develop PF. Despite this close relationship, these tests cannot be used for the diagnosis of PF. This would have required a cohort study with prospective followup of subjects with shortening of these muscles to verify whether or not they eventually develop PF.

Nonetheless, in the authors' opinion, the present results could serve as a basis for future investigations.

Regarding to the fact that the sleeping posture could also influence the contracture of these muscles, some references to the impact that sleeping posture might have on the musculature of the calf were found.[4, 10] Bowers et al.[5] suggested that, during the hours of sleep in a prone or supine position, the foot assumes a plantarflexed posture, which could lead to contracture of the gastrocnemius muscle. The prolonged stays in bed in a supine position of ICU patients caused equinnus feet.[10] The authors believe that a prone/supine sleep posture may also contribute to contracture of the calf muscles and plantar fascia by maintaining the foot in a plantarflexed posture, and thus be a factor influencing the development of PF, but this subject requires further research.

A practical application of the present results could be for the therapist to include examination of the posterior muscles of the lower extremity in the examination protocol of PF patients. Also, stretching exercises programs could be recommended for treatment of PF, focusing on stretching the entire course of triceps surae and hamstrings. It could be introduced together with other preventive measures such as rest or use of physiological footwear and foot orthoses.

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LEGENDS

Table 1. Comparison of variables SLET, PA, ADFKE, ADFKF and PFI between the two groups. IR: interquartile range.

Table 2. Correlations between the four quantitative variables studied. ** Significant at the 0.01 level (two-tailed).

Figure 1a. Measurement of the straight leg elevation test.

Figure 1b. Measurement of the popliteal angle test.

Figure 1c. Measurement of the ankle dorsiflexion with the knee extended.

Figure 1d. Measurement of the ankle dorsiflexion with the knee flexed.

Figure 2. The ROC curve for the straight leg elevation test. Vertical axis: sensitivity; Horizontal axis: 1 - specificity.

Figure 3. The ROC curve for the ankle dorsiflexion with knee extended. Vertical axis: sensitivity; Horizontal axis: 1 - specificity.