Risk Factors for Plantar Fasciitis: A Matched Case-Control Study

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Background: Plantar fasciitis is one of the more common soft-tissue disorders of the foot, yet little is known about its etiology. The purpose of the present study was to use an epidemiological design to determine whether risk factors for plantar fasciitis could be identified. Specifically, we examined the risk factors of limited ankle dorsiflexion with the knee extended, obesity, and time spent weight-bearing.

Methods: We used a matched case-control design, with two controls for each patient. The matching criteria were age and gender. We identified fifty consecutive patients with unilateral plantar fasciitis who met the inclusion criteria. The data that were collected included height, weight, whether the subject spent the majority of the workday weight-bearing, and whether the subject was a jogger or runner. We used a reliable goniometric method to measure passive ankle dorsiflexion bilaterally. The main outcome measure was the adjusted odds ratio of plantar fasciitis associated with varying degrees of limitation of ankle dorsiflexion, different levels of body mass, and the subjects' reports on weight-bearing.

Results: Individuals with ≤0° of dorsiflexion had an odds ratio of 23.3 (95% confidence interval, 4.3 to 124.4) when compared with the referent group of individuals who had >10° of ankle dorsiflexion. Individuals who had a body-mass index of >30 kg/m^2 had an odds ratio of 5.6 (95% confidence interval, 1.9 to 16.6) when compared with the referent group of individuals who had a body-mass index of ≤25 kg/m^2. Individuals who reported that they spent the majority of their workday on their feet had an odds ratio of 3.6 (95% confidence interval, 1.3 to 10.1) when compared with the referent group of those who did not.

Conclusions: The risk of plantar fasciitis increases as the range of ankle dorsiflexion decreases. Individuals who spend the majority of their workday on their feet and those whose body-mass index is >30 kg/m^2 are also at increased risk for the development of plantar fasciitis. Reduced ankle dorsiflexion, obesity, and work-related weight-bearing appear to be independent risk factors for plantar fasciitis. Reduced ankle dorsiflexion appears to be the most important risk factor.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

Plantar fasciitis, typically a localized inflammatory condition of the plantar aponeurosis of the foot, is reported to be the most common cause of inferior heel pain[1]. The disorder is seen relatively frequently in athletically active individuals[2] and military personnel[3] but also is diagnosed in individuals with sedentary lifestyles[4,5]. Researchers have estimated that the condition occurs in approximately two million Americans per year[6] and affects as much as 10% of the population during the course of a lifetime[7]. It has been reported that approximately 5% of patients who are diagnosed with plantar fasciitis undergo surgery for the condition[4,8]. The etiology of plantar fasciitis is poorly understood[9,10]. It is well known that plantar fasciitis can occur in association with various arthritides, but in approximately 85% of cases the etiology is unknown[1,11]. Several causes have been hypothesized, with the most common being overuse due to prolonged weight-bearing, obesity, unaccustomed walking or running, and limited dorsiflexion of the ankle joint[1,12].

There is no accepted so-called gold standard for the diagnosis of plantar fasciitis. The diagnosis is typically made on the basis of clinical findings. The general consensus in the literature is that patients with plantar fasciitis report pain and tenderness in the area of the medial tubercle of the calcaneus, pain when taking the first few steps in the morning, and pain that is generally worse while weight-bearing[1,7,12]. We conducted a matched case-control study to determine whether risk factors for the disorder could be identified.

Materials and Methods

Subjects

The study group consisted of fifty consecutive patients with a diagnosis of unilateral plantar fasciitis who met the inclusion criteria. All patients had been referred by physicians to one of two outpatient physical therapy clinics in the suburban Richmond, Virginia area. All patients reported pain in the area of the insertion of the plantar aponeurosis on the medial tubercle of the calcaneus. In all cases, the pain was provoked when the patient took the first few steps in the morning and increased with weight-bearing during the day. All patients reported that they were not performing ankle stretching exercises as treatment of the plantar fasciitis. Patients who had been diagnosed with a systemic arthritic condition, tarsal tunnel syndrome, or a calcaneal stress fracture by the referring physician were excluded, as were patients with bilateral plantar fasciitis. We excluded patients with bilateral plantar fasciitis because we wanted to compare the passive ankle dorsiflexion on the uninvolved side with the measurements for the control subjects. The mean age of the patients (and standard deviation) was 49 ± 11 years (range, thirty-one to eighty-five years). The mean duration between the onset of pain and admission to the study was 287 ± 550 days (median, 123 days; range, fourteen to 3650 days). Five patients had diabetes, and five had hypertension. No other comorbidities were reported.

We designed the study to have 2:1 matching, with two controls for each patient. The matching criteria were age in years (based on decade) and gender. The control sample consisted of 129 subjects who reported that they had never been diagnosed with plantar fasciitis. These subjects also reported that they had had no injury of the lower extremities during the previous year. The control subjects were recruited from the outpatient clinics themselves as well as from a local church congregation. The mean age of the control subjects was 50 ± 12 years (range, thirty-one to eighty-five years). The control subjects initially were recruited without regard to whether they could be matched to a patient. Matching was done by pairing patients with age and gender-matched control subjects in the chronological order in which they were admitted to the study. Eighty of the first 109 control subjects could be matched to a patient on the basis of age and gender. The final twenty control subjects were recruited after all study patients had been evaluated and we determined that a study patient had not yet been paired with two matched controls. Control subjects were recruited without our knowing the range of ankle dorsiflexion or the amount of time that they spent weight-bearing at work. For the ankle dorsiflexion data, the involved and uninvolved sides of the study patients were matched with the same sides (right or left) of the control subjects. All subjects read and signed an institution-approved consent form prior to participation.

Procedures

For each subject, we collected data for the variables that have been identified most frequently in the literature as being a potential risk factor for plantar fasciitis[1,12]. We calculated body-mass index (kg/m^2) from the height and weight data reported by each subject. It has been reported that height and weight data that are self-reported correlate highly with actual measures of body-mass index (Pearson correlation coefficient [r] = 0.89 to 0.97, depending on age)[13]. We therefore had confidence that the subjects' self-reported data on height and weight were valid. We asked each subject to answer yes or no to the following questions: "Do you spend the majority of your workday on your feet?" and "Do you run or jog on a regular basis?" No data were collected on the actual number of hours spent weight-bearing or the work surfaces on which the subjects stood.

We also recruited a physical therapist with twenty-five years of clinical experience to make goniometric measurements of passive ankle dorsiflexion with the subject lying prone with knees extended and with the feet over the edge of a plinth. Briefly, the examiner first identified the neutral position of the subtalar joint and then dorsiflexed the foot until a firm end point was felt. The goniometer, which was marked in 1° increments, was positioned on the lateral side of the ankle with the axis over the lateral malleolus.

The examiner kept the subtalar joint in a neutral position during the dorsiflexion measurements to keep the foot from pronating because pronation of the foot can mimic the motion of ankle dorsiflexion[14,15] and give a false reading.

In a pilot study, we examined the reliability of passive ankle dorsiflexion measurements made by this examiner for ten patients with plantar fasciitis. The therapist performed the measurements for both feet of each patient twice, with a few minutes separating the repeated measurements. The therapist was blinded to the goniometric readings during the reliability study. We found an intraclass correlation coefficient (version 2,1) of 0.97 (95% confidence interval, 0.88 to 0.99), indicating excellent reliability[16].

The physical therapist who performed the ankle dorsiflexion measurements was not told whether the subject being tested was a member of the study group or the control group. Because the therapist measured both ankles, no mention was made as to which side was the involved side. We also concealed the identity of the subject with use of a curtain so that the therapist could only observe the subject's legs and feet.

Statistical Methods

The increased risk of plantar fasciitis for all risk factors was estimated by calculating odds ratios with use of conditional logistic regression. In this context, the odds ratio described the odds that a patient with plantar fasciitis had been exposed to the risk factor (e.g., limited dorsiflexion) divided by the odds that a control subject had been exposed to the risk factor, after adjusting for all other variables in the model. The more that the odds ratio deviated from 1, the stronger the association between the exposure variable and the condition being studied.

The relationship between dorsiflexion measurements and the risk of plantar fasciitis was tested for trend by including linear, quadratic, and cubic terms for degrees of limitation of ankle dorsiflexion. The relationship between body-mass index and the risk of plantar fasciitis was tested for trend in a similar fashion. Tests for trend are used to determine whether greater amounts of the exposure variable increase the odds of the disorder. For example, we were able to determine whether

TABLE I Characteristics of Patients and Control Subjects in Relation to Risk of Plantar Fasciitis

	No. of Patients (N = 50)	No. of Controls (N = 100)	Odds Ratio (95% Confidence Interval)
Gender			
Male	17 (34%)	34 (34%)	
Female	33 (66%)	66 (66%)	
Age (in years)			
30-40	11 (22%)	22 (22%)	
41-50	18 (36%)	36 (36%)	
51-60	16 (32%)	32 (32%)	
61-70	1 (2%)	2 (2%)	
>70	4 (8%)	8 (8%)	
Body-mass index (in kg/m^2)*			
22.5 (≤25)	10 (20%)	54 (54%)	1.0 (referent)
27.5 (25 to 30)	11 (22%)	29 (29%)	2.0 (1.28-3.08)†
35 (>30)	29 (58%)	17 (17%)	5.6 (1.9-16.6)†
On feet majority of workday			
Yes	12 (24%)	47 (47%)	3.6 (1.3-10.1)‡
No	38 (76%)	53 (53%)	1.0 (referent)
Recreational jogger			
Yes	4 (8%)	4 (4%)	2.8 (0.4-22.7)
No	46 (92%)	96 (96%)	1.0 (referent)
Ankle dorsiflexion on involved side (in degrees)*§			
12.5 (>10)	5 (10%)	37 (37%)	1.0 (referent)
7.5 (6 to 10)	4 (8%)	26 (26%)	2.9 (1.6-5.0)#
2.5 (1 to 5)	24 (48%)	32 (32%)	8.2 (2.7-24.9)#
−2.5 (≤0)	17 (34%)	5 (5%)	23.3 (4.3-124.4)#

*Body-mass index and ankle dorsiflexion were analyzed as continuous variables. The data for dorsiflexion are presented in the table in quartiles, and the data for body-mass index are presented in tertiles. We chose a point at approximately the midrange of each quartile or tertile category to represent the odds ratio for that category. †$p < 0.01$. ‡$p < 0.05$. §The involved side of the study patient was matched with the same sides (right or left) of the control subjects. #$p < 0.001$.

a person with 5° of dorsiflexion had an increased risk of plantar fasciitis relative to a person who had 10° of dorsiflexion. In some texts, this phenomenon has been described as a "dose-response" effect[17,18]. All two-way interactions were initially included in the model. A backward elimination method was used to select the prediction model.

Both dorsiflexion and body-mass index were analyzed as continuous variables. To simplify presentation of the results, we divided the dorsiflexion data into quartiles and the body-mass index data into tertiles. We chose a point at approximately the midrange of each quartile or tertile category to represent the odds ratio for that category. For example, one of the dorsiflexion quartiles was >10° of dorsiflexion. We chose the value of 12.5° to represent that quartile. The data were analyzed with use of SAS/STAT software (version 8 of the SAS System for Windows; SAS Institute, Cary, North Carolina). All p values are two-tailed.

Two conditional logistic regression models were estimated. The first model included as primary variables dorsiflexion of the involved ankle, body-mass index, an indicator of spending a majority of the workday on the feet, and an indicator of jogging on a regular basis. Secondary variables were included initially but were removed with the backward elimination method. These included dorsiflexion of the uninvolved ankle, quadratic and cubic values for dorsiflexion and body-mass index, and all two-way interactions between primary variables. The second model was similar except that dorsiflexion of the uninvolved ankle replaced dorsiflexion of the involved ankle as a primary variable. As in the first model, the secondary variables were removed with the backward elimination method.

Results

Limited ankle dorsiflexion on the involved side significantly increased the risk of plantar fasciitis after adjustment for the other variables in the model (Table I). Compared with the referent group of subjects who had >10° of dorsiflexion (representative value, 12.5°), those who had 6° to 10° of dorsiflexion (representative value, 7.5°) had an odds ratio of 2.9 (95% confidence interval, 1.6 to 5.0), those who had 1° to 5° of dorsiflexion (representative value, 2.5°) had an odds ratio of 8.2 (95% confidence interval, 2.7 to 24.9), and those who had ≤0° of dorsiflexion (representative value, –2.5°) had an odds ratio of 23.3 (95% confidence interval, 4.3 to 124.4). An exponential relationship was found for the ankle dorsiflexion measurements (linear term, $p < 0.001$).

Increased body-mass index also significantly increased the risk of plantar fasciitis after adjustment for the other variables in the model (Table I). Compared with the referent group of subjects who had a body-mass index of ≤25 kg/m^2, those who had a body-mass index of 25 to 30 kg/m^2 (representative value, 27.5 kg/m^2) had an odds ratio of 2.0 (95% confidence interval, 1.28 to 3.08) ($p < 0.01$) and those who had a body-mass index of >30 kg/m^2 (representative value, 35 kg/m^2), which is the cutoff for grade-II obesity[19], had an odds ratio of 5.6 (95% confidence interval, 1.9 to 16.6) ($p < 0.01$). Subjects who reported being on their feet for the majority of the workday also had a significantly increased risk of plantar fasciitis (odds ratio, 3.6; 95% confidence interval, 1.3 to 10.1) ($p < 0.05$).

Limited ankle dorsiflexion on the uninvolved side also significantly increased the risk of plantar fasciitis after adjustment for body-mass index, time spent weight-bearing, and jogging status (Table II). Compared with the referent group of subjects who had >10° of dorsiflexion on the uninvolved side (representative value, 12.5°), those who had 6° to 10° of dorsiflexion (representative value, 7.5°) had an odds ratio of 2.1 (95% confidence interval, 1.3 to 3.4) ($p < 0.01$), those who had 1° to 5° of dorsiflexion (representative value, 2.5°) had an odds ratio of 4.6 (95% confidence interval, 1.8 to 11.5) ($p < 0.01$), and those who had ≤0° of dorsiflexion (representative value, –2.5°) had an odds ratio of 9.8 (95% confidence interval, 2.5 to 39.2) ($p < 0.01$). An exponential relationship was found for the ankle dorsiflexion measurements on the uninvolved side (linear term, $p < 0.01$).

Discussion

The findings of the present study indirectly support the hypothesis that limited ankle dorsiflexion, obesity, and prolonged weight-bearing at work play a role in the etiology of plantar fasciitis. The odd ratios suggested that limited dorsiflexion may be the most important of these three factors. Previous research has suggested that limited ankle dorsiflexion[20,21], obesity[22], and prolonged weight-bearing[23] may increase the risk of plantar fasciitis. Those studies, however, involved the use of univariate analytical approaches and, in some cases, did not include a control group.

The three risk factors identified in this study all appear to have a biologically plausible explanation for causality. Approximately 10° of ankle dorsiflexion, with the knee extended, is required during normal walking[24]. If the Achilles tendon is shortened, thereby limiting the amount of ankle dorsiflexion, excessive pronation of the foot may occur to compensate for the limited ankle dorsiflexion. Excessive pronation of the foot increases tensile loads on the plantar aponeurosis[25,26]. In theory, the greater the limitation in ankle dorsiflexion, the more the plantar fascia is loaded because of the compensatory pronation and the higher the risk for the development of plantar fasciitis. Individuals who spend the majority of the workday weight-bearing and those who are obese also theoretically have increased tensile loads on the plantar fascia compared with those who spend less time weight-bearing and those who have a normal body weight.

We examined risk factors for plantar fasciitis in the context of a case-control study. Case-control designs are commonly used in medicine to study causality, especially for disorders that are not common. The primary limitation associated with case-control studies is that the temporal relationship between the risk factor and the disorder of interest cannot be examined because cases are assessed only after the disorder has been diagnosed. To make an argument for causality, case-control studies must avoid bias, demonstrate that a strong association is present, show a "dose-response" relationship, and provide a biologically plausible explanation for the relationship[17,18].

TABLE II Risk of Plantar Fasciitis Based on Range-of-Motion Data for the Uninvolved Side

	No. of Patients (N = 50)	No. of Controls (N = 100)	Odds Ratio (95% Confidence Interval)*
Ankle dorsiflexion on uninvolved side (in degrees)†‡			
12.5 (>10)	6 (12%)	34 (34%)	1.0 (referent)
7.5 (6 to 10)	11 (22%)	31 (31%)	2.1 (1.3-3.4)§
2.5 (1 to 5)	24 (48%)	31 (31%)	4.6 (1.8-11.5)§
–2.5 (≤0)	9 (18%)	4 (4%)	9.8 (2.5-39.2)§

*Data are adjusted for body-mass index (weight in kilograms divided by the square of the height in meters), whether the person spent the majority of time on their feet at work, and whether the patient was a recreational jogger. †Ankle dorsiflexion was analyzed as a continuous variable. The data for dorsiflexion are presented in quartiles. We chose a point at approximately the midrange of the quartile category to represent the odds ratio for that category. ‡The uninvolved side of the case subject was matched with the same sides (right or left) of the control subjects. §$p < 0.01$.

We attempted to avoid bias in our study by blinding the examiner and by selecting our sample from one defined population: adults in one suburban setting. We attempted to reduce the chances for confounding by controlling for age and gender and by adjusting for all other variables in the statistical analysis. Patients were selected for the study only if they met the most frequently described clinical criteria for plantar fasciitis. We also found what we consider to be a strong association between plantar fasciitis and the risk factors that were studied, especially limited dorsiflexion.

The temporal relationship between the risk factor of limited dorsiflexion and plantar fasciitis is unclear from our study. It is possible that limited dorsiflexion developed after the onset of the disorder. Theoretically, if plantar fasciitis had caused the loss of dorsiflexion, then the motion on the involved side would have been reduced and the motion on the uninvolved side would not have been reduced. However, we found that dorsiflexion on the uninvolved side was also reduced relative to that in the control group. We also found a "dose-response" relationship for the risk factor of limited dorsiflexion on the uninvolved side. We believe that these data support our hypothesis that ankle dorsiflexion may have been limited before the onset of the disorder.

Our study met the main criteria of association, a dose-response relationship and biological plausibility. Our study did not appear to meet the criterion of temporal progression. It is not clear from our study whether the risk factor of limited ankle dorsiflexion was a cause or a consequence of plantar fasciitis. Given the lack of evidence in the literature, we chose first to determine whether risk factors could be identified with use of a cost-efficient, case-control design. We found what appears to be the strongest evidence to date linking three risk factors (limited dorsiflexion, obesity, and spending the majority of the workday weight-bearing) with plantar fasciitis. To provide stronger evidence, a cohort study would need to be conducted to examine the temporal relationship between the risk factors and plantar fasciitis. Cohort studies are traditionally more time-consuming and costly to conduct than case-control studies are because a large group comprising hundreds of asymptomatic subjects would have to be followed for an extended period of time until a sufficient number had the disorder.

Crawford et al., in a recent systematic review of randomized clinical trials on the treatment of plantar fasciitis, reported that none of the studies had examined the effectiveness of exercises designed to improve the range of ankle dorsiflexion[7]. Given the results of the present study, exercise interventions that are designed to increase ankle dorsiflexion appear to warrant study. Populations at risk for the development of plantar fasciitis also may benefit from preventive exercises designed to increase ankle dorsiflexion. Weight loss also may be an effective preventive intervention.

We cannot exclude the possibility of chance or other confounders as an explanation for our findings. We believe that we minimized the risks of confounding by matching on the basis of age and gender, two variables that have been suggested to influence the risk of the disorder. We also accounted for the variables that have been most frequently implicated in the etiology of plantar fasciitis.

Our study was not designed to examine the risk factors for plantar fasciitis specifically in athletes or competitive runners. Only eight subjects in our study reported that they were recreational noncompetitive joggers. The findings of our study should probably not be generalized to athletic populations.

Within the framework of a case-control study, we found what we consider to be good evidence of an association between plantar fasciitis and the risk factors of limited ankle dorsiflexion, obesity, and work-related weight-bearing. We also found "dose-response" relationships between plantar fasciitis and the risk factors of limited dorsiflexion and body-mass index and offered biologically plausible arguments for these relationships. ■

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