First ray mobility and posterior tibial tendon dysfunction (PTTD) in persons with flat foot: A case control study

Abstract

Background: While posterior tibial tendon dysfunction (PTTD) commonly presents with flat feet, many flat-footed individuals are asymptomatic and do not experience any symptoms of PTTD. Thus, there is a need to control for foot type when studying factors related to PTTD. This study aimed to clarify if first ray mobility differed between flat-footed individuals with and without symptoms of PTTD. It was hypothesized that PTTD patients would display higher mobility of the first ray than asymptomatic flat-footed controls.

Methods: Given that PTTD patients were often flat footed, asymptomatic flat-footed individuals were chosen as controls to remove flat foot as a potential confounding factor. We recruited 32 flat-footed subjects, of which 16 exhibiting PTTD symptoms and 16 asymptomatic controls matched for age, sex and body mass index. First ray mobility was assessed using subjective classification ("stiff", "normal" or "hypermobile") and maximum dorsal displacement using a ruler indicator. Mann-Whitney U was used to test for between-groups differences.

Results: Subjective classification was similar between PTTD and control groups (both groups: 38% "normal" joint mobility). No significant differences were found between PTTD patients and asymptomatic controls in first ray displacement [median (IQR), PTTD: 6.00 (1.75) mm; control: 6.00 (1.00) mm; *P* = .31].

Conclusions: First ray mobility was not associated with PTTD in flat-footed persons. When evaluating symptoms of PTTD, clinicians should pay attention to factors other than first ray mobility.

Word Count: 227

1. Introduction

Posterior tibial tendon dysfunction (PTTD) is a progressive and debilitating condition of the tendon of tibialis posterior muscle. It is suggested that surgery is the only definitive treatment for late stage PTTD [1]. Flat foot has been commonly associated with PTTD, among other risk factors including female sex, age-related degeneration, systemic conditions such as diabetes, hypertension and obesity, and trauma [1-5].

From a biomechanical perspective, instability of the medial column of the foot has been linked to posterior tibial tendinopathy [6,7]. Chi et al. [6] found that 80% posterior tibialis tendon insufficiency cases experienced decrease in pain or were pain free after lateral column lengthening and medial column stabilization by corrective fusion of the naviculocuneiform and first metatarsocuneiform joints. More specifically pertaining to the first ray (first metatarsocuneiform joint), Glasoe and Saltzman [7] reported a case where chronic posterior tibial tendinopathy was resolved with surgical fixation of hypermobile first ray. A more recent study showed that patients with posterior tibial tendonitis (tendinopathy) had greater first ray mobility than patients without tibialis tendonitis, however the difference did not reach statistical significance [8]. Collectively, these findings provide weak evidence that tibialis posterior tendon condition may be associated with first ray mobility but the mechanism is not fully understood.

While PTTD commonly presents with flat feet [2,4,5], many flat-footed individuals are asymptomatic and do not experience any symptoms of PTTD. Previous studies examining the clinical and biomechanical factors of PTTD did not clearly differentiate the foot type of PTTD patients [1-5], making it difficult to isolate the effect of PTTD or flat foot. The muscle activation patterns of the tibialis posterior differ between flat foot and neutral foot populations [9-11]. During the mid-stance

phase of walking, the tibialis posterior muscle in flat-footed individuals is more activated in holding up the low arch of foot in inversion as body weight is loaded and passed over the foot when compared to those with neutral foot type [9]. Considering these biomechanical differences between individual of flat and neutral foot types, there is a need to control for foot type of the patients when studying factors related to PTTD.

The aim of this study was to clarify if first ray mobility differed between flat-footed individuals with and without symptoms of PTTD. Given that PTTD patients were often flat footed, asymptomatic flat-footed individuals were chosen as controls to remove flat foot as a potential confounding factor. It was hypothesized that PTTD patients would display higher mobility of the first ray than asymptomatic flat-footed controls.

2. Materials and Methods

2.1. Subjects

Ethical approvals were received from the (xx university) Institutional Review Board (IRB number xx) and the (yy hospital) Institutional Review Board (CIRB number yy). This was a case control study where 16 flat-footed subjects exhibiting PTTD symptoms were compared to 16 asymptomatic flat-footed controls matched for age, sex and body mass index (Table 1). A priori power analysis was performed (large effect size, $\alpha = 0.05$, power = 0.8) to determine that a total of 32 subjects (16 PTTD patients, 16 asymptomatic controls) were required.

*** Table 1 goes here ***

2.2 Screening

All screening and testing procedures were performed by the same investigator who was a certified podiatrist with 6 years of clinical experience. Subjects were recruited through personal contacts and patients from the (yy hospital) Podiatry Clinic. After obtaining written informed consent from the subjects, the height and body mass of subjects were taken. All subjects filled out a survey of past medical history and took the General Practice Physical Activity Questionnaire (GPPAW) online to determine their activity level in four categories: Active, Moderately Active, Moderately Inactive, and Inactive [12]. GPPAQ is a validated screening tool, used in primary care to assess the physical activity levels of adults (16 to 74 years). It provides a simple, 4 level physical activity index (https://www.gov.uk/government/publications/general-practice-physical-activity-questionnaire-gppaq). Their generalised joint hypermobility was assessed using Beighton score [13].

Foot type was assessed using the foot posture index (FPI), a scoring system that considers the standing position of various anatomical segments (forefoot, mid-foot and rearfoot) in all planes (frontal, transverse, and sagittal). Flat foot was defined as FPI score of ≥ 6 [14]. Symptoms of PTTD were screened based on the guidelines set by Johnson and Strom for early stage (I and II) PTTD [1,15-17]: (i) tenderness to palpation of the posterior tibial muscle belly or tendon, (ii) swelling behind medial malleolus, (iii) weakness or pain during single limb heel rise or (iv) inability of heel to swing into inversion upon heel rise.

The inclusion criteria for the PTTD group were (i) age between 15 to 39 years, (ii) FPI score of ≥ 6 and (iii) at least one symptom of PTTD described above. The same inclusion criteria applied to subjects in the control group except that they did not exhibit any PTTD symptoms. Each control subject was matched pairwise to a PTTD patient based on age, sex and body mass index. The exclusion criteria for

both groups were (i) diabetes, (ii) hypertension, (iii) rheumatic inflammatory disease, (iv) related foot trauma (v) steroidal intervention in affected area, or (vi) previous foot surgery [1-5,9,16,17].

2.3. Procedures

To avoid confounding of sidedness, all measurements were taken on the master side of the subject {1,819}. First ray mobility was assessed using two procedures: subjective assessment and maximal displacement. Details of each method were described below:

Subjective assessment. Subjective evaluation by a clinician is the most practiced approach in clinical settings to evaluate foot joint mobility since this assessment is fast, simple and does not require any equipment. The lesser metatarsals of the subject were held in place while the tester applied an upward and downward force to displace the first metatarsal. Based on personal experience and subjective judgment, the tester then classified the first ray as "stiff", "normal" or "hypermobile". The widely accepted description of hypermobility is "an excessive dorsal excursion with a soft end-point of motion" [20-22].

Maximum first ray displacement. A practical way to quantify first ray mobility is measuring the vertical dorsal displacement of the first ray using simple ruler indicators [8,23]. We custom made a ruler device similar to those previously used in the literature (Figure 1a). With the lesser metatarsals held in place, the tester applied an upward force underneath the first metatarsal head. The maximum dorsal displacement (in mm) of the first ray was then measured using the ruler device (Figure 1b). Five trials were taken per subject and the maximum value was used for further analysis. The root mean squared difference of 17 repeated measurements,

taken 7 days apart by the same tester, was 0.97 mm. This assures that the

maximum displacement measurements were sufficiently reliable.

*** Figure 1 goes here ***

2.4. Statistical Analyses

Statistical analyses were performed using SPSS version 21.0 (SPSS Inc, IL,

Chicago). Descriptive statistics were calculated for physical characteristics of

subjects and test variables. Normality of the data was checked using Shapiro-Wilk

statistic and observation of Q-Q plot. Although the subjects were matched pair-wise

for age, sex and BMI, independent group comparisons were made because the

matching would not have likely controlled for all possible variations or influence of

the covariates, leading to understated variations. As such, Mann Whitney U tests

were used to compare the maximal displacement of the first ray between the PTTD

and control groups. Statistical significance was set at 0.05 level. Data are expressed

as median [interquartile range (IQR)] unless stated otherwise. Effect size (r) was also

calculated, where applicable, to show the magnitude of difference between groups

using the following equation: $r = Z / \sqrt{N}$, where Z is the standard Z statistics, N is

number of observations made [24]. Post hoc powers were also computed.

3. Results

Overall, the physical characteristics were similar between the PTTD and control

groups, except that flatter foot type was observed in the PTTD patients (P = .03,

Table 1). The activity level of the PTTD group was also lower than the control group.

For first ray mobility assessment, subjective classification were similar

between PTTD and control group (38% classified as "normal" joint mobility for both

groups, Table 2). First ray maximum displacement also did not statistically differ between PTTD patients and the matched controls and the effect size was small (Table 2).

*** Table 2 goes here ***

4. Discussion

This study aimed to compare first ray mobility between flat-footed individuals with and without symptoms of PTTD. In contrast to our hypothesis, there was no significant difference in first ray mobility between PTTD patients and asymptomatic flat-footed matching controls regardless of the assessment methods.

In the literature, there is weak evidence to suggest that first ray hypermobility and instability may be associated with PTTD [7,8]. In a case report, Glasoe and Saltzman [7] demonstrated improvement and even resolution of PTTD symptoms with the surgical fixation of a laxed first ray joint. The authors postulated that laxity in the arch due to hypermobile first ray would overload the posterior tibial tendon and result in chronic tendinopathy. The fixation hence reinforced the posterior tibial tendon. To clarify this postulation, the present study provided empirical evidence that first ray mobility did not differ between PTTD patients and asymptomatic controls. Given that PTTD patients are often flat footed, we intentionally targeted the flat footed population to remove foot type as a confounding factor. This improved study design allows us to isolate the effect of PTTD from flat foot as compared to previous studies which did not control for the foot type of PTTD patients [1-5]. Since our findings suggested that first ray mobility is unlikely associated with PTTD, clinicians should direct their attention to factors other than first ray mobility when evaluating PTTD conditions.

The lack of difference in first ray mobility is in agreement with the study by Griesberg et al. [8] who observed similar first ray displacement between patients with (22 feet) and without (323 feet) posterior tibial tendinitis. From our findings, it may be inferred that not all PTTD patients are affected by first ray instability. The posterior tibial tendon courses behind the medial malleolus and attaches to the navicular, cuneiform, cuboid, and second to fourth metatarsals. Since this tendon does not cross the first metatarsocuneiform joint, it has no direct anatomical relationship with the first ray. Thus, it is reasonable to also expect no direct biomechanical relationship between the first ray and posterior tibial tendinopathy.

The present study intended to include subjects of similar severity of flat foot by a criteria of FPI ≥ 6 for both groups. Yet, the PTTD patients (median FPI = 9) had slightly flatter feet than their asymptomatic counterparts (median FPI = 8, Table 1). Future studies can better match the severity of flat foot to avoid potential confounding factors. In our study, the flatter foot type in the PTTD patients supports previous findings that flat foot or low medial arch are known mechanical factors associated with PTTD [17,25-26]. In parallel with the higher FPI, PTTD patients also displayed higher Beighton score (median = 3) for generalised hypermobility than the control group (median = 2), although this difference did not reach statistical significance. Future studies can investigate the relationship between hypermobility and joint stiffness with consideration of the severity of flat foot. Since PTTD is associated with more severe flat foot types, screening and early intervention of flat foot may be a plausible way of preventing PTTD. Moving forward, it will be useful to investigate what predisposes certain flat-footed individuals to further progress into PTTD.

There were several limitations to our study. Firstly, the severity of flat foot and physical activity level varied between the PTTD and control groups. While this could be an inherent issue of PTTD patients may be experiencing pain and therefore less active, future studies should control these potential confounding factors. Secondly, the tester who performed the assessments was not blinded to subject's group allocation. Since the subjective assessment for mobility classification was performed before the objective quantification of displacement, it is believed that the influence due to bias would be minimal. Thirdly, we acknowledged that many mechanical factors may have contributed to the development of PTTD and that this study investigated medial column stability in isolation. Such univariate analysis could be oversimplifying the complex biomechanics of the foot. Future studies can consider the inter-play of multiple factors that may be associated with PTTD, for example, foot structure (rearfoot eversion, arch height), muscle (foot invertors) strength, and foot joints mobility. Fourthly, we did not include a third group of asymptomatic individuals with normal foot type. Having this additional control group would allow a clearer comparison of PTTD, mobility and foot type.

In conclusion, this study showed that first ray mobility was not associated with PTTD in flat-footed individuals. When evaluating symptoms of PTTD, clinicians should pay attention to factors other than first ray mobility.

Word Count = 2134

Brief Summary

What Is Already Known?

- There are weak evidence to suggest that tibialis posterior tendon condition may be associated with first ray mobility

- Posterior tibial tendon dysfunction (PTTD) commonly presents with flat feet

- Flat-footed individuals can be asymptomatic and do not experience any symptoms of PTTD

What This Study Adds?

- Maximum dorsal displacement of the first ray did not differ between PTTD patients and asymptomatic flat-footed controls

- Clinical evaluation of first ray stiffness also did not differ between PTTD patients and controls

- First ray mobility was not associated with PTTD in flat-footed persons.

Declarations of Interest

None

Figure Captions

Figure 1 (a) Ruler device positioned on the dorsum of the foot to measure first ray

displacement; (b) As the first ray was displaced upwards dorsally, the

difference noted on the graduated ruler was recorded.

Table 1 Physical characteristics of the symptomatic posterior tibial tendon dysfunction (PTTD) patients and asymptomatic flat-footed controls.

	PTTD (*n* = 16)	Control (*n* = 16)	*P*-value
Sex			
- Female	13 (81%)	13 (81%)	
- Male	3 (19%)	3 (19%)	
Age [yrs]	29.5 (12.75)	28.0 (9.75)	.56
Height (m)	1.60 (0.01)	1.65 (0.12)	.20
Body mass (kg)	58.1 (22.7)	62.3 (12.7)	.52
Body Mass Index [kg/m^2]	22.9 (10.53)	23.0 (3.36)	.91
Foot Posture Index	9.00 (2.00)	8.00 (2.00)	**.03***
Beighton score	3.00 (3.75)	2.00 (3.00)	.62
Activity Level			
- Inactive	6 (37%)	0	
- Moderately inactive	2 (13%)	3 (19%)	
- Moderately active	4 (25%)	6 (37%)	
- Active	4 (25%)	7 (44%)	

Sex and activity level are expressed as n (% group total). All other data are expressed in median (IQR) and were compared using Mann-Whitney U tests. "*" denotes statistically significant value at 0.05 level. Beighton score of less than 5 are considered normal. Activity level was determined by an online General Practice Physical Activity Questionnaire.

Table 2 First ray mobility measurements of the symptomatic posterior tibial tendon dysfunction (PTTD) patients and asymptomatic flat-footed controls.

Assessment methods	PTTD (*n* = 16)	Control (*n* = 16)	*P*-value	*Z*	*Effect Size*	*Post hoc power*
Subjective first ray assessment						
- Stiff	1 (3%)	0				
- Normal	6 (38%)	6 (38%)		NA		
- Hypermobile	9 (56%)	10 (62%)				
Maximum first ray displacement [mm]	6.00 (1.75)	6.00 (1.00)	.31	-1.10	.19	.84

Subjective assessment outcomes expressed as n (% group total). All other data are expressed in median (IQR) and were compared using Mann-Whitney U tests. Level of significance was set at 0.05.

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