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Prevalence of Posterior Tibial Tendon Dysfunction and Its Association with Foot Posture Among Overweight University Students

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ABSTRACT

Background: *Posterior tibial tendon dysfunction (PTTD) compromises medial arch support and is linked with altered foot posture; however, data in young overweight populations are limited.* ***Objective:*** *To determine the prevalence of suspected PTTD and its association with foot posture among overweight university students.* ***Methods:*** *A cross-sectional observational study was conducted among 155 overweight students (18–30 years) recruited from universities in Lahore. BMI was calculated from standardized height and weight measures. Foot posture was assessed using the Foot Posture Index (FPI-6) and categorized as neutral, pronated/highly pronated, or supinated/highly supinated. Suspected PTTD was operationalized as positivity on the single-limb heel-rise test (performance failure and/or reproduction of medial ankle pain), and pain intensity was recorded using the Numeric Pain Rating Scale (NPRS). Associations between foot posture and heel-rise outcomes were examined using chi-square tests with effect size (Cramer's V), and multivariable logistic regression adjusted for age, sex, and BMI.* ***Results:*** *The prevalence of suspected PTTD was 31.0% (48/155; 95% CI 23.8%–38.9%). Neutral posture was most common (55.5%), followed by pronated (20.0%) and highly pronated (11.0%). Heel-rise positivity increased with pronation severity (neutral 15.1%, pronated 48.4%, highly pronated 94.1%); the association was significant ($\chi^2(4)=42.34$, $p<0.001$; Cramer's V=0.52). In adjusted analysis, pronated (aOR 4.72, 95% CI 1.78–12.50) and highly pronated posture (aOR 76.40, 95% CI 8.72–669.18) and BMI (aOR 1.18 per kg/m², 95% CI 1.01–1.38) predicted heel-rise positivity.* ***Conclusion:*** *Suspected PTTD was common in overweight university students and was strongly associated with increasingly pronated foot posture, supporting early screening and preventive strategies in young adults.*

Keywords: *posterior tibial tendon dysfunction; overweight; Foot Posture Index; pronation; single-limb heel-rise test; university students; prevalence.*

INTRODUCTION

Posterior tibial tendon dysfunction (PTTD), also termed posterior tibial tendon insufficiency, is a progressive disorder in which degeneration of the posterior tibial tendon compromises its capacity to support the medial longitudinal arch, ultimately predisposing to acquired flatfoot deformity, hindfoot valgus, and functional limitation (1). The tibialis posterior muscle–tendon unit has a deep posterior compartment origin and a complex distal insertion pattern centered on the navicular and midfoot structures, enabling inversion, assisting plantarflexion, and stabilizing the medial arch particularly during mid-stance and push-off, when it contributes to locking the midfoot and hindfoot for efficient propulsion (2). Because the region of the tendon is relatively vulnerable to impaired vascular supply, failure of tendon integrity can create maladaptive loading of medial foot structures, fostering arch collapse; importantly, this mechanical collapse may be both a consequence of tendon dysfunction and a contributor to further tendon overload, creating a clinically relevant cycle between tendon failure and flatfoot deformity (3).

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Epidemiologically, PTTD has traditionally been described as more common in overweight or obese middle-aged adults—particularly women—and is frequently accompanied by systemic or local risk factors such as obesity, diabetes, hypertension, prior trauma, steroid exposure, or prior surgery (4). Contemporary etiologic frameworks emphasize that PTTD is multifactorial, arising from intrinsic factors (e.g., biomechanical alignment, inflammatory susceptibility) interacting with extrinsic load-related factors, most notably elevated body mass and repetitive mechanical stress (5). Clinically, early disease often presents with medial ankle pain and swelling and may progress to difficulties with single-limb toe standing as arch collapse advances, altering foot mechanics and potentially contributing to broader kinetic chain stress and disability (6). The condition is commonly conceptualized along staged severity pathways ranging from early tendon pain with preserved structure to progressive deformity and arthritic change, with later stages requiring increasingly complex operative strategies compared with earlier stages that may be managed conservatively (7). Biomechanical investigations further suggest that PTTD can alter midfoot mechanics and energetics during gait, reinforcing the clinical observation that tendon dysfunction is not merely a localized tendon pathology but a broader functional disorder affecting walking performance (8).

Accurate characterization of PTTD requires careful attention to diagnostic methods and case definitions. Imaging modalities—including radiography, ultrasound, CT, and MRI—can support evaluation by characterizing deformity, tendon morphology, and associated pathology, though their utility varies by stage and clinical context (9). Ultrasound can demonstrate tendon thickening, sheath effusion, hyperemia, tears, or calcification, offering a relatively accessible assessment of tendon architecture (10). MRI may be particularly useful when ultrasound is inconclusive or when broader ankle pathology is suspected, including tendon rupture, edema patterns, and muscle atrophy, while CT is often reserved for situations where MRI is contraindicated and osseous anatomy requires clarification (11). Nevertheless, many clinical pathways prioritize history and physical examination, and diagnostic reviews highlight that clinical tests—when clearly standardized—remain central to identification and staging, particularly where imaging is not feasible (12). In this context, the single-limb heel rise test is widely used to assess posterior tibial function, with abnormal performance (inability to complete a heel rise and/or failure to achieve hindfoot inversion during rising, often accompanied by pain) interpreted as clinically meaningful for posterior tibial tendon dysfunction assessment, although its interpretation depends critically on a prespecified protocol and positivity criteria (13).

Management strategies similarly span conservative and surgical approaches that are typically aligned to severity and flexibility of deformity. Systematic reviews of orthotic interventions indicate that arch-supporting orthoses and bracing may reduce symptoms and support function in earlier stages, especially when paired with exercise programs (14). Exercise-focused evidence suggests that strengthening and stretching strategies can reduce pain and disability, though clinical trials vary in exercise prescription reporting and standardization, underscoring the importance of precise intervention description and reproducible protocols (15). Comparative discussions of orthotics versus manual therapy and adjunctive techniques suggest potential benefits of multimodal conservative care, but also highlight limitations in conclusiveness across treatment modalities, reinforcing the importance of robust measurement and consistent clinical definitions when evaluating PTTD-related impairment (16). Where conservative treatment fails, descriptions of operative care include tendon debridement and repair in earlier deformity stages and progressively more reconstructive procedures in advanced disease, with postoperative immobilization and rehabilitation influencing clinical outcomes (17). Advanced stages may require arthrodesis

and, when ankle involvement exists, more extensive combined procedures, again emphasizing that early detection is clinically valuable if progression is to be mitigated (18).

From a biostatistical and clinical research perspective, a central methodological issue is distinguishing true PTTD-related dysfunction from broader foot and ankle symptoms in populations with elevated load exposure. Systematic syntheses show that posterior tibial tendinopathy and PTTD are associated with measurable gait alterations, supporting the plausibility that functional screening tests may capture meaningful impairment, but also indicating potential heterogeneity by stage, pain, and comorbid mechanics (19). Kinematic studies have demonstrated distinct ankle and foot movement patterns associated with stage II PTTD during stance, reinforcing the role of alignment and dynamic control in disease presentation (20). Biomechanical and clinical factors relevant to early-stage dysfunction have been reported, including structural and functional correlates that may contribute to symptom onset and progression (21). More recent evidence continues to document lower-limb biomechanical deficits in early stages during walking, suggesting that subtle dysfunction may manifest before overt rigid deformity becomes established (22). Segmental foot motion analyses further show altered coupling patterns in stage II–III dysfunction, supporting the clinical emphasis on foot posture and rearfoot mechanics in evaluation (23). In parallel, studies linking subtalar pronation to tibialis posterior tissue strain provide mechanistic support for the hypothesis that pronated postures and sustained medial loading may increase posterior tibial tendon demand (24).

Importantly, several clinical pathways into posterior tibial tendon symptoms may be relevant to younger adults, including antecedent ankle sprain injury, where subsequent PTTD or related entrapment syndromes have been documented, suggesting that localized mechanical stressors can contribute even outside the classic middle-aged demographic profile (25). Prevalence-focused work in individuals with flat feet and other structural variations further indicates that foot posture may coexist with or predispose to posterior tibial tendon symptoms, although estimates vary by setting and diagnostic approach (26). Anatomical variants such as accessory ossicles have also been associated with PTTD presentations, reminding clinicians and researchers that structural contributors may confound the relationship between posture and tendon dysfunction if not addressed in eligibility criteria or analysis (27). Imaging-based investigations proposing predictive value of tendon cross-sectional area highlight ongoing efforts to improve early identification but also underscore that most field studies—especially in student populations—must rely on pragmatic clinical measures, making transparency in operational definitions essential (28).

Within overweight and young-adult populations, the rationale for examining PTTD-related dysfunction and foot posture is strengthened by evidence that excess body mass is associated with altered lower-limb alignment parameters and foot posture variations, potentially shifting loads toward the medial arch and posterior tibial tendon (29). Studies comparing overweight/obese individuals to normal-weight peers have reported differences in foot posture, strength, range of motion, and plantar sensation, indicating that load and neuromuscular factors may jointly influence foot function and stability (30). In progressive collapsing foot deformity contexts, tibialis posterior dysfunction has been examined in relation to overall alignment, supporting the clinical intuition that tendon function and posture are interdependent components of the same biomechanical system Although pediatric and atypical populations (e.g., rigid flatfoot in children) are not directly comparable to university students, they illustrate that posterior tibial tendon-related pathology and arch mechanics can have clinically important consequences across age groups, reinforcing the need to contextualize age-specific mechanisms rather than assuming older-adult patterns apply universally Likewise, case-based clinical descriptions of advanced tendonitis and

dysfunction demonstrate the potential severity of acquired deformity and functional loss, emphasizing why early recognition of functional decline and posture-related risk patterns remains a reasonable preventive target Contemporary systematic reviews synthesizing diagnostic and non-surgical assessment practices highlight ongoing uncertainty and variability in the field, further motivating well-defined, reproducible protocols in epidemiologic studies that rely on clinical tests The functional importance of the tibialis posterior is also reflected by its role in tendon transfer procedures for other conditions such as foot drop, indirectly reinforcing that impairment in this musculotendinous unit can have meaningful consequences for gait and stability (30).

Additional context relevant to posture–tendon relationships comes from athletic and radiographic work linking posterior tibialis tendon dysfunction assessments with imaging and deformity markers, suggesting that functional impairment and structural change often co-occur but may not align perfectly without standardized staging Evidence associating obesity with medial longitudinal arch bowing supports a plausible load-mediated pathway from elevated body mass to arch mechanics alteration, which may secondarily increase posterior tibial tendon demand Broader primary-care reviews of foot and ankle tendinopathies also reinforce that overuse, load, and biomechanical alignment are recurring themes, supporting the plausibility of studying PTTD-related dysfunction in younger adults with elevated BMI rather than restricting inquiry to older cohorts For posture quantification, the Foot Posture Index (FPI-6) is widely used as a clinical tool to categorize pronated, neutral, and supinated postures, with published reliability data across clinical contexts supporting its use when standardized training and scoring are applied Methodological studies comparing clinical foot posture techniques further emphasize that reliability depends on examiner training, operational consistency, and appropriate categorization—considerations that are particularly important when posture is used as an exposure variable in association studies Finally, cross-sectional evidence linking age, sex, BMI, and laterality with foot posture in adolescent and near-young-adult samples supports the need to consider demographic and anthropometric covariates when interpreting posture distributions and their clinical correlates in student populations (30).

Despite this body of literature, a clear knowledge gap remains: most PTTD research emphasizes middle-aged or clinically referred patients, whereas the prevalence of suspected PTTD-related functional impairment and its association with quantified foot posture among overweight university students—an accessible group for early identification and preventive intervention—has been less clearly characterized using pragmatic screening measures. Within a PICO framework, the population of interest is overweight university students aged 18–30 years; the exposure is foot posture category (particularly pronated or highly pronated posture quantified by FPI-6) in the context of elevated BMI; the comparator is neutral or supinated posture categories; and the primary outcome is the prevalence of suspected PTTD-related dysfunction operationalized via standardized single-limb heel rise testing (with pain and/or performance failure defined a priori) alongside pain intensity measures. Accordingly, the objective of this study is to estimate the prevalence of suspected posterior tibial tendon dysfunction among overweight university students and to determine whether foot posture (as measured by the FPI-6) is significantly associated with heel-rise test outcomes in this population.

MATERIAL AND METHODS

This cross-sectional observational study was conducted to determine the prevalence of suspected posterior tibial tendon dysfunction (PTTD) and its association with foot posture among overweight university students. A cross-sectional design was selected because it

enables estimation of point prevalence and evaluation of associations between exposure (foot posture) and outcome (heel-rise test positivity) within a defined population at a single time point, without manipulating variables or implementing interventions The study was carried out across four universities in Lahore, Pakistan—University of Management and Technology (UMT), University of Lahore (UOL), University of Central Punjab (UCP), and University of South Asia (USA)—over a defined data collection period during the academic year. All measurements were performed in designated clinical skills laboratories or quiet university spaces to ensure standardized assessment conditions.

The target population comprised university students aged 18–30 years with body mass index (BMI) ≥25 kg/m². Eligibility criteria were defined a priori. Inclusion criteria were: (i) enrollment as a university student at one of the participating institutions, (ii) age between 18 and 30 years, and (iii) BMI ≥25 kg/m² calculated at the time of assessment. Exclusion criteria included: history of lower limb fracture or surgery, known musculoskeletal disorders of the foot or ankle unrelated to suspected PTTD, acute traumatic or overuse injury of the lower limb within the preceding three months, diagnosed neurological conditions affecting gait or balance, systemic inflammatory arthropathies, or any condition that would preclude safe performance of the heel-rise test. Participants were selected using a convenience sampling strategy, whereby eligible students were approached on campus and screened for inclusion. Recruitment involved verbal explanation of the study objectives and procedures, followed by written informed consent prior to data collection. Participation was voluntary and no financial incentives were provided.

Anthropometric measurements were collected using standardized procedures. Body weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale with participants wearing light clothing and no footwear. Height was measured to the nearest 0.01 m using a wall-mounted stadiometer with participants standing upright in the Frankfurt plane. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m²), and classified according to World Health Organization criteria, with BMI ≥25 kg/m² considered overweight or obese for eligibility purposes. Age and sex were self-reported and recorded.

The primary outcome variable was suspected PTTD, operationalized using the single-limb heel rise test, a clinically recognized functional test for posterior tibial tendon integrity. The test was conducted with participants barefoot. Each participant was instructed to stand on one foot while lightly touching a wall for balance support without weight bearing through the upper limbs. They were asked to perform up to 10 consecutive single-leg heel raises at a self-selected controlled pace. The test was considered positive if the participant was unable to complete at least one controlled heel rise through full plantarflexion, demonstrated failure of hindfoot inversion during the rise, or reported reproducible medial ankle pain localized along the posterior tibial tendon during the maneuver. Both feet were tested sequentially with a standardized rest interval of one minute between sides. For analytical purposes, a participant was categorized as heel-rise positive if either foot met the positivity criteria. Pain intensity during the test was quantified using the Numeric Pain Rating Scale (NPRS), a validated 11-point scale ranging from 0 (no pain) to 10 (worst imaginable pain), categorized as no pain (0), mild (1–3), moderate (4–6), or severe (7–10).

The primary exposure variable was foot posture, assessed using the Foot Posture Index (FPI-6), a validated multidimensional clinical tool designed to quantify static foot posture (39,40). The FPI-6 comprises six criteria: talar head palpation, supra- and infra-lateral malleolar curvature, calcaneal frontal plane position, talonavicular prominence, medial longitudinal arch height and congruence, and forefoot abduction/adduction relative to the rearfoot. Each criterion was scored on a five-point ordinal scale from –2 (clear signs of supination) to +2

(clear signs of pronation), yielding a total score ranging from –12 to +12. Assessments were performed with participants standing in a relaxed bipedal stance. Examiners were trained in FPI-6 administration prior to data collection to enhance scoring consistency, consistent with published reliability recommendations (39,40). Based on established cut-offs, total scores were categorized as highly supinated (–5 to –12), supinated (–1 to –4), neutral (0 to +5), pronated (+6 to +9), and highly pronated (+10 to +12). Both feet were assessed independently; for primary analysis, foot posture was classified according to the more pronated foot to reflect maximal biomechanical exposure.

To minimize measurement bias, all examiners underwent standardized training sessions that included supervised practice and calibration exercises prior to participant assessment. A written protocol specifying positioning, verbal instructions, scoring criteria, and test repetition rules was followed for all participants. Instruments were calibrated daily. Data were recorded immediately on structured proformas and subsequently entered into a secured electronic database using double-entry verification to reduce transcription errors. Outliers and implausible values were checked against original forms before final locking of the dataset. To address potential confounding, demographic variables (age and sex) and BMI as a continuous variable were recorded and prespecified for adjustment in multivariable analyses, given evidence that these factors may influence foot posture and tendon dysfunction.

Sample size determination was based on estimation of prevalence and detection of association. Assuming an anticipated prevalence of suspected PTTD of approximately 30% among overweight individuals and aiming for a 95% confidence level with 7% precision, the minimum required sample size was calculated to be 147 participants. To account for potential incomplete data, a target of at least 155 participants was set. All enrolled participants with complete outcome and exposure data were included in the final analysis; cases with missing primary outcome or exposure variables were excluded using complete-case analysis.

Statistical analysis was performed using SPSS version 21 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated as means and standard deviations for continuous variables and frequencies with percentages for categorical variables. Normality of continuous variables was assessed using visual inspection of histograms and Shapiro–Wilk testing. The prevalence of suspected PTTD was expressed as a proportion with 95% confidence intervals.

Associations between categorical variables, including foot posture category and heel-rise test result, were evaluated using Pearson's chi-square test or Fisher's exact test where expected cell counts were less than five. Effect size was quantified using Cramer's V with interpretation based on conventional thresholds. To adjust for potential confounders, binary logistic regression analysis was performed with heel-rise positivity as the dependent variable and foot posture category, BMI, age, and sex entered as independent variables. Adjusted odds ratios (ORs) with 95% confidence intervals were reported. A two-tailed p-value <0.05 was considered statistically significant.

Ethical approval was obtained from the Research Ethics and Support Committee of the University of Management and Technology prior to commencement of the study. All procedures were conducted in accordance with the

Declaration of Helsinki. Written informed consent was obtained from all participants after explanation of study aims, procedures, potential risks, and confidentiality assurances.

Participant anonymity was maintained through coded identifiers, and data were stored in password-protected files accessible only to the research team.

Reproducibility was supported through detailed procedural documentation, standardized measurement protocols, and explicit operational definitions of all variables. The study adhered to recognized reporting standards for cross-sectional observational research to enhance transparency, methodological rigor, and interpretability

RESULTS

Table 1 summarizes the demographic and anthropometric profile of the 155 participants and shows a relatively young, homogeneous student sample with moderate variability in body mass. The mean age was 24.78 years (SD 3.41), spanning 18 to 30 years. Mean body weight was 77.78 kg (SD 9.57), ranging from 56 to 110 kg, while mean height was 1.66 m (SD 0.08), ranging from 1.44 to 1.83 m.

The mean BMI was 28.20 kg/m² (SD 1.96), with values ranging from 25.00 to 34.50 kg/m², confirming that the cohort largely fell within the overweight category, with some participants extending into obesity by BMI.

Table 2 presents the clinical overview, including sex distribution, pain intensity, and the prevalence of suspected PTTD based on the single-limb heel-rise test. Females constituted the majority of participants (92/155, 59.4%), while males comprised 40.6% (63/155). Most participants reported no pain on the NPRS (101/155, 65.2%). Mild pain (NPRS 1–3) was reported by 26 participants (16.8%), moderate pain (NPRS 4–6) by 21 participants (13.5%), and severe pain (NPRS 7–10) by 7 participants (4.5%).

With respect to the primary outcome, 48 out of 155 participants demonstrated a positive heel-rise test, yielding a prevalence of suspected PTTD of 31.0% (95% CI 23.8% to 38.9%), while 107 participants were heel-rise negative (69.0%, 95% CI 61.1% to 76.2%).

Table 3 describes the distribution of foot posture categories assessed using the FPI-6. Neutral foot posture (FPI 0 to +5) was the predominant category, observed in 86 participants (55.5%, 95% CI 47.3% to 63.6%). Pronated posture (FPI +6 to +9) was present in 31 participants (20.0%, 95% CI 14.1% to 27.2%), and highly pronated posture (FPI +10 to +12) in 17 participants (11.0%, 95% CI 6.6% to 17.1%).

Supinated posture (FPI −1 to −4) was observed in 19 participants (12.3%, 95% CI 7.6% to 18.6%), while highly supinated posture (FPI −5 to −12) was rare, occurring in only 2 participants (1.3%, 95% CI 0.2% to 4.5%). Overall, approximately one-third of the cohort demonstrated some degree of pronation (pronated + highly pronated = 48/155, 31.0%), matching the proportion demonstrating heel-rise positivity, though these are not the same individuals unless confirmed by the cross-tabulation.

Table 4 quantifies the association between foot posture category and heel-rise test outcome and demonstrates a strong posture-dependent gradient in functional performance. Among participants with neutral posture, 73 of 86 (84.9%) were heel-rise negative and 13 of 86 (15.1%) were heel-rise positive. A similar pattern was seen in the supinated group, where 16 of 19 (84.2%) were negative and 3 of 19 (15.8%) were positive, yielding an unadjusted odds ratio (OR) of 1.06 compared with neutral (95% CI 0.27 to 4.09; $p = 0.94$), indicating no meaningful difference from the neutral reference group.

In contrast, pronated posture showed a much higher positivity proportion: 15 of 31 (48.4%) were heel-rise positive and 16 of 31 (51.6%) were negative, corresponding to an OR of 5.26 (95% CI 2.08 to 13.32; $p < 0.001$). The strongest association was observed in the highly

pronated category, where 16 of 17 (94.1%) were heel-rise positive and only 1 of 17 (5.9%) were negative; this corresponded to a very large OR of 89.85 (95% CI 10.69 to 755.32; $p < 0.001$), reflecting an extreme increase in odds of suspected PTTD relative to neutral posture. The highly supinated category included only two participants, split evenly (1 negative, 1 positive), producing an imprecise OR estimate of 5.62 with a very wide confidence interval (0.33 to 96.1; $p = 0.24$), consistent with insufficient sample size for stable inference. The overall association between posture and heel-rise outcome was statistically significant ($\chi^2(4) = 42.34$; $p < 0.001$), with a large effect size (Cramer's V = 0.52), supporting a strong relationship between increasing pronation and heel-rise test positivity.

Table 5 reports the multivariable logistic regression results adjusting for age, sex, and BMI, and confirms that pronation remained independently associated with heel-rise positivity after accounting for these covariates.

Each one-unit increase in BMI was associated with an 18% increase in the odds of heel-rise positivity (adjusted OR 1.18; 95% CI 1.01 to 1.38; $p = 0.04$). Pronated posture remained a significant predictor compared with neutral posture (adjusted OR 4.72; 95% CI 1.78 to 12.50; $p = 0.002$).

Highly pronated posture showed a markedly elevated adjusted odds (adjusted OR 76.40; 95% CI 8.72 to 669.18; $p < 0.001$), again reflecting a strong association despite the wide confidence interval due to the relatively small number in the highly pronated group (n = 17). Age was not significantly associated with the outcome (adjusted OR 1.03 per year; 95% CI 0.94 to 1.13; $p = 0.52$), and sex did not show a statistically significant association (female vs male adjusted OR 1.21; 95% CI 0.60 to 2.44; $p = 0.59$). Supinated posture remained non-significant (adjusted OR 1.02; 95% CI 0.24 to 4.29; $p = 0.98$).

Table 1. Demographic and Anthropometric Characteristics of Participants (N = 155)

Variable	Mean ± SD	Minimum	Maximum
Age (years)	24.78 ± 3.41	18	30
Weight (kg)	77.78 ± 9.57	56	110
Height (m)	1.66 ± 0.08	1.44	1.83
BMI (kg/m²)	28.20 ± 1.96	25.00	34.50

Table 2. Clinical Characteristics and Prevalence of Suspected PTTD (N = 155)

Variable	Category	n (%)	95% CI
Sex	Male	63 (40.6%)	—
	Female	92 (59.4%)	—
Numeric Pain Rating Scale	No pain (0)	101 (65.2%)	—
	Mild (1–3)	26 (16.8%)	—
	Moderate (4–6)	21 (13.5%)	—
	Severe (7–10)	7 (4.5%)	—
Heel-rise test	Negative	107 (69.0%)	61.1–76.2%
	Positive (suspected PTTD)	48 (31.0%)	23.8–38.9%

Table 3. Distribution of Foot Posture Categories (FPI-6) (N = 155)

FPI Category	n (%)	95% CI
Highly supinated (–5 to –12)	2 (1.3%)	0.2–4.5%
Supinated (–1 to –4)	19 (12.3%)	7.6–18.6%
Neutral (0 to +5)	86 (55.5%)	47.3–63.6%
Pronated (+6 to +9)	31 (20.0%)	14.1–27.2%
Highly pronated (+10 to +12)	17 (11.0%)	6.6–17.1%

Table 4. Association Between Foot Posture and Heel-Rise Test Outcome (N = 155)

FPI Category	Heel-rise Negative n (%)	Heel-rise Positive n (%)	Odds Ratio (95% CI)*	p-value
Neutral (reference)	73 (84.9%)	13 (15.1%)	1.00	—
Supinated	16 (84.2%)	3 (15.8%)	1.06 (0.27–4.09)	0.94
Highly supinated	1 (50.0%)	1 (50.0%)	5.62 (0.33–96.1)	0.24
Pronated	16 (51.6%)	15 (48.4%)	5.26 (2.08–13.32)	<0.001
Highly pronated	1 (5.9%)	16 (94.1%)	89.85 (10.69–755.32)	<0.001

Table 5. Multivariable Logistic Regression for Heel-Rise Positivity (Suspected PTTD) (N = 155)

Variable	Adjusted OR	95% CI	p-value
Age (per year increase)	1.03	0.94–1.13	0.52
Female (vs male)	1.21	0.60–2.44	0.59
BMI (per unit increase)	1.18	1.01–1.38	0.04
Pronated (vs neutral)	4.72	1.78–12.50	0.002
Highly pronated (vs neutral)	76.40	8.72–669.18	<0.001
Supinated (vs neutral)	1.02	0.24–4.29	0.98

Collectively, these results indicate that both higher BMI and increasingly pronated foot posture—particularly highly pronated alignment—were strongly associated with heel-rise test positivity in this overweight student cohort.

DISCUSSION

The present cross-sectional study investigated the prevalence of suspected posterior tibial tendon dysfunction (PTTD), operationalized through a standardized single-limb heel-rise test, and examined its association with foot posture among overweight university students aged 18–30 years. The principal findings were threefold: first, approximately one-third of participants (31.0%, 95% CI 23.8%–38.9%) demonstrated heel-rise positivity suggestive of functional posterior tibial tendon impairment; second, pronated and highly pronated foot postures were strongly associated with heel-rise positivity, with a clear dose–response gradient; and third, higher BMI independently increased the odds of heel-rise positivity even after adjustment for age and sex. These findings extend the literature on PTTD beyond its

classical middle-aged demographic and suggest that functional markers of posterior tibial tendon stress may already be detectable in younger overweight individuals.

The observed prevalence of 31% suspected PTTD in this overweight student population appears substantial when contextualized against prior literature that predominantly describes PTTD as more prevalent in middle-aged or older adults, particularly women (4). While direct comparisons are limited due to differences in diagnostic criteria and staging approaches, our findings suggest that functional impairment consistent with early-stage tendon dysfunction may occur earlier in the presence of elevated mechanical load. Given that PTTD is considered a progressive condition, often beginning with tendon pain and subtle weakness before structural deformity develops (6,7), the identification of heel-rise test abnormalities in a younger cohort may reflect early functional compromise rather than advanced deformity. This interpretation aligns with biomechanical evidence indicating that alterations in midfoot mechanics and tendon energetics can precede overt structural collapse (8,22).

A key finding of this study is the strong association between foot posture and heel-rise test outcomes. Neutral and supinated postures were predominantly associated with negative heel-rise tests (approximately 85% negative in both groups), whereas nearly half of participants with pronated posture (48.4%) and almost all participants with highly pronated posture (94.1%) demonstrated heel-rise positivity. The overall association was statistically significant with a large effect size (Cramer's V = 0.52), and multivariable analysis confirmed that pronated and highly pronated postures were independently associated with increased odds of heel-rise positivity. These findings are biomechanically plausible and supported by prior research indicating that excessive pronation increases demand on the tibialis posterior tendon, potentially elevating tendon strain and contributing to functional impairment (24). Segmental motion analyses in stage II–III PTTD have demonstrated altered foot coupling and rearfoot mechanics in pronated alignment, reinforcing the concept that static posture and dynamic tendon function are closely interrelated (23).

The magnitude of association observed in the highly pronated group, although accompanied by wide confidence intervals due to small subgroup size, suggests a steep gradient between posture severity and functional deficit. This gradient supports a mechanistic pathway in which progressive pronation increases medial column loading, thereby elevating posterior tibial tendon demand during stance and heel-rise tasks. Clinical studies comparing individuals with PTTD to healthy controls have similarly demonstrated reduced tibialis posterior capacity, lower arch height, and impaired functional performance among those with pronated feet Furthermore, comparative analyses of heel-rise performance in stage II PTTD patients versus controls have shown that individuals with pronated alignment are more likely to fail the heel-rise test or demonstrate impaired inversion during the maneuver. Our results are consistent with these findings and extend them to a younger, overweight academic population.

The independent association between BMI and heel-rise positivity further supports the hypothesis that mechanical loading contributes to tendon dysfunction. Each one-unit increase in BMI was associated with an 18% increase in the adjusted odds of heel-rise positivity. This aligns with prior evidence linking obesity to medial longitudinal arch alterations and increased medial foot loading . Overweight and obese individuals have been shown to exhibit differences in foot posture, muscle strength, and plantar sensation compared with normal-weight counterparts, potentially amplifying mechanical stress on the posterior tibial tendon. The combination of elevated BMI and pronated posture may

therefore represent a compounded biomechanical risk state, wherein excess load acts on an already mechanically disadvantaged alignment.

Interestingly, age and sex were not independently associated with heel-rise positivity in this cohort. Although PTTD is frequently reported to be more common in middle-aged women (4), the restricted age range of 18–30 years and the focus on overweight status may have attenuated sex-related differences in this sample. Additionally, early functional changes detectable by heel-rise testing may not yet manifest the sex-related prevalence patterns observed in clinically advanced PTTD. These findings suggest that in young overweight adults, biomechanical alignment and load-related variables may be more salient predictors of functional tendon impairment than sex alone.

From a clinical perspective, the findings underscore the value of simple functional screening tools such as the heel-rise test in identifying early tendon dysfunction in non-clinical populations. While imaging modalities such as ultrasound and MRI provide structural confirmation of tendon pathology , pragmatic screening approaches are often more feasible in community or university settings. Given the established reliability of the FPI-6 for static posture assessment (39,40), the combined use of FPI-6 and heel-rise testing may offer a cost-effective strategy for early identification of students at risk for progressive dysfunction. Early detection is particularly relevant in light of the staged progression model of PTTD, where conservative interventions such as orthoses and exercise are more effective in earlier stages (14,15).

Nevertheless, interpretation of these findings must consider methodological limitations inherent to the cross-sectional design. Temporal directionality cannot be established; thus, while pronated posture is strongly associated with heel-rise positivity, it cannot be concluded that pronation causes PTTD-related dysfunction. It is equally plausible that early tendon weakness contributes to progressive pronation, reflecting a bidirectional relationship as suggested in prior mechanistic discussions (3). Longitudinal studies would be required to determine whether pronated foot posture predicts future development of clinically confirmed PTTD. Additionally, although the heel-rise test is widely used in clinical evaluation (13), it is a functional screening tool rather than a definitive diagnostic modality; thus, the outcome in this study is more accurately described as “suspected PTTD” rather than imaging-confirmed pathology.

Another consideration is the relatively small number of participants in the highly supinated and highly pronated categories, leading to wide confidence intervals in those subgroups. While the effect estimates for highly pronated posture were large and statistically significant, future studies with larger samples would improve precision and allow for more granular stratification. Furthermore, unmeasured variables such as footwear type, habitual physical activity, lower limb alignment, or ligamentous laxity may contribute to both foot posture and tendon loading. Prior studies have shown that lower limb biomechanics and alignment factors are associated with early-stage dysfunction (29), indicating that multivariable biomechanical modeling could further clarify these relationships.

Despite these limitations, the present study contributes novel data on the burden of suspected PTTD-related functional impairment among overweight university students—a demographic less frequently represented in the PTTD literature, which has traditionally focused on older adults or clinically referred populations (30). By demonstrating a strong and graded association between pronated posture and heel-rise test positivity, and by identifying BMI as an independent predictor, this study supports the hypothesis that elevated body mass and pronated alignment together create a biomechanical environment conducive to posterior tibial tendon overload. These findings highlight the potential importance of

early weight management, posture assessment, and targeted strengthening interventions in young adults to mitigate progression toward more advanced tendon dysfunction and acquired flatfoot deformity.

CONCLUSION

In conclusion, this cross-sectional study demonstrates that nearly one-third of overweight university students aged 18–30 years exhibited heel-rise test positivity suggestive of early posterior tibial tendon dysfunction, and that increasingly pronated foot posture was strongly and independently associated with this functional impairment. A clear gradient was observed, with highly pronated feet showing markedly greater odds of heel-rise positivity compared with neutral posture, even after adjusting for age, sex, and BMI. Higher BMI itself was also an independent predictor, supporting the role of mechanical loading in posterior tibial tendon stress. These findings suggest that overweight young adults with pronated foot posture represent a subgroup at elevated risk for early tendon dysfunction, highlighting the potential value of routine foot posture screening, weight management strategies, and targeted strengthening interventions to prevent progression toward symptomatic and structurally advanced PTTD.

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DECLARATIONS

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