Biomechanical Interdependence between flat foot posture and pelvic alignment : A Narrative Review

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Abstract
Flat foot (pes planus) is a flattened medial longitudinal arch and excessive pronation, thus changing the biomechanics of the lower extremity. These distal changes can travel up the body, affecting the orientation of the pelvis and thus contributing to anterior pelvic tilt. Clinically this relationship is important because the gait efficiency, musculoskeletal loads and injury risk may be altered due to compensatory postural adaptations. A narrative review was conducted to identify and synthesize the existing literature to evaluate the correlation between flat foot and pelvic mechanics, and to highlight its implications for physiotherapy assessment and management, by searching the databases of PubMed (since 2015), Scopus (since 2013) and ResearchGate (since 2016). A total of 15 papers were screened and eight papers were chosen because of their study design and because they measured foot and pelvic alignment in the population. The descriptive synthesis of data for study characteristics, evaluation methods and outcomes was conducted. Eight studies found a high correlation between flat foot and anterior pelvic tilt (calcaneal eversion, tibial and femoral rotation and compensation mechanisms). There was a limitation identified of variability in participant characteristics and methodological approaches. The results indicate that there is a strong relationship between flat foot and pelvic alignment through the lower extremity kinetic chain. The pelvic examination in physiotherapy should then take into account the distal foot alignment. Standardized assessment protocols and longitudinal studies are recommended for further research to increase evidence.
Key words- Flat foot; Foot pronation; Anterior pelvic tilt; Pelvic alignment; Lower limb biomechanics; Kinetic chain; Posture.
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1. Introduction

1.1 Foot in the Lower Extremity Kinetic Chain

The distal part of LEX kinetic chain is foot. Supports the body to maintain balance, an important part of standing and walking.

1.2 Complex Movements of the Ankle

- Key movements: pronation (inward) and supination (outward).
- **Pronation:** abduction, dorsiflexion, eversion [1].
- **Supination:** adduction, plantar flexion, inversion [1].
- These occur during stance phase to aid mobility, stability, and reduce forces in foot and lower limb.
- If it moves too much or too little, the foot can't perform its functions of shock absorber, torque converter, terrain adaptor and rigid lever for push off.
- This impaired joint mobility results in changes in the function of the connective tissue and muscle [2].

1.3 Medial Longitudinal Arch Stress

- Feet are subjected to excessive forces on the medial longitudinal arch during normal activities.
- Structural deficiencies such as excessive pronation and supination may result (3,4,5).
- The medial longitudinal arch is diminished by increased pronation brought on by ligament laxity and recurrent stress.
- Arch height is proportional to likelihood of lower extremity injury (6).
- Repetitive loads produce creep and hysteresis in foot ligaments (7).

1.4 Biomechanical characteristics of flat foot

- Excessive subtalar joint pronation with calcaneal eversion is a primary feature.
- It is important to note the presence of medial arch structures (plantar fascia, spring ligament) [8,9].
- During push off, foot becomes less effective as rigid lever, thus decreasing propulsion efficiency [10].

1.5 Proximal Kinetic Chain Effects

- Flat foot affects tibial and femoral mechanics.
- Calcaneal eversion accompanied by tibial internal rotation transferred proximally to femur and hip [11,12].
- Reported modified knee alignment, higher valgus stress and changed hip loading patterns with sustained internal rotation [13].
- Highlights flat foot as a factor in proximal joint dysfunction.

1.6 Pelvic Orientation Changes

- Foot mechanics can change the pelvis' orientation in the sagittal plane. The increased internal rotation and different ground reaction forces may lead to anterior pelvic tilt [14].
- The long-term pronated posture affects the hip through the compensatory mechanisms such as the hip flexor, hamstrings and lumbopelvic muscles [15].
- Suggests foot posture abnormalities may affect pelvis and spine biomechanics.

1.7 Modifications to Gait

Flat foot alters kinematic and kinetic patterns during gait.

- Findings: greater midfoot mobility, longer pronation duration, altered timing of resupination [10,16].
- Impacts pelvic motion in frontal and transverse planes → greater pelvic drop or rotation during walking [12].
- Long-term deviations increase mechanical stress in lumbopelvic area.

1.8 Evidence from the literature since 2015

Growing studies on foot posture and pelvic alignment in static and dynamic conditions.

- Cross-sectional studies show significant correlation between anterior pelvic tilt and pronated/flat foot posture in adults [8,14] and young populations.
- Affects pelvic movement in frontal and transverse planes increases the pelvic drop or rotation during walking [12].
- The long term deviations create more mechanical stress in the lumbopelvic area [10].

1.9 Clinical Implications

- An anterior pelvic tilt is clinically significant in relation to flat foot in physiotherapy.
- Assessing foot or pelvic abnormalities in isolation may lead to suboptimal management.
- Literature is patchy in methodology, assessment tools, and participant characteristics, limiting conclusions.

1.10 Aim of the Review

- To summarize and critically analyse literature since 2015 on the association between anterior pelvic tilt and flat foot. Focus: Biomechanics mechanisms and implications for physiotherapeutic assessment and intervention.

2. Methods

2.1 Literature Search

This narrative review is based upon literature published and available through 2015-01. Databases included: Medline, PubMed, CINAHL, ISI and IBSS. Search terms used were: flat foot, pes planus, pelvic alignment, anterior pelvic tilt, foot posture, lower limb biomechanics, kinetic chain.

2.2 Eligibility Criteria

Inclusion Criteria

Studies from January 2015 onwards.

- Original research articles addressing "flat foot", foot posture or "pes planus".

- Research that evaluates pelvic tilt or pelvic alignment.
- Studies that include an adult or juvenile population.
- Article(s) that address the biomechanical or postural considerations of the foot and its relationship to the pelvis.

Exclusion Criteria

- Articles not addressing pelvic alignment or pelvic tilt.
- Non-English language publications.

Author and year	Study design	Sample size and population	ASSESSMENT OF FLAT FOOT	Assessment of Anterior Pelvic Tilt / Pelvic Alignment	Clinical relevance
Khamis & Yizhar (2015) (8)	Cross-sectional	n = 100, healthy adults	Foot posture index.	Pelvic inclination via postural analysis.	Significant association between pronated foot posture and altered pelvic alignment.
Buldt et al. (2015) (10)	Cross-sectional gait study	n = 92 adults	Static foot posture classification	3D motion capture system	Pronated feet showed altered pelvic motion during stance phase
Barton et al. (2016) (13)	Cross-sectional	n = 60 adults with flat foot	Rearfoot posture assessment	Motion analysis of hip–pelvis	Flat foot associated with increased internal rotation influencing pelvic mechanics
Resende et al. (2021) (12)	Observational study	n = 28 asymptomatic adults	Navicular Drop Test	3D gait analysis	Excessive pronation altered pelvic motion during early stance
Eldesoky & Abutaleb (2020) (14)	Cross-sectional	N=60 young adults	Clinical flat foot assessment	Pelvic tilt angle measurement	Flat foot significantly correlated with increased anterior pelvic tilt

Buldt & Menz (2018) (11)	Narrative review	Multiple studies	Foot posture classification	Lower limb alignment analysis	Foot posture influences proximal segments including pelvis
Tyagi et al. (2024) (17)	Cross-sectional	N=120 young adults	Foot posture index	Pelvic inclinometer measurement	Positive correlation between pronated foot posture and anterior pelvic tilt
Gül et al. (2025) (15)	Cross sectional	n = 90 asymptomatic adults	Foot posture index	Pelvic & lumbar alignment analysis	Pronated foot posture associated with increased anterior pelvic tilt and lumbar lordosis.

Features of the included studies (n = 8)

3. Results

3.1 Overview of Included Studies

- A total of **eight studies** published from January 2015 onwards were included.
- Study designs: primarily cross-sectional observational, with one narrative biomechanical review.
- Populations: healthy adults and young adults.
- Sample sizes: ranged from **28 to 120 participants**.

3.2 Study Designs and Assessment Tools

- One observational gait analysis, one narrative biomechanical evaluation, and six cross-sectional analyses.
- Age range: mostly **18–40 years**, both men and women.
- **Flat foot assessment methods:** Foot Posture Index (FPI), navicular drop test.
- **Pelvic alignment assessment methods:** pelvic inclinometer, postural analysis, technologies for capturing motion in three dimensions.
- **3.3 Research on Static Standing**
- Five studies [8,10,12,13,14] assessed flat foot and pelvic alignment in standing posture.
- Consistent findings: pronated/flat foot posture associated with increased anterior pelvic tilt compared to neutral foot posture.
- **Key findings:**
- Khamis and Yizhar [8]: significant relationship between pronated foot position and pelvic tilt.
- Eldesoky and Abutaleb [14], Tyagi et al. [17] – Young people with flat feet had a higher anterior pelvic tilt.
- Gül et al. [15]: pronated foot posture indicates lumbopelvic involvement and is linked to increased anterior pelvic tilt and worsened lumbar lordosis.

3.4 Dynamic Activity Studies

- Three studies [10–12] examined pelvic mechanics during walking.
- **Key findings:**
  - Buldt et al. [10]: pronated foot posture altered pelvic kinematics during stance phase.
  - Resende et al. [12]: excessive pronation during loading response contributed significantly to pelvic motion.
  - Barton et al. [13]: flat feet linked to increased tibial internal rotation, indirectly affecting pelvic alignment during dynamic activity.

3.5 Overall Associations

- Most studies reported a positive association between anterior pelvic tilt and flat feet in both static and dynamic evaluations.

- Excessive subtalar pronation → tibia and femur internal rotation → anterior pelvic compensation [13,10].

4. Discussion

The main objective of this narrative review was to broadly review the association between flat foot and anterior pelvic inclination since January 2015. The results were always supportive of the concept of a distal to proximal influence in the lower limb kinetic chain, with individuals with a flat foot or pronated foot posture often having increased anterior pelvic tilt. This correlation can be attributed mainly to the abnormal foot biomechanics, specifically excessive subtalar joint pronation. Biomechanically, pronated foot posture (calcaneal eversion and medial rotation of the talus) is associated with internal rotation of both tibia and femur. The lower limb is then subjected to an internal rotation and the pelvis rotates anteriorly in the sagittal plane as a result of this. The ground reaction forces in the stance phase of gait have been affected by long-term pronation of pes planus, as several authors have noted. This movement leads to an abnormal imbalance between the muscles, which makes the hip flexors (iliopsoas, rectus femoris and sartorius) active, and tightening of the pectineus and tensor fascia late. The shortening of these muscle groups also helps to reinforce the biomechanical relationship between the distal foot posture and the proximal pelvic mechanics with anterior pelvic tilting. Static vs Dynamic Comparisons There are significant differences revealed by static and dynamic studies. Khamis et al. (2015) and Tyagi et al. (2024) revealed a stronger association between anterior pelvic tilt and flat foot in static and dynamic situations; the static position (standing) yielded more consistent results. All static postural evaluations demonstrated an increase in anterior pelvic tilt in the participants with a pronated foot position. Conversely, Resende et al. (2021) and Hillstrom et al. (2018) observed modifications in pelvic movement in the loading response phase of gait. Conversely, dynamic data were less consistent, perhaps because of compensating neuromuscular mechanisms occurring during movement. This change highlights the need to look at static posture and dynamic function when examining postural adjustments of the feet and pelvis in clinical practice. Application of physiotherapy in clinical practice. This review has highlighted the importance of GPA from the physiotherapy perspective. If flat foot is not addressed and considered possible effects on pelvic alignment, complete or satisfactory treatment may not be achieved. Proximal alignment and movement patterns have been shown to be affected by interventions with foot orthoses, intrinsic foot muscle strengthening and proprioceptive training. In addition, an excessive anteversion (APT) of the pelvis caused by flat feet has been shown to be one of the causes of lower back pain and altered hip musculature biomechanics. A holistic approach – in line with the kinetic chain model – makes it possible to manage postural dysfunctions comprehensively. While the majority of studies found a positive correlation between anterior pelvic tilt and flat foot, others found weak to nonexistent correlations. Such differences may be due to different assessment measures, patient populations, and methodologies. Strengths The evidence for the correlation between anterior pelvic tilt and flat foot obtained from biomechanical, postural and clinical studies is summarized in this review. It uses a variety of study designs and assessment techniques, thus offering a more comprehensive view of the foot–pelvis kinetic chain. Biomechanical interpretation is emphasized which increases the clinical relevance, especially for physiotherapists involved in the postural assessment and rehabilitation. Limitations It should be recognized that some of these studies failed to account for confounding factors (such as muscle imbalance, body mass index and activity level). Further, the strength of the direct inferences might have been limited by variations in assessments and by possible selection bias. Additional variations in methods and subject differences further limit the generalizability of the results.

5. Conclusion

The present narrative review validates the strong association between AP and FFP, and emphasizes the biomechanical relationship between the lower extremity kinetic chain. Hype pronation of the foot may result in changes in the alignment of the proximal segments due to compensatory pelvic changes. There was variation between the studies but results indicate that foot posture assessment is related to postural and lumbopelvic assessment. More interventional research is needed, however, to better grasp the processes of attribution and to offer evidence-based therapeutic management.

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