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ASSESSMENT OF POSTURAL STABILITY USING BALANCE PLATFORM IN HEALTHY ADULT WITH FLAT FOOT –A CROSS SECTIONAL STUDY

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Abstract:
Postural stability depends on the integrity of sensory input and musculoskeletal alignment, with the foot serving as the primary base of support during standing and movement. Flat foot (pes planus) alters plantar pressure distribution and lower-limb biomechanics, potentially influencing balance control. However, evidence regarding its effect on both static and dynamic balance in healthy young adults remains limited.

Objective: To assess the impact of flat foot on static and dynamic postural stability in healthy young adults using an instrumented balance platform.

Methods: A cross-sectional observational study was conducted on 45 healthy adults aged 18–25 years. Foot posture was assessed using footprint analysis and the Plantar Arch Index. Static and dynamic balance parameters were evaluated using the HUR Balance Master system. Static balance was assessed under eyes-open and eyes-closed conditions on stable and unstable surfaces, while dynamic balance was measured using the Limits of Stability (LOS) test. Data were analyzed using SPSS version 24.0. Paired *t*-tests were used for within-condition comparisons, and Pearson's correlation coefficient was applied to examine the relationship between plantar arch index and balance parameters. Statistical significance was set at $p < 0.05$.

Results: Participants demonstrated increased postural sway, trace length, and sway velocity under sensory-challenged conditions, particularly during eyes-closed and unstable-surface testing, indicating reduced static balance. Dynamic balance assessment revealed reduced limits of stability, especially in forward and lateral directions. A moderate positive correlation was observed between plantar arch index and sway velocity ($r = 0.42$), while a negative correlation was found between plantar arch index and forward LOS ($r = -0.36$), suggesting that lower arch height is associated with poorer balance performance.

Conclusion: Healthy young adults with flat foot exhibit impaired static and dynamic postural stability despite the absence of overt pathology. Early identification of altered foot posture may be important for preventing future balance-related dysfunctions and lower-limb injuries.

KEYWORDS - Flat foot, postural stability, static balance, dynamic balance, plantar arch index, balance platform

Introduction Postural stability, commonly referred to as balance, is the ability of an individual to maintain control of the body's center of gravity within the base of support during both stationary and moving tasks. Efficient balance control is essential for performing everyday activities and plays a vital role in preventing falls. During standing, the feet provide the primary base of support; therefore, their structure and alignment are key determinants of postural stability.

Balance is generally categorized into static and dynamic components. Static balance refers to the ability to maintain an upright position while the body remains still, with the center of gravity maintained within the base of support. Dynamic balance, on the other hand, involves maintaining postural control while the body or base of support is in motion, such as during walking, reaching, or directional changes. Effective postural control depends on the integration of sensory input from three major systems: the visual, vestibular, and somatosensory (proprioceptive) systems. These systems continuously provide information regarding body position and movement, enabling appropriate neuromuscular responses to maintain stability. Any dysfunction in one or more of these systems may compromise balance and increase the risk of instability or falls.

Among the various postural control mechanisms, the ankle strategy is considered a primary strategy for maintaining balance during quiet standing and minor postural disturbances. This strategy involves corrective movements centered around the ankle joint to realign the body's center of mass. For example, during forward body sway or single-leg stance, activation of the gastrocnemius and associated synergistic muscles generates a plantarflexion moment that helps slow and reverse forward movement, thereby restoring upright posture. Foot posture plays a significant role in balance control and lower-limb biomechanics. Variations in foot arch structure and flexibility can alter load distribution and movement patterns, potentially affecting postural stability. Previous research has shown that abnormal foot posture can influence lower-extremity kinematics and may contribute to the development of musculoskeletal injuries.

Flat foot (pes planus) is one of the most commonly observed foot deformities. It may be present from childhood due to incomplete development of the foot arch or may be acquired later in life as a result of injury, ageing, or repetitive mechanical stress. Flat foot is classified as flexible or rigid. In flexible flat foot, the medial longitudinal arch is absent during weight-bearing but reappears when the foot is non-weight-bearing. In contrast, rigid flat foot is characterized by a consistently absent arch regardless of weight-bearing status. In individuals with flat foot, collapse of the medial longitudinal arch results in increased contact between the midfoot and the ground during standing. This structural alteration can change plantar pressure distribution and loading patterns across the foot. Flat foot is a common condition and has been associated with long-term musculoskeletal consequences, including altered lower-limb alignment and impaired postural control. Differences in both internal forces and external loading patterns have been reported between individuals with flat feet and those with normal foot arches.

Several clinical methods are used to assess foot posture, including the Navicular Drop Test, Feiss Line Test, Foot Posture Index, and Plantar Arch Index. Similarly, balance can be evaluated using both functional and instrumented assessments. Clinical tools such as the Berg Balance Scale and Functional Reach Test provide general information regarding balance performance, whereas computerized systems offer more objective and detailed analysis.

The Balance Master system is a computerized posturography tool that provides objective assessment of both static and dynamic balance. It allows evaluation of sensory integration and voluntary motor control through visual biofeedback under stable and unstable surface conditions. The Sensory Organization Test (SOT) is used to identify deficits within the visual, vestibular, and somatosensory systems contributing to postural control. Static balance can be quantified by measuring postural sway velocity under different sensory conditions, while dynamic balance is assessed using the Limits of Stability (LOS) test, which evaluates the maximum voluntary displacement of the center of gravity in multiple directions.

Although flat foot is a prevalent condition, there is limited evidence examining its specific impact on both static and dynamic balance in young adults. Understanding this relationship is important for early identification of balance impairments and for developing targeted preventive and rehabilitative strategies. Therefore, the present study aimed to investigate the effect of flat foot on static and dynamic balance in young adults using the Balance Master system

I. RESEARCH METHODOLOGY

3.1Population and Sample

The population of the present study consisted of healthy young adults aged between 18 and 25 years. Both male and female participants were included. Individuals with low medial longitudinal arch (flat foot) were identified and recruited for the study. A total of 45 healthy participants meeting the inclusion criteria were selected using a convenience sampling technique. Participants with a history of musculoskeletal, neurological, or cardiovascular disorders affecting balance were excluded. The selected sample was considered representative for assessing the association between flat foot and postural stability in healthy young adults.

3.2 Data and Sources of Data

Primary data were collected directly from the participants. Foot posture data were obtained using footprint analysis, and the plantar arch index was calculated to identify flat foot. Static and dynamic balance data were collected using the HUR Balance Master system under standardized testing conditions. Demographic details and clinical information were recorded using a structured data collection sheet. All measurements were conducted in a controlled laboratory environment to ensure accuracy and reliability of the data.

3.3 Study Tools and Instruments

The following tools and instruments were used for data collection and assessment:

- Foot tub/tray
- Sponge and ink
- Plain paper
- HUR Balance Master system
- Participant information and informed consent form
- Data collection sheet

Foot posture was assessed using footprint analysis, while static and dynamic balance parameters were evaluated using the HUR Balance Master system.

3.4 Inclusion and exclusion

Participants included in the study were healthy male and female individuals aged between 18 and 25 years who were willing to participate and provided written informed consent. Only individuals identified with a low medial longitudinal arch using footprint analysis and the plantar arch index were selected. Participants were required to have no history of musculoskeletal, neurological, or cardiovascular disorders that could affect balance or lower-limb function. Individuals were excluded if they had a history of foot or ankle fractures, previous surgery involving the foot, ankle, or knee, structural deformities of the knee, recent lower-limb soft tissue injury within the past three months, or the presence of heel pain or any condition that could interfere with accurate balance assessment.

3.5 Outcome measures

The primary outcome measure of the study was postural stability, assessed using the HUR Balance Master system. Static balance parameters, including postural sway area, trace length, and sway velocity, were recorded under eyes-open and eyes-closed conditions on stable and unstable surfaces. Dynamic balance was evaluated using the Limits of Stability test, which measured the maximum voluntary displacement of the center of gravity in forward, backward, and lateral directions.

The secondary outcome measure was foot posture, assessed using footprint analysis and quantified by the Plantar Arch Index. The plantar arch index was calculated to determine the presence and severity of flat foot by comparing the midfoot support width to the heel support width during standing.

3.6 Procedure

The study was initiated after obtaining approval from the Institutional Ethical Committee. Eligible participants were screened according to the inclusion and exclusion criteria, and written informed consent was obtained from all participants after explaining the purpose and procedure of the study. Demographic details and baseline information were recorded using a structured data collection sheet. Foot posture assessment was performed using footprint analysis, wherein participants stood on an inked sponge and then on plain paper to obtain footprints for both feet. The plantar arch index was calculated by dividing the midfoot support width by the heel support width to identify flat foot. Following foot posture assessment, static and dynamic balance evaluations were conducted using the HUR Balance Master system under standardized conditions, including eyes-open and eyes-closed positions on stable and unstable surfaces. All assessments were carried out in a controlled environment to ensure participant safety and measurement reliability.

3.7 Statistical tools and econometric models

All data were analyzed using SPSS software (version 24.0). Descriptive statistics were used to summarize demographic variables, plantar arch index values, and balance parameters, and results were expressed as mean ± standard deviation. Normality of the data was assessed using the Shapiro–Wilk test. Comparisons of static balance parameters between eyes open and eyes closed conditions, on both stable and unstable surfaces, were performed using paired t-tests. Dynamic balance performance assessed using the Limits of Stability test was analyzed descriptively across different movement directions. The relationship between plantar arch index and balance parameters was examined using Pearson's correlation coefficient. A p-value of <0.05 was considered statistically significant

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

A total of 45 healthy young adults with low medial longitudinal arch (flat foot) were assessed using the Plantar Arch Index and HUR Balance Master.

Table 1. Participant Characteristics (n = 45)

Variable	Mean ± SD / n
Age (years)	23.1 ± 1.6
Sex (Male/Female)	20 / 25
Plantar Arch Index – Right	1.26 ± 0.18
Plantar Arch Index – Left	1.29 ± 0.21

Table 1 summarizes the demographic characteristics and plantar arch index values of the study participants. The mean plantar arch index values for both feet indicate the presence of a low medial longitudinal arch in the study population.

Table 2. Static Postural Stability Parameters in Individuals With Low Arch

Condition	C90 Area (mm²)	Trace Length (mm)	Sway Velocity (mm/s)
Stable surface – Eyes open	112.4 ± 38.6	165.2 ± 42.1	6.8 ± 1.9
Stable surface – Eyes closed	305.8 ± 92.4	276.5 ± 68.3	11.4 ± 3.2
Unstable surface – Eyes open	285.6 ± 96.7	345.1 ± 88.5	12.3 ± 3.5
Unstable surface – Eyes closed	510.3 ± 145.2	565.4 ± 132.8	18.6 ± 4.7

Table 2 presents static postural stability measures obtained under different sensory conditions. An increase in postural sway parameters was observed with removal of visual input and surface instability, reflecting reduced static balance control in individuals with low medial longitudinal arc

Table 3. Dynamic Balance Performance (Limits of Stability Test)

Direction	LOS (degrees)
Forward	3.8 ± 0.9
Backward	5.6 ± 1.2
Leftward	6.4 ± 1.1
Rightward	5.9 ± 1.0

Table 3 illustrates the limits of stability values in different directions. Reduced displacement of the center of gravity, particularly in the forward and lateral directions, suggests impaired dynamic balance control associated with low arch foot posture.

Table 4. Association Between Plantar Arch Index and Balance Parameters

Variables	Correlation (r)
Plantar Arch Index vs Sway Velocity	+0.42
Plantar Arch Index vs Forward LOS	−0.36

Table 4 demonstrates the relationship between plantar arch index and balance variables. Higher plantar arch index values were associated with increased postural sway and reduced limits of stability, indicating that lower arch height is linked to balance impairment

DISCUSIION

The present cross-sectional study investigated the association between low medial longitudinal arch and postural stability in healthy young adults using objective balance measures. The findings demonstrate that individuals with low arch exhibit impaired static and dynamic balance, even in the absence of pain, neurological deficits, or musculoskeletal pathology.

Static balance assessment revealed increased postural sway under sensory-challenged conditions, particularly during eyes-closed and unstable-surface testing. This suggests that individuals with low arch rely more heavily on visual input to maintain postural stability. The collapse of the medial longitudinal arch alters plantar pressure distribution and reduces the efficiency of plantar mechanoreceptor feedback, which may compromise somatosensory input essential for postural control. These findings are consistent with previous studies reporting increased postural sway in individuals with pronated or flat foot posture.

Dynamic balance performance, assessed using the Limits of Stability test, was also reduced, especially in the forward and lateral directions. Efficient control of the center of gravity during voluntary movement requires an intact ankle strategy and stable base of support. In individuals with low arch, excessive foot pronation and midfoot mobility may impair force transmission through the ankle and reduce the effectiveness of postural adjustments, resulting in restricted limits of stability.

The observed association between increased plantar arch index values and poorer balance parameters further supports the role of foot posture in postural control. As arch height decreases, postural sway increases and dynamic balance capacity diminishes, indicating that foot structure contributes significantly to balance regulation. These results align with earlier research demonstrating that altered foot posture influences both static and dynamic postural stability in healthy populations.

Importantly, the study population consisted of young, healthy adults, suggesting that balance impairments related to low arch may be present before the onset of symptoms or injury. This highlights the potential clinical relevance of early identification and management of flat foot to prevent future balance-related dysfunctions, falls, or lower limb overuse injuries.

While the cross-sectional design does not allow causal inference, the consistent pattern of findings across multiple balance parameters strengthens the evidence for an association between low arch and impaired postural stability. Objective assessment using a balance platform enhances the reliability of the findings and provides quantitative insight into subtle balance alterations associated with foot posture.

CONCLUSION

The findings of the present study indicate that flat foot has a significant influence on postural stability in healthy young adults. Individuals with a low medial longitudinal arch demonstrated impaired static and dynamic balance, particularly under sensory-challenged conditions and during voluntary displacement of the center of gravity. The observed association between plantar arch index and balance parameters suggests that alterations in foot posture contribute to reduced postural control even in asymptomatic individuals. Early identification of flat foot and incorporation of preventive strategies such as balance training and foot posture correction may help improve postural stability and reduce the risk of future balance-related dysfunctions and lower-limb injuries.

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