

Gender-Wise Comparison of Dynamic Balance and Its Correlation with BMI in Adolescents with Flat Feet

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Abstract

Background: Flat foot may alter lower-limb alignment and functional balance, while increased Body Mass Index (BMI) may increase mechanical loading on the foot. Evidence regarding gender-specific relationships between BMI and dynamic balance in adolescents with flat feet is limited. **Objective:** To compare dynamic balance between male and female adolescents with flexible flat feet and to examine the gender-wise relationship between BMI and dynamic balance. **Methods:** A cross-sectional correlational study was conducted in 40 adolescents with flexible flat feet (20 females and 20 males). Flexible flat foot was identified using the Sit-to-Stand Navicular Drop Test with navicular drop greater than 10 mm. BMI was calculated from measured height and weight, and dynamic balance was assessed using the Y-Balance Test Composite Score (YBTCS). Normality was assessed using the Shapiro-Wilk test. Independent t-test or Mann-Whitney U test were used for gender comparisons as appropriate, Spearman correlation was used for correlational analysis, and regression was used to assess the BMI-by-gender interaction. **Results:** Mean YBTCS was 75.93 ± 3.78 in females and 76.46 ± 3.71 in males. There was no significant gender difference in YBTCS ($U = 222.00$, $p = 0.565$). BMI and YBTCS were strongly and negatively correlated in females ($\rho = -0.765$, $p < 0.001$), whereas the association in males was weak and non-significant ($\rho = 0.123$, $p = 0.604$). The BMI $\times$ gender interaction was significant ($B = -1.354$, $p < 0.001$), and the regression model explained 37.7% of the variation in YBT scores. **Conclusion:** Dynamic balance scores did not differ significantly between genders; however, the relationship between BMI and dynamic balance differed by gender, with a strong inverse association observed among females.

Keywords: Gender Wise Comparison, Adolescents, Body Mass Index, Dynamic Balance, Flat Foot, Y-Balance Test

1. Introduction

The human foot provides a stable base for weight bearing and functions as a flexible lever during locomotion. Its arches contribute to shock absorption, pressure distribution and efficient movement. The

medial longitudinal arch is particularly important for adapting to loading and supporting balance [1]. Pes planus, or flat foot, is characterized by partial or complete lowering of the medial longitudinal arch with increased plantar contact. Flexible flat foot is identified when the arch is reduced during weight bearing but reappears during non-weight bearing or toe standing. Altered foot posture can affect lower-limb alignment, plantar sensory input and neuromuscular control, which may influence both static and dynamic balance [2, 4].

Dynamic balance is the ability to maintain postural stability while the body is moving. It depends on coordinated visual, vestibular and somatosensory input together with appropriate motor responses. The Lower Quarter Y-Balance Test is commonly used to assess single-limb dynamic balance through reach performance in the anterior, posteromedial and posterolateral directions [8, 9].

BMI is a commonly used indicator of body weight relative to height. Increased body mass may increase plantar loading and encourage a more pronated foot posture. Previous work has examined BMI, flat-foot characteristics and balance; however, gender-specific evidence in adolescents with flexible flat feet remains limited [3, 7, 11]. Therefore, the present study compared dynamic balance between genders and examined whether the relationship between BMI and dynamic balance differed between female and male adolescents with flat feet.

2. Aim and Objectives

The aim was to compare gender-wise differences in dynamic balance and analyze its correlation with BMI among adolescents with flat feet.

1. To assess flexible flat foot using the Sit-to-Stand Navicular Drop Test.
2. To assess dynamic balance using the Y-Balance Test.
3. To assess BMI using the Asia-Pacific Scale.
4. To compare dynamic balance performance between genders.
5. To examine whether gender influences the relationship between BMI and dynamic balance in adolescents with flat feet.

3. Materials and Methods

3.1 Study Design and Participants

A cross-sectional correlational study was conducted using purposive sampling. Forty adolescents with flexible flat feet were enrolled, including 20 females and 20 males. Participants were recruited from Shivai Vidya Mandir, Nahur, and BES P.A.'s Menon High School, Bhandup. Institutional ethics approval was obtained before data collection.

Adolescents aged 10-19 years with flexible flat feet, identified by a Sit-to-Stand Navicular Drop Test value greater than 10 mm, were eligible. Participants with unstable or postoperative ankle joints, congenital foot deformities, ankle contractures, or vascular or neurological problems were excluded.

3.2 Outcome Measures

Dynamic balance was assessed using the Y-Balance Test, which has demonstrated high intra- and inter-rater reliability for the Y-Balance Test (ICC = 0.85-0.97). Flexible flat foot was assessed using the Sit-to-Stand Navicular Drop Test, with a navicular drop greater than 10 mm interpreted as flexible flat foot. BMI was calculated as weight in kilograms divided by height in metres squared.

3.3 Procedure

The purpose and procedure of the study were explained to the school authorities and participants, and wr

Written consent forms and assent forms were obtained. Demographic information was recorded. Navicular height was measured in sitting with the hips and knees at 90 degrees and the ankle/subtalar joint in neutral, followed by measurement in standing with equal weight bearing. Navicular drop was calculated as sitting height minus standing height.

For the Y-Balance Test, limb length was measured from the anterior superior iliac spine to the medial malleolus. Movements and invalid-trial criteria were demonstrated. Participants completed three practice trials per direction and then three successful reaches in each direction on both extremities. Maximal reach distance was recorded. The aggregate score was calculated as (sum of three reach directions ÷ [3 × limb length]) × 100, and the YBT Composite Score was the mean of the right and left aggregate scores.

3.4 Statistical Analysis

Data were analyzed using Microsoft Excel 2024 and IBM SPSS version 32. Continuous variables were summarized using mean ± standard deviation. Shapiro-Wilk testing was used to assess normality. Independent t-test was used for normally distributed gender comparisons and Mann-Whitney U test for variables showing non-normality in at least one gender group. Spearman's correlation was used to examine associations involving YBTCS and navicular drop. Regression analysis was used to assess the interaction between BMI and gender. Statistical significance was considered at $p < 0.05$.

4. Results

The study included 40 adolescents with flexible flat feet, with equal gender distribution: 20 females (50%) and 20 males (50%).

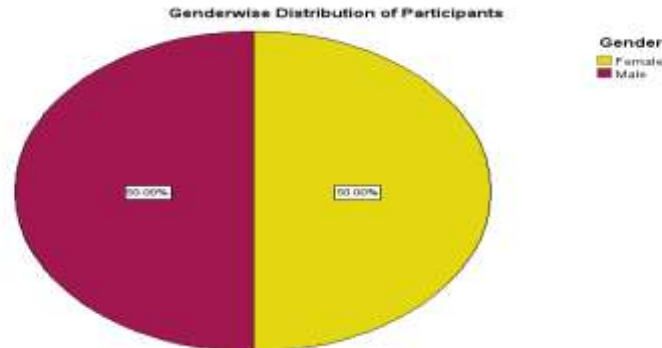


Table 1: Gender-Wise Descriptive Statistics

Variable	Female Mean ± SD	Male Mean ± SD
Age (years)	14.15 ± 2.30	14.40 ± 1.93
Weight (kg)	50.25 ± 9.87	56.15 ± 14.58
Height (cm)	150.63 ± 8.48	159.82 ± 10.60
BMI (kg/m ²)	21.98 ± 2.53	22.20 ± 3.87
Navicular Drop (mm)	11.15 ± 0.37	11.05 ± 0.22
YBTCS	75.93 ± 3.78	76.46 ± 3.71

Age and BMI were normally distributed in both groups. Weight, height, navicular drop and YBTCS were non-normally distributed in at least one gender group; therefore, parametric and non-parametric tests were selected as appropriate.

Table 2: Gender-Wise Comparison of Study Variables

Variable	Test	Statistic	p-value	Result
Age	Independent t-test	t = -0.372	0.712	Not significant
BMI	Independent t-test	t = -0.220	0.827	Not significant
Weight	Mann-Whitney U	U = 244.00	0.242	Not significant
Height	Mann-Whitney U	U = 298.50	0.007	Significant
Navicular Drop	Mann-Whitney U	U = 180.00	0.602	Not significant
YBTCS	Mann-Whitney U	U = 222.00	0.565	Not significant

No statistically significant gender difference was observed in age, BMI, weight, navicular drop or YBTCS. Height differed significantly between groups ($p = 0.007$), with males having a higher mean height. Dynamic balance measured by YBTCS did not differ significantly between females and males ($U = 222.00$, $p = 0.565$).

Table 3: Overall Spearman Correlations

Variables	Spearman's ρ	p-value	Result
BMI vs YBTCS	-0.229	0.156	Not significant
BMI vs Navicular Drop	0.217	0.179	Not significant
YBTCS vs Navicular Drop	-0.137	0.399	Not significant

In the overall sample, no statistically significant correlation was observed between BMI and YBTCS, BMI and navicular drop, or YBTCS and navicular drop.

Table 4: Gender-Wise Correlation between BMI and YBTCS

Gender	n	Spearman's ρ	p-value	Result
Female	20	-0.765	<0.001	Strong negative, significant
Male	20	0.123	0.604	Not significant
Overall	40	-0.229	0.156	Not significant

Among females, BMI showed a strong negative and statistically significant correlation with YBTCS ($\rho = -0.765$, $p < 0.001$). Among males, the correlation was weak and not statistically significant ($\rho = 0.123$, $p = 0.604$).

Figure 4: Gender-Wise Correlation Between BMI and YBTCS

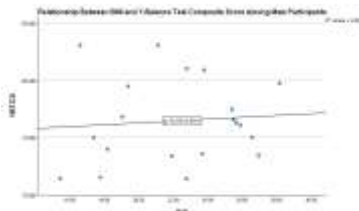
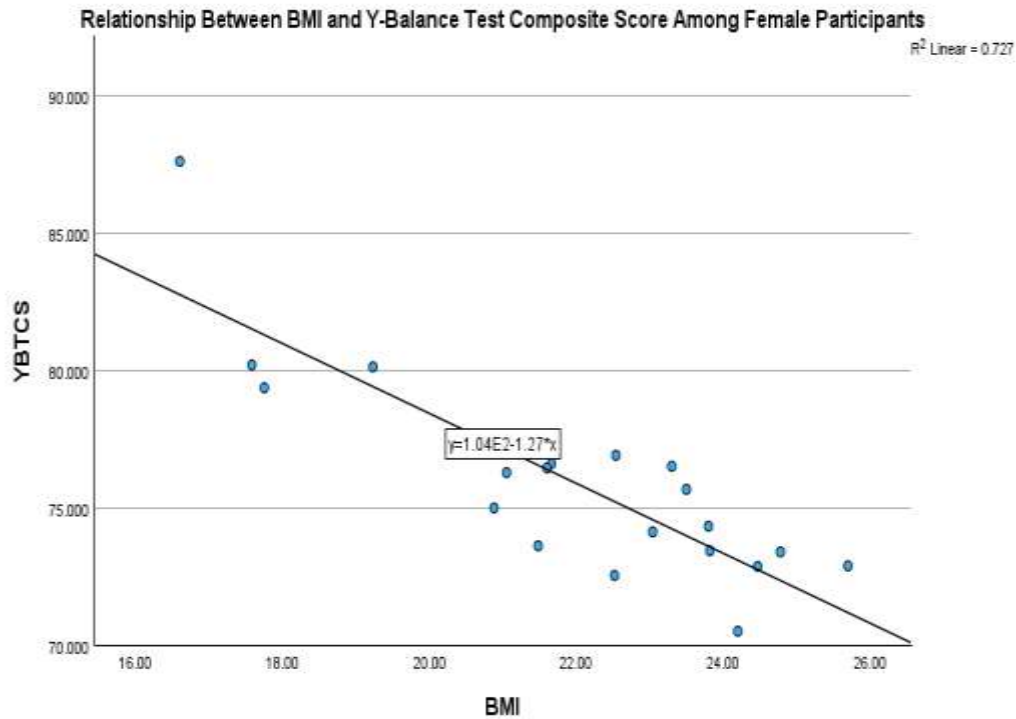


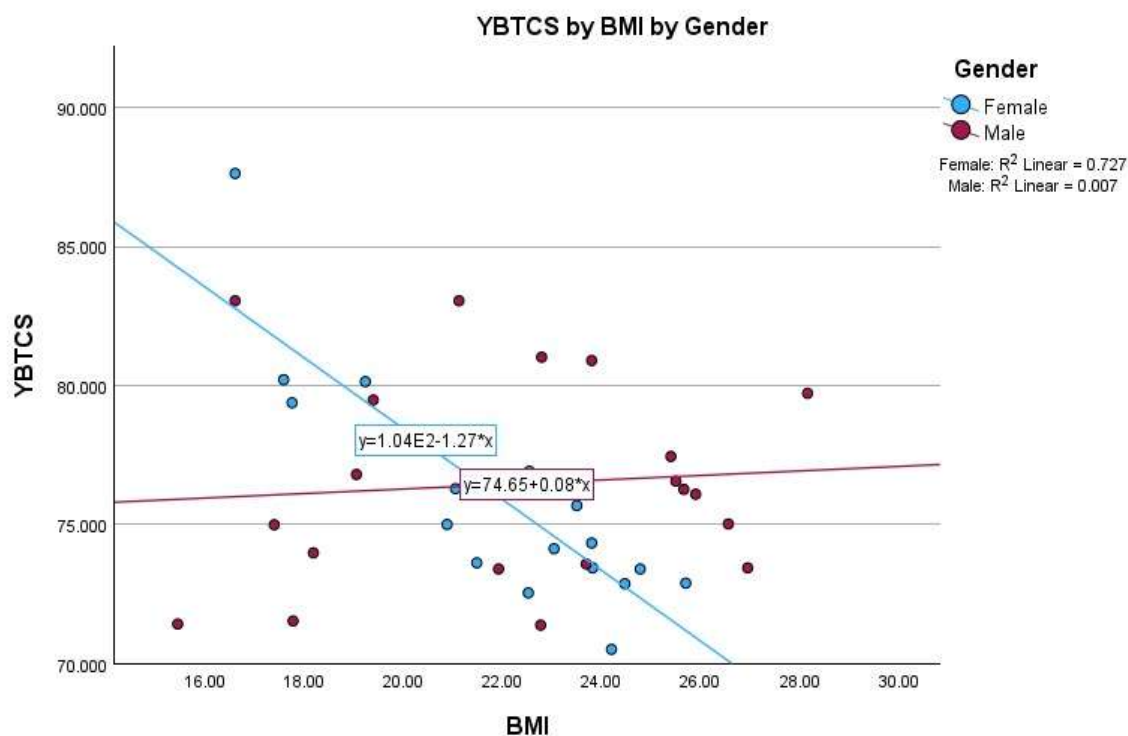
Table 5: Regression Analysis for BMI, Gender and BMI × Gender Interaction

Variable	B	p-value	Interpretation
BMI	0.081	0.655	Not statistically significant
Gender	29.255	<0.001	Statistically significant

BMI × Gender	-1.354	<0.001	Statistically significant interaction
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The BMI × gender interaction was statistically significant ($B = -1.354$, $p < 0.001$), indicating that the relationship between BMI and YBT score differed by gender. The overall model was statistically significant and explained 37.7% of the variation in YBT scores ($R^2 = 0.377$).

Figure 5: Comparison of Correlations Between Genders



5. Discussion

The present study compared dynamic balance and examined its relationship with BMI among 40 adolescents with flexible flat feet. Although mean YBTCS values were similar in females and males and there was no significant gender difference in dynamic balance, the gender-specific association between BMI and YBTCS differed.

In females, BMI demonstrated a strong negative and statistically significant correlation with YBTCS ($\rho = -0.765$, $p < 0.001$), indicating that higher BMI was associated with poorer dynamic balance performance. Bhavé et al. (2021) examined BMI and Y-Balance Test performance in individuals with flexible flat foot and emphasized the relevance of BMI when evaluating dynamic balance in this population. The present female-specific finding is also consistent with the importance of body composition and functional stability described in research involving females with flat feet.

The inverse relationship observed in females may be considered in the context of greater mechanical loading with increasing body mass. Higher loading may influence plantar pressure, pronated foot posture and lower-limb alignment. Because the Y-Balance Test requires controlled single-limb movement while reaching outside the base of support, such changes may influence functional stability.

In males, the correlation between BMI and YBTCS was weak and non-significant ($\rho = 0.123$, $p = 0.604$). Therefore, the present data do not support a meaningful BMI-YBTCS association in the male subgroup. This differs from the clear inverse relationship observed among females and is consistent with the significant BMI $\times$ gender interaction identified in the regression analysis.

Aenumulapalli et al. (2017) reported no significant association of flexible flat foot with BMI or gender in young adults, although navicular drop showed some relationship with height and weight. Kaur and Kaur (2024) reported an association between BMI and flat-foot characteristics in adolescents, while Kahile et al. (2020) reported an association between flat feet and BMI in the 10-18-year age group. The present study adds a functional balance perspective by examining YBTCS rather than only the presence or characteristics of flat foot.

Taken together, the findings suggest that BMI, foot posture and gender may need to be considered together when evaluating adolescents with flexible flat feet. The significant interaction observed in the regression analysis indicates that a single overall correlation may conceal gender-specific patterns.

6. Conclusion

There was no statistically significant difference in dynamic balance between female and male adolescents with flexible flat feet. However, BMI showed a strong negative and statistically significant relationship with YBTCS among females, whereas no significant relationship was observed among males. The significant BMI $\times$ gender interaction further indicated that the association between BMI and dynamic balance differed by gender. These findings support consideration of BMI, dynamic balance and foot posture together during physiotherapy assessment of adolescents with flexible flat feet.

7. Limitations

1. The sample size was relatively small, with 40 participants, which may limit generalization of the findings.
2. Only adolescents with flexible flat feet were included; the findings may not apply to rigid flat feet or other foot conditions.
3. Potential influences such as physical activity level, footwear, muscle strength and previous physical activity were not specifically considered.
4. The study was conducted in a limited population and setting; larger studies across different settings are recommended.

8. Clinical Significance

Physiotherapy assessment of adolescents with flat feet may benefit from considering BMI together with foot posture and dynamic balance. The strong inverse BMI-YBTCS relationship observed among females suggests that female adolescents with higher BMI may warrant particular attention to functional balance and lower-limb control. Based on individual assessment, interventions may include balance and proprioceptive training, intrinsic foot muscle strengthening, lower-limb strengthening and functional exercises. The findings also support monitoring functional performance rather than focusing only on structural foot posture.

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