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Impact of Overweight and Flat Foot on Walking Speed in University Students: A Cross-Sectional Study

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Abstract

Introduction: University students are in a transitional phase from adolescence to adulthood, which is a productive period that requires adequate physical fitness to perform daily activities. Walking is one of the most common activities and represents an essential mode of transportation in daily routines. Walking speed varies among individuals, and one factor influencing it is foot posture abnormalities, such as flat foot, which may lead to musculoskeletal complaints and ultimately reduce walking speed. In adults, flat foot is often associated with excessive body mass index (BMI), which increases pressure on the foot arch. This study aimed to explore the relationship between overweight, flat foot, and walking speed.
Methods: A cross-sectional study was conducted using purposive sampling. A total of 86 participants meeting the inclusion and exclusion criteria, who did not withdraw, were included. BMI was measured, flat foot was assessed using the wet footprint test, and walking speed was evaluated using the 4-meter walk test.
Results: Spearman's rho correlation analysis revealed no significant association between overweight BMI and flat foot with walking speed ($p=0.893$, $p>0.05$), nor between obese BMI and flat foot with walking speed ($p=0.723$, $p>0.05$).
Conclusion: The findings indicate that there is no significant relationship between BMI and flat foot with walking speed among university students.

Keywords: Body mass index, flat foot, walking speed, university students, cross-sectional study

Introduction

University students are in early adulthood, a productive phase that requires adequate physical fitness to support daily activities.[1] Any disruption or impairment in physical condition can negatively impact productivity and daily functioning during their academic life. Walking is one of the most common daily activities and represents a primary mode of transportation. Walking speed varies among individuals and is influenced by multiple factors, including age, sex, physical fitness, height, body weight, and body anatomy.[2] Individuals with pathological conditions may experience gait disturbances, which can reduce walking speed. Moreover, aging contributes to slower walking speed due to muscle strength decline and decreased range of motion (ROM), which can further affect gait efficiency.[3]

Flat foot, or pes planus, is a postural foot abnormality characterized by a reduced medial longitudinal arch, resulting in a flattened sole that contacts the ground.[4] The foot arch functions to support body weight and facilitate efficient movement during walking or running. Flat foot can lead to early muscle fatigue, affecting leg movements, including the tibialis anterior responsible for dorsiflexion and the tibialis posterior, gastrocnemius, and soleus muscles responsible for plantarflexion.5 Previous studies, such as the research by Dewi, found differences in walking speed between individuals with normal arches and those with flat foot, with reduced speed observed in the latter. Flat foot is often associated with overpronation, which decreases foot stability and can limit walking ability.[4]

The prevalence of flat foot is highest between ages 2–6 years, ranging from 21% to 57%, and decreases to 13.4%–27.6% during early school age. In adults, the prevalence is approximately 15%–20%. Adult flat foot may result from congenital or genetic conditions, trauma, inflammation, or excessive body mass index (BMI).[5]

Excessive BMI arises from an imbalance between caloric intake and expenditure. According to the World Health Organization, in 2016, 13% of the global population was obese, including 11% of men and 15% of women.[6] In Bali Province, Indonesia, 2017 data reported obesity in 11.6% of men and 13.71% of women, with Denpasar city showing 10.42% of men and 10.64% of women affected.[7] Excess body weight can lead to fat accumulation in the medial longitudinal arch, increasing pressure and contributing to flat foot.[5] Obese individuals tend to shift their weight medially, leading to overpronation and increased stress on the medial arch, which may cause plantar pain and reduce walking speed.[8]

Excess body weight increases plantarflexion load and alters foot pressure patterns toward medial orientation, causing ankle pronation, malalignment, and repetitive overloading of the medial arch.[8] This may ultimately lead to flat foot. Flat

foot can contribute to musculoskeletal injuries, including tibialis posterior dysfunction, ankle sprains, and plantar fasciitis, which impair walking and reduce gait speed. Early adulthood is characterized by both physical and psychological changes, rendering this period vulnerable to energy imbalance and weight gain.[9] Young adults with excessive body weight are more likely to develop low foot arches. Body weight is a crucial factor in foot development, as the medial arch functions to distribute body load across different foot regions during walking.[10]

In Indonesia, literature on flat foot in young adults and its impact on walking speed remains limited. Most studies focus on pediatric and adolescent populations, leaving a knowledge gap regarding flat foot and its consequences in adults. Furthermore, overweight and obesity are prevalent, serving as potential risk factors for flat foot, which may subsequently influence walking speed and overall productivity. To date, no studies in Indonesia have investigated the relationship between excessive BMI, flat foot, and walking speed in university students.

Therefore, this study aims to examine the association between overweight BMI and flat foot with walking speed in undergraduate students from semesters 2 to 8 at Udayana University. BMI will be measured through height and weight assessments, flat foot will be evaluated using the wet footprint test, and walking speed will be measured via the 4-meter walk test. Based on the literature and background, the study hypothesizes that excessive BMI is associated with flat foot and that this combination negatively affects walking speed in young adults. This research is expected to provide foundational data for future studies, enhance understanding in educational and health contexts, and inform preventive strategies. Additionally, it may increase awareness among students that excessive BMI poses a risk for postural changes, including flat foot, which may lead to musculoskeletal injuries and affect walking performance. The findings could also encourage healthcare professionals, particularly physiotherapists, to further investigate the impact of BMI and flat foot on gait in young adults.

Methods

This study employed an analytical observational design with a cross-sectional approach. A cross-sectional study examines the relationship between independent and dependent variables by observing and measuring subjects at a single point in time. The independent variables in this study were excessive body mass index (BMI) and flat foot, while the dependent variable was walking speed. The primary objective of this cross-sectional study was to determine the correlation between overweight and flat foot with walking speed.

Excessive BMI results from an imbalance between caloric intake and expenditure, leading to fat accumulation in the body. Nutritional status can be assessed using BMI, calculated by dividing body weight (kg) by the square of height (m^2). In this study, participants with a BMI >23 kg/m^2 were included as part of the sample. Flat foot, characterized by a flattened medial longitudinal arch, may result from excessive loading and can be measured using the wet footprint test, which evaluates arch shape by observing the footprint for absence of concavity or nearly full contact of the foot with the paper.[5] For the test, one dominant foot is moistened using ink and pressed onto a sheet of paper, after which the print is assessed to determine the presence of flat foot.

Walking speed represents an individual's average walking velocity, expressed in meters per second (m/s). Walking speed was assessed using the 4-meter walk test, in which participants walked a 4-meter distance, and the time taken to complete the distance was measured with a stopwatch.

Data collection was conducted in May 2023 at the Faculty of Medicine, Udayana University, specifically in the lecture building of the Physiotherapy Study Program. The month of May was selected as students had returned from the semester break, facilitating sample recruitment. The total sample size was calculated using cross-sectional formulae, resulting in 86 students from various faculties at Udayana University. Purposive sampling was used to recruit participants. Respondents were initially screened using a Google Form containing questions regarding inclusion and exclusion criteria. Eligible participants were then grouped to facilitate communication regarding research procedures.

Inclusion criteria were undergraduate students from semesters 2–8, aged 20–23 years, with excessive BMI (>23 kg/m^2), and willingness to participate by signing informed consent. Exclusion criteria included students who required walking aids (e.g., crutches) or had a history of lower limb injuries such as ankle sprains or fractures. Dropout criteria included voluntary withdrawal or absence during data collection. Participant age, semester, and injury history were initially collected through the Google Form and confirmed via brief anamnesis and personal data verification during measurement sessions.

Measurements were conducted over three days, allowing participants to select a convenient day to minimize dropouts. A research team assisted with measurements and documentation to reduce bias. The primary researcher instructed the team regarding measurement procedures and device usage to ensure objectivity and data accuracy.

BMI was measured using a tape measure for height and a scale for weight. Flat foot was assessed using the wet footprint test as described above. Walking speed was measured using the 4-meter walk test, with a stopwatch used to record time. Materials included measuring tape, weighing scale, ink, water, paper, and stopwatch.

Collected data were analyzed using SPSS version 25. Univariable analysis described sample characteristics, including BMI, flat foot status, walking speed, and age. Bivariable analysis tested the hypothesis regarding the relationship between excessive BMI and flat foot with walking speed using Spearman's rho non-parametric correlation. Two analyses were conducted: one examining overweight BMI with flat foot and walking speed, and the other examining obese BMI with flat foot and walking speed. Statistical significance was determined using Spearman's rho probability, where $p < 0.05$ indicated a significant correlation, and $p > 0.05$ indicated no significant relationship.[11] This study received ethical approval from the Udayana University Ethics Committee (Approval No. 114/UN14.2.2.VII.14/LT/2023).

Results

This study was conducted at the Faculty of Medicine, Udayana University, in May 2023. The participants comprised active undergraduate students from semesters 2–8 who met the inclusion and exclusion criteria, totaling 86 students. Table 1 presents the frequency distribution of participants based on age. This table provides an overview of the age range and the number of participants in each age category, which is important for understanding the demographic characteristics of the study population.

Table 1. Frequency Distribution Based on Age

Age (years)	Frequency	Percentage (%)
20	38	44.2
21	18	20.9
22	25	29.1
23	5	5.8
Total	86	100.0

Table 1 shows that the majority of participants were 20 years old (38 students, 44.2%), followed by 22 years (25 students, 29.1%), 21 years (18 students, 20.9%), and 23 years (5 students, 5.8%). Table 2 shows the frequency distribution of participants based on sex. By presenting the number of male and female participants, this table helps to describe the gender composition of the sample.

Table 2. Frequency Distribution Based on Sex

Sex	Frequency	Percentage (%)
Male	36	41.9
Female	50	58.1
Total	86	100.0

Table 2 indicates that 36 participants (41.9%) were male, and 50 participants (58.1%) were female. Table 3 summarizes the distribution of foot arch types among the participants. Understanding the prevalence of flat foot or normal arch is essential, as foot structure may influence walking biomechanics.

Table 3. Frequency Distribution Based on Foot Arch

Arch Type	Frequency	Percentage (%)
Normal	53	61.6
Flat Foot	33	38.4
Total	86	100.0

As shown in Table 3, among participants with excessive BMI, 33 students (38.4%) had flat foot, while 53 students (61.6%) had normal foot arches. Table 4 displays the frequency distribution of body mass index (BMI) in relation to flat foot and walking speed. This table allows for the observation of patterns between BMI categories, foot structure, and walking performance. Table 4 displays the frequency distribution of body mass index (BMI) in relation to flat foot and walking speed. This table allows for the observation of patterns between BMI categories, foot structure, and walking performance.

Table 4. Frequency Distribution of BMI with Flat Foot and Walking Speed

Walking Speed	Overweight Normal Arch	%	Overweight Flat Foot	%	Obese Normal Arch	%	Obese Flat Foot	%	Total	%
Slow	23	26.7	15	17.4	27	31.4	16	18.6	81	94.2
Moderate	2	2.3	1	1.2	1	1.2	1	1.2	5	5.8
Total	25	29.1	16	18.6	28	32.6	17	19.8	86	100.0

Table 4 shows that among overweight participants with normal arches, 23 students (26.7%) walked slowly and 2 students (2.3%) walked at a moderate pace. Overweight participants with flat foot had 15 students (17.4%) walking slowly and 1 student (1.2%) walking at a moderate pace. Obese participants with normal arches included 27 students (31.4%) walking slowly and 1 student (1.2%) walking moderately. Obese participants with flat foot included 16 students (18.6%) walking slowly and 1 student (1.2%) walking moderately. Table 5 presents the correlation between overweight BMI, flat foot, and walking speed. This analysis examines whether being overweight is associated with changes in foot structure and walking speed**.** Table 6 shows the correlation between obese BMI, flat foot, and walking speed. Similar to Table 5, this table explores the relationship between obesity, foot arch characteristics, and walking performance, providing insight into potential biomechanical implications.

Table 5. Correlation Between Overweight BMI with Flat Foot and Walking Speed

Variable	Correlation Coefficient	Significance (p)
Overweight BMI with Flat Foot and Walking Speed	-0.033	0.893

Table 6. Correlation Between Obese BMI with Flat Foot and Walking Speed

Variable	Correlation Coefficient	Significance (p)
Obese BMI with Flat Foot and Walking Speed	-0.054	0.723

Based on Tables 5 and 6, no significant correlation was observed between excessive BMI and flat foot with walking speed. The Spearman's rho significance value for overweight BMI with flat foot and walking speed was 0.893 ($p>0.05$), while the significance for obese BMI with flat foot and walking speed was 0.723 ($p>0.05$), indicating no statistically significant relationship between these variables.

Discussion

Participant Characteristics

In this study, the most predominant age group was 20 years old, comprising 38 participants, whereas the smallest group was 23 years old, with only 5 participants. This age range corresponds to early adulthood, a period associated with significant lifestyle changes as individuals adapt to new routines, which may increase susceptibility to energy imbalance and weight gain. In general, early adulthood is strongly influenced by social and environmental factors, which can contribute to unhealthy lifestyle behaviors.[9] The focus on young adults, particularly university students, is justified because this population is in a productive age range and requires adequate physical fitness to perform daily activities efficiently.

The study sample was predominantly female, with 50 female participants and 36 male participants meeting the inclusion criteria for excessive BMI. This sex distribution can be attributed to post-pubertal differences in physical fitness. Males generally exhibit higher physical fitness levels than females due to greater muscle strength. Physiologically, hormonal factors influence muscle fiber growth, resulting in females having lower muscle mass and higher fat mass compared to males.[12]

Regarding foot arch characteristics, among participants with excessive BMI, 53 individuals had normal foot arches, while 33 participants (38.4%) exhibited flat foot. Flat foot is more commonly observed in children due to ligamentous weakness, age-related factors, and excessive BMI, which may persist into adulthood if left uncorrected. Previous studies have reported no direct correlation between BMI and foot posture changes, indicating that increased BMI does not necessarily lead to greater foot pronation. Although individuals with excessive BMI may experience higher medial loading, plantar pressure distribution and center of pressure remain similar to individuals with normal BMI.[13]

Most participants in this study exhibited slow walking speeds, with 81 individuals (94.2%) walking slowly. None of the participants achieved maximum walking speed. Slow walking may be influenced by excessive BMI and the presence of flat foot. Overweight or obese individuals typically have shorter step lengths, wider step widths, and a reduced swing phase to maintain stability and minimize the risk of imbalance during ambulation.[14] Individuals with flat foot may experience excessive activation of lower limb muscles and increased plantar loading as walking speed increases, potentially causing plantar discomfort and reduced walking speed.[15]

Relationship Between Excessive BMI with Flat Foot and Walking Speed

Bivariate analysis using Spearman's rho was conducted to evaluate the relationship between excessive BMI with flat foot and walking speed. Two analyses were performed: the relationship between overweight BMI with flat foot and walking speed, and the relationship between obese BMI with flat foot and walking speed. Both analyses showed no significant correlations ($p>0.05$).

Among overweight participants, 16 individuals had flat foot, while 25 had normal arches, indicating no significant relationship between overweight status and flat foot. The presence of overweight participants without flat foot may be influenced by factors other than BMI, such as footwear. Chougala reported that continuous use of hard-soled footwear can promote adaptive arch elongation and redistribute medial loading, thereby reducing flat foot risk.[16] These findings contrast with Amir et al., who reported a significant association between overweight and flat foot, where overweight individuals had a 5.4-fold increased risk of developing flat foot due to increased ligament, tendon, and muscle strain from excess loading.[17]

Similarly, among obese participants, 17 individuals had flat foot, whereas 28 had normal arches. These results align with studies by Wijaya and Bhoir, which reported no significant association between BMI and flat foot. Conversely, Azzahra found that individuals with obesity (BMI grades 1 and 2) had a higher prevalence of flat foot, likely due to increased arch loading.[18] Discrepancies among studies may result from differences in flat foot assessment methods, examiner objectivity, sample characteristics, and other risk factors.[5],18

Excessive BMI generally affects lower extremity posture, causing medial knee alignment and increased medial foot loading, potentially increasing flat foot risk. Ummunnah et al. investigated the relationship between BMI, Q-angle, and tibiofemoral angle, which influence knee joint alignment, although the study did not fully clarify the specific relationships.[20] Tibiofemoral angle (representing valgus angle between femur and tibia axes) affects patellar and tibial tuberosity positioning, influencing Q-angle. Their study reported significant differences in tibiofemoral and quadriceps angles between males and females, with males exhibiting larger angles due to longer hip-to-patella distance. The higher

proportion of female participants in the present study may partly explain the low prevalence of flat foot despite excessive BMI.

Tables 4 and 5 show that neither overweight nor obese BMI with flat foot significantly correlated with walking speed. Similarly, Daekyo Kim et al.8 reported no significant bidirectional interactions among BMI, arch height, and walking speed ($p>0.05$). However, they noted that arch height could affect gait mechanics based on BMI classification, and arch interventions in obese individuals with flat foot may reduce musculoskeletal injury risk and facilitate walking.

The lack of significant findings in this study may also be due to the specificity of walking speed measurements. Walking involves complex biomechanical integration, and previous studies suggest evaluating kinematic and gait parameters in addition to walking speed to fully capture postural changes associated with excessive BMI and flat foot. Physical fitness may further influence walking speed, as individuals with lower fitness levels, commonly observed in those with excessive BMI, may fatigue more quickly and have limited activity capacity due to increased joint loading.[21] Additionally, sedentary walking habits, prevalent among the Indonesian population, may contribute to the slow walking speeds observed.

Study Limitations and Recommendations

This study has several limitations. Potential biases may arise from unmeasured factors influencing walking speed, such as physical fitness and sex. Excessive BMI is more prevalent in females, and sex-based fitness differences were not controlled. Furthermore, only walking speed was measured, omitting more complex gait analyses. Future studies should incorporate comprehensive gait assessments, including kinematic and gait parameter evaluations, and control for confounding variables such as physical fitness and sex.

The generalizability of these findings is limited to the studied population (Udayana University students, semesters 2–8). Different populations may yield different outcomes. Although this study found no significant correlation between excessive BMI with flat foot and walking speed, theoretically, excessive BMI increases the risk of flat foot due to excessive arch loading. Flat foot may also elevate musculoskeletal injury risk through postural changes and excessive foot loading, potentially impacting walking ability. Therefore, this study provides promotive and preventive insight, highlighting that excessive BMI may contribute to postural alterations, including flat foot, which can increase musculoskeletal injury risk and impair walking function if not addressed.

Conclusion

Based on the results of this study, it can be concluded that there is no significant relationship between excessive body mass index and flat feet with walking speed among second- to eighth-semester students at Udayana University. This study comprehensively assessed walking kinematics and related parameters, providing insight into the potential impact of foot posture alterations on walking speed. Further research on walking speed in the Indonesian population is recommended to establish average walking speed values and their implications for public health.

Author Contribution

Fatimah Azzahra Rachim: Conceptualization, methodology, data collection, data analysis, and manuscript drafting.

I Putu Yudi Pramana Putra: Supervision, guidance on research design, and critical review of the manuscript.

Gede Parta Kinandana: Supervision, validation, and manuscript editing.

I Made Niko Winaya: Supervision, methodological consultation, and final manuscript review.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this study.

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Ethics Statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was not required as the study involved only non-invasive procedures (blood pressure measurement and questionnaire surveys) and posed minimal risk to participants. Informed consent was obtained from all participants prior to their inclusion in the study, and confidentiality was strictly maintained.

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