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The association between Body Mass Index (BMI) and knee pain on flexible flat foot among students at Universitas Warmadewa, Bali, Indonesia

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ABSTRACT

Background: Flatfoot (pes planus) causes mechanical pressure in the knee and increases contact between the patellar articulation surfaces, increasing knee pain. The weight gain can increase the risk of flatfoot because of excessive loading and ligament stretching beyond the elastic limit. This study aims to determine the association between body mass index (BMI) and knee pain on flexible flat foot among students at Universitas Warmadewa, Denpasar.

Methods: A cross sectional analytic study was conducted among 100 new students of the Universitas Warmadewa Denpasar between May-December 2019. Flat foot screening was carried out using the wet footprint test and plantar arch index (PAI) measurement. BMI was measured through the weight and height of the sample. Patellofemoral pain was measured using the Kujala anterior knee pain scale questionnaire. Descriptive analysis was analyzed by SPSS version 20 for Windows to determine the mean, SE, maximum, and minimum value of all ratio variables. The correlation was tested with Spearman with a significance level of $p < 0.05$.

Results: The average BMI value was 27.6 kg/m^2, the average PAI of the right foot was 1.42, the average PAI of the left foot was 1.48, and the average score of the Kujala score was 77.22. There was a positive correlation between BMI with flexible flat foot on the right and left foot with significant results ($p = <0.05$, $r = -0.24$; $p = <0.05$, $r = 0.307$ respectively). There was a negative correlation between Kujala score with flexible flat foot on the right and left foot with significant results ($p = <0.05$, $r = -0.238$; $p = <0.05$, $r = -0.366$ respectively).

Conclusion: Flexible flat foot significantly correlates to BMI and Kujala score. The higher BMI value, the PAI leg will be higher. The higher PAI value of the foot, the Kujala score will be lower.

Keywords: Flexible Flat Foot, BMI, Knee Pain, Students

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INTRODUCTION

Flatfoot (pes planus) is a condition in which the medial longitudinal arch (MLA) of the foot collapses, so the sole is in contact with the ground.[1,2] Flatfoot can be physiological if found in infants and children at a certain age due to bone and tissue structure that has not been fully formed.[1,2] Any abnormalities that arise during this period will be easier to handle than the onset found in older age.[3] However, several factors, such as obesity, can cause flatfoot to last into adulthood.[4] Foot and ankle specialists agree that flatfoot is a pathology and often found in the adult population.[5] Adult flatfoot is defined as the partial or complete collapse of the MLA that persists or develops after bone maturity.[4,5] Adult flatfoot can be present as an incidental finding or symptomatic condition with clinical consequences ranging from mild limitations to severe disability.[4,5] Flat foot prevalence is still unknown due to no clinical consensus or radiological criteria for diagnosing flat foot. Several studies have determined the prevalence of flat foot in children and the prevalence decreased with increasing age.[4-6] In the adult population, flatfoot prevalence is around 15-20%, associated with obesity, and more commonly found in male sex.[6] A previous study by Aenumulapalli A et al. showed the majority of flatfoot, which aged 18-21 years were 13.6%.[6] Another study by Bhoir et al. found a flatfoot prevalence was 11.25% using physiotherapy student subjects aged 18-25 years.[7]

Weight gain can impose a higher load on the skeletal structure and can cause musculoskeletal pain.[8] Weight gain associates with repeated excessive loading, which can stretch the ligaments beyond their elastic limit, damage soft tissue, and increase foot discomfort.[8] Another mechanism in weight gain is a change in plantar fat pads, enhancement of plantar pressure, and inadequate muscle strength, especially in activities that require movement against gravity.[9] Shree et al. analyzed overweight and obese students who showed a flatfoot prevalence was 44%.[9] Previous studies showed that weight gain had a positive association with a higher prevalence of flatfoot.[7,9,10] Riddiford-Harland et al. demonstrated the footprint angle (FA) in obese patients is lower and the Chippaux-

Smirak (CSI) index value is more significant.[11] Decreased FA and increased CSI are characteristic of structural changes in the foot, such as lower longitudinal internal arches, a fatter cavity, and a broader mid-foot area of the footprint that have been associated with impaired foot function.[10,11]

Legs and knees are biomechanically connected in a closed kinetic chain when walking in which foot position and movements can affect knee loads.[12] Pathological flatfoot can change muscle balance, gait, and joint motion alignment, so it has mechanical pressure in the knee, increasing rotational tension of the tibiofemoral compartment load-bearing tissues, and increase contact between the lateral patellar articulation surfaces.[12] These conditions will cause knee pain.[3,13] Gross KD et al. showed that flatfoot conditions were associated with more frequent knee pain and damage to the medial cartilage of the knee joint.[14]

Studies show a vicious circle in which overweight, musculoskeletal pain, and low fitness status reinforce each other.[15] Pain in the individual's legs which are overweight can be a basic problem and has not received adequate attention. Experiencing pain during an activity tends to prevent someone from taking part in physical activity. Withdrawal from physical activity can exacerbate weight gain and aggregates structural complications in the foot.[7,15] The majority of studies analyze the prevalence of flatfoot in children under the age of 10 years, but the amount of literature is minimal in the 18-25 year age group.[10-13] Therefore, the purpose of this study is to determine the association between body mass index (BMI) and knee pain on flexible flat foot among students at Universitas Warmadewa, Denpasar.

METHODS

A cross-sectional analytic study was conducted used 100 new students of Universitas Warmadewa Denpasar between May to December 2019. The inclusion criteria were new students willing to be the study subject and filled out informed consent. Flat foot screening on the left and right foot used the wet footprint test followed by the plantar arch index (PAI) measurement. PAI measurement was conducted by dividing the width of the central region of the foot (A) and the calcaneus region (B) in millimetres. The greater central area of the foot showed the flatfoot.[16,17] BMI was measured through body weight and height by trained medical staff using standardized protocols. BMI was calculated using the formula weight in kilograms divided by height in meters squared.[18] Patellofemoral pain was measured using the Kujala anterior knee pain scale questionnaire, which consisted of 13 screening items and was a patient-reported assessment. The Kujala score ranged from 0-100, which the smaller value indicated worse patellofemoral function.[19]

The independent variable in this study was the PAI. The dependent variables were the BMI and Kujala score. Data were analyzed using SPSS version 20 for Windows. The univariate analysis was conducted descriptively to see the mean, SE, maximum, and minimum value of all ratio variables. Data normality was tested by the Kolmogorov-Smirnov test at a significance level of $p > 0.05$. The correlation test between independent and dependent variables was analyzed using the Pearson correlation when normally distributed or Spearman if the data were not normally distributed at significance level $p < 0.05$. During the data collection, researchers used codes to maintain the confidentiality of patient identities.

RESULTS

This study involved 100 new students at Universitas Warmadewa as respondents during the study period. The baseline characteristics of the respondents were presented in Table 1. The age mean of respondents was 18.16 years with a SE of 0.83. Analysis of respondents' BMI showed that a mean value were 27.60 kg/m^2 with a SE of 5.36 (Table 1). The mean of PAI on the right foot were 1.42 with a SE of 0.19 and on the left foot were 1.48 with a SE of 0.18 (Table 1). The mean of the Kujala score was 77.22, with a SE of 7.96 (Table 1).

A data normality test was performed to determine the distribution of data using the Kolmogorov-Smirnov because the number of samples was more than 50. Table 2 showed the normality test of BMI, right foot PAI, left foot PAI, and Kujala score, which was already transformed. All variables have a probability value (p) less than 0.05, so all variables were not normally distributed (Table 2). Based on these results, the Spearman correlation test was conducted for inter-variable analysis.

The results of the spearman correlation test between PAI and BMI variables were presented in Table 3. The significance value between BMI and right foot PAI was smaller than 5%, so BMI significantly correlates with PAI right foot. The correlation coefficient was 0.240 indicated a positive correlation between BMI and right foot PAI. If BMI increased by 1 unit, then the right foot PAI will increase by 0.240 units. Table 3 also explained the correlation between BMI and left leg PAI. The significance value of BMI with left foot PAI was also smaller than 5%. The correlation coefficient was 0.307 indicated a positive correlation between BMI and left foot PAI (Table 3).

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Table 1. **Baseline characteristics of respondents**

Characteristic	Maximum	Minimum	Mean	SE
Age (year)	21.00	17.00	18.16	0.83
BMI (kg/m^2)	40.10	19.70	27.60	5.36
PAI of the right foot	1.84	0.75	1.42	0.19
PAI of the left foot	2.04	1.05	1.48	0.18
Kujala Score	93.00	64.00	77.22	7.96

Table 2. **Kolmogorov-Smirnov for data that has been transformed**

Variables	p
Log_IMT	0.000
Log_PAI of the right foot	0.000
Log_PAI of the left foot	0.005
Log_Kujala Score	0.000

Table 3. **The Spearman Correlation Analysis between BMI and Kujala Score variables with PAI.**

Variables	n	r	p
Body Mass Index (BMI)			
PAI of the right foot	100	-0.240	<0.050
PAI of the left foot		0.307	<0.050
Kujala Score			
PAI of the right foot	100	-0.238	<0.050
PAI of the left foot		-0.366	<0.050

Spearman correlation test results between the PAI with the Kujala score were also presented in Table 3. There was a significant correlation between the Kujala Score with PAI of the right foot (p<0.05). The correlation coefficient was -0.238 showed a negative correlation between Kujala Score and right foot PAI. In Table 3, the correlation between the left foot PAI and the Kujala score also showed significant results (p <0.050). The results showed a negative correlation between Kujala Score and left foot PAI (r = -0.366) (Table 3).

DISCUSSION

Foot posture has a contribution in the lower limb musculoskeletal development because it can change the mechanical alignment and lower dynamic limb functions, which one of the foot posture analysis is pes planus.[9,20] Flatfoot or called pes planus is a condition in which MLA collapses, so the soles of the feet contact with the floor or the surface of the ground during load-bearing activity.[9] In this study, a significant correlation was found between knee pain measured using a Kujala score and a flat foot calculated based on the plantar arch index. Gross et al. showed a significant relationship between flatfoot and knee pain, with an odds ratio value was 1.31 in the elderly adult population.[14] Flatfoot conditions can result in activity avoidance due to knee pain. The result of activity avoidance is muscle weakness, which can slow performance based on decreased physical function.[12, 21]

The feet act immediately as a buffer from mechanical stress when in contact with the ground or floor. Foot and knee postures are combined in closed kinematic chains during weight-bearing activities. Closed chain coupling can connect planus foot morphology with internal rotation of the lower limb. The rotation may affect mechanical pressure in the knee and result in enhancement of rotational stress and/or shear stress on the load-bearing tissues of the tibiofemoral (TF) or patellofemoral (PF) compartment. The other effect is the enhancement of contact between the surface of the lateral patellar articulation with the lateral femoral trochlea causing cartilage damage and knee pain.[14,22]

Flatfoot, which holds excessive loads, has the potency to increase rotational pressure in the tibiofemoral joint load-bearing tissue. Because the largest proportion of the transversal plane rotation occurs in the medial compartment, so the shear strain on the cartilage is most likely to occur at this location. Gross et al. found a relationship between flatfoot and TF medial cartilage damage but found no significant association with TF lateral cartilage.[14]

In this study, there was a positive correlation between nutritional status measured using BMI and flat foot, as seen from the plantar arch index. An excessive weight-bearing caused by overweight or obesity can negatively impact the lower extremities. This result is consistent with the study of Shree et al., which showed a significant relationship between BMI and flatfoot by using a footprint test on student subjects. Shree et al. also showed a strong relationship between BMI and grade of flatfoot (Pearson correlation = 0.42, p-value <0.001).[9]

Enhancement of body weight is a significant problem for public health. The frequency of flatfoot increases with a higher BMI. Under static conditions, weight gain causes greater peak force in the soles of the feet when individuals stand.[1] Overweight or obese individuals have a reduced range of dorsoflexion, more pronated heel, and a flatter plantar arch. Limited dorsiflexion range can cause distal compensation in the legs during walking. Distal compensation often occurs in the midfoot because the ligaments in this section are not as dense as the ligaments and tendons that support the proximal joints.[7,23] Cumulative stress on the midfoot can cause plastic deformation of ligaments in this area and show overpronation when walking or flatfoot.[7,24]

Enhancement of body weight can cause fat accumulation in the abdominal area resulting in weakness in the abdominal wall and excessive lordotic position. These conditions cause alteration in linea gravity and transfer the load through the legs. As a result, the weight buffer to move. An increase in the body fat and a decrease in muscle strength causes a reduction of muscle fibers, so the pedis arch diminishes and may even disappear.[25]

Pain complaints during physical activity and exercise increase in overweight individuals. Foot problems can reduce routine physical activity and perpetuate the overweight cycle, so the foot structure of overweight individuals should receive more attention from health professionals. It is assumed that foot deformity leads to foot dysfunction, affecting the ability to make regular movements.[7]

The PAI is related to the central foot region. Based on a study conducted by Rithanya et al., the PAI is a compatible method for diagnosing flatfoot in older populations and has a high sensitivity. Footprint using ink is relatively economical, available, and an easy process to use as an appropriate alternative for radiographic assessment.[16] This method is also noninvasive, reliably shows MLA form, is not exposed to radiation so it can be applied to anyone compared to radiographic procedures.[2,16] The index of arcs obtained from the ink is a good predictor of MLA height because flatfoot causes a larger contact area at the medial border of the footprint.[7, 26]

This study has several limitations. The cross-sectional design of the study limits the ability to conclude the direction of causation in observed associations.[14] Second, this study does not evaluate foot pain, which is also a significant limitation. Foot pain, especially ipsilateral foot pain, can affect knee pain, disability, and physical performance. We cannot prevent the possibility of foot pain associated with flatfoot and knee pain. Further studies show that foot pain and other confounding factors such as lifestyle, occupation, primary shoes, range of motion, and non-surgical ligament injuries in the knee or ankle will be needed to validate the adverse effects of the flat on knee pain.[12] Third, the footprint analysis in our study is limited to static evaluation. Riddiford-Harland et al. showed that the foot posture that was evaluated in a standing position caused no pressure to the Achilles tendon or leg ligaments.[2,11] Therefore, this study cannot predict dynamic foot behavior during moving, and further research is needed to investigate hypermobility and midfoot deformation.[7]

CONCLUSION

BMI and Kujala scores have a significant correlation to flexible flat foot in students among Universitas Warmadewa. The higher BMI value, the PAI leg will be higher. The higher PAI value of the foot, the Kujala score will be lower.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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Not applicable to this research.

AUTHOR CONTRIBUTION

All of the authors are equally contribute to the study from the conceptual framework, data gathering, data analysis, until reporting the results of study through publication.

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