Relationship between Body Mass Index, Type of Weight Bearing Activity and Beighton and Horan Joint Mobility Index with Pes Planus in Adult Athletes

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Abstract

High body mass index, increased weight-bearing activity, ligament laxity are risk factors for pes planus, however, there is no research that looks for the relationship between these three risk factors in athletes. Adult athletes have a higher prevalence of pes planus than young athletes. In a conceptual framework regarding the etiology of injury in athletes, the interaction of multiple injury risk factors will further increase the risk of injury to athletes. This study aims to determine the relationship between body mass index, type of weight bearing activity and the Beighton and Horan Joint Mobility Index with pes planus in adult athletes. Secondary data from athletes screening of Regional Exercise Center (PUSLATDA) East Java was used in this study. Randomization technique was applied to recruit 96 proper respondents. Binary Logistics Regression test for calculating the relationship between BMI, type of weight bearing activity (high/low impact sport), BHJMI score and Chippaux-Smirax Index (CSI) with the statistical significance of $p < 0.05$. There was a significant relationship between body mass index and pes planus on the right foot ($p = 0.042$) and left foot ($p = 0.000$), as well as BHJMI and pes planus on the left foot only (p 0.032), but there was an increased risk of pes planus in adult athletes as their BMI, type of weight bearing activity, and BHJMI increased. In adult athletes, there is a strong link between body mass index and pes planus in both feet, as well as BHJMI and pes planus on the left foot only; nevertheless, the risk of pes planus increases as body mass index, type of weight bearing activity, and BHJMI rise.

Keywords: Pes planus, body mass index, type of weight bearing activity, BHJMI, adult athletes

INTRODUCTION

Pes planus is a foot posture with a low height of the medial longitudinal arch (Gwani et al., 2017). The medial longitudinal arch of the foot is composed of the tarsal and metatarsal bone structures, ligaments, intrinsic and extrinsic muscles of the foot and plantar fascia (Neumann, 2010; Floyd, 2012). The decrease in the height of the medial longitudinal arch occurs due to the failure of the arch structure which can reduce the ability of the foot as a shock absorber in various weight bearing activities (Floyd, 2010; Kirby, 2017). This can increase the forces acting on the legs and proximal body parts and increase the risk of musculoskeletal injuries (Chan and Rudins, 1994; William et al., 2001; Kirby, 2017). Athletes are individuals whose most sports activities are weight bearing activities (Bartlett, 2014). Pes planus in athletes can increase the risk of musculoskeletal injury which in turn increases the risk of withdrawing athletes from training or competition (William et al., 2001; Lisman et al., 2017). In the study of Korkmaz et al (2020), adult athletes had a higher prevalence of pes planus than young athletes.

Increased body mass index, excessive type of weight bearing activity and ligament laxity are risk factors for pes planus (Beeson, 2014; Ross et al., 2018). An increase in body mass index has a correlation with an increase in plantar pressure, especially in the 2,3 metatarsal area and calcaneus (Hills et al., 2002). The increase in plantar pressure, especially in the 2, 3rd metatarsal area and the calcaneus, causes stretching of the plantar fascial structures attached to these areas. Stretching the plantar fascia will reduce the height of the medial longitudinal arch of the foot, causing pes planus (Buldt et al., 2013; Kurniaagung et al., 2020). In a meta-analysis study by Butterworth et al (2012), a high body mass index has a positive correlation with an increased incidence of pes planus, however, there are no studies that have looked for a relationship between body mass index and the incidence of pes planus in adult athletes.

The type of weight bearing activity also affects the ground reaction force (GRF) as a result of the weight of the body supporting the ground. The greater the weight bearing activity, the greater the GRF so that the force transmitted to the proximal body will also increase (Newmann, 2010). Forces that work beyond musculoskeletal capabilities will cause injury (McGinnis, 2013). Based on the type of weight bearing activity that increases the risk of lower extremity injury in athletes, there are 3 types of sports, namely high impact sports, medium impact sports and low impact sports (Hill, 2002). Increased weight bearing activity will cause repetitive mechanical overloading on the posterior tibial tendon which is the main dynamic stabilizer of the medial longitudinal arch of the foot (Guelfi et al., 2017). This will cause posterior tibial tendon dysfunction due to the degeneration process (Cook and Purdam, 2009). In a study by Dyal et al (1997), there is a positive correlation between posterior tibial dysfunction and the incidence of pes planus, however, until now there has been no study looking for a relationship between the type of weight bearing activity and pes planus.

Ligament laxity is a condition of joint hypermobility due to weakness of the ligament as a joint support which then increases the risk of ligament injury and further deformity (Jansson et al., 2004; Seçkin et al., 2005; Barber Foss et al., 2009). Ligament laxity can be measured using the Beighton and Horan Joint Mobility Index/BHJMI, where the higher the BHJMI value, the higher the incidence of ligament laxity (Boyle et al., 2003; Barber Foss et al., 2009). The increase in the Beighton and Horan Joint Mobility Index is related to a decrease in the integrity of the ligament which then increases the stretch of the ligament, including the spring ligament which is the constituent of the medial longitudinal arch of the foot. The presence of a spring ligament stretch can cause pes planus conditions (Neumann, 2010; Flores et al., 2019). In a study by Barber Foss et al (2009), there was a significant correlation between the incidence of ligament laxity and pes planus in adolescent athletes, however, there have been no studies examining this condition in adult athletes.

High body mass index, increased weight bearing activity, ligament laxity and pes planus are internal risk factors for injury in athletes. In a conceptual framework on the etiology of injury by Meeuwisse (1994), the interaction of multiple internal risk factors will further increase the risk of injury in athletes. This study aims to determine the relationship of each risk factor. Knowledge of the relationship between each risk factor is expected to be a reference for injury prevention intervention strategies in the field of sports.

METHODS

Secondary data from athletes screening of Regional Exercise Center (PUSLATDA) East Java was used in this study. We obtained the data from Sport Clinic of Dr. Soetomo General Hospital Surabaya as the location for the athletes to do screening process. The study was begun from October 2021 to December 2021. Analyzed variables were including BMI, type of weight bearing activity (high/low impact sport), BHJMI score and foot posture using Chippaux-Smirax Index (CSI).

Population and Sampling

Randomization technique was applied to recruit proper respondent. The inclusion criteria were consisted of

(1) athletes who were aged 18-35 years, (2) doing weight bearing activities, (3) having completed all stage of Puslatda East Java screening at Sport Clinic of Dr. Soetomo General Hospital Surabaya in March 2020, (3) athletes whose medical record has fully completed with the information including: BMI, type of weight bearing activity (high/low impact sport), BHJMI score and Chippaux-Smirax Index (CSI), age, gender, sports category. Finally, about 96 data respondents were collected for final analysis.

Data Analysis
The analysis of quantitative data was performed SPSS for Windows versi 24 (SPSS Inc., Chicago, IL). Specific tests was applied based on the aims of the study, namely Binary Logistics Regression test for calculating the correlation between BMI, type of weight bearing activity, BHJMI score and Chippaux-Smirax Index (CSI). The statistical significance had set at $p < 0.05$.

RESULT

1. Characteristics of Research Subjects

With a total of 96 individuals, the features of research subjects based on gender, sports, and foot dominant will be described descriptively and assessed using percentages. Male study subjects account for 51% (49), while female research subjects account for 49%. (47). Athletics accounted for 30.2 percent (29), wrestling 15.6 percent (14), fencing 11.5 percent (11), hockey 10.4 percent (10), wushu 10.4 percent (10), handball 10.4 percent (10), basketball 8.3 percent (8), and gymnastics 3.1 percent of the research subjects (3). The right foot was used by 90.6 percent of the research participants (87), whereas the left foot was used by 9.4 percent (9). The average body mass index of male research subjects was 24.66 kg/m2, whereas female research subjects had a body mass index of 21.82 kg/m2. This demonstrates that male athletes have a substantially higher body mass index than female athletes. Fencing research subjects had an average body mass index of 22.88 kg/m2, athletics 22.86 kg/m2, basketball 22.18 kg/m2, wrestling 27.64 kg/m2, handball 21.65 kg/m2, hockey 22.76 kg/m2, gymnastics 18.02 kg/m2 kg/m2, and wushu 22.96 kg/m2. This means that, when compared to other sports, wrestling has the highest average body mass index of 27.64 kg/m2, while gymnastics has the lowest average body mass index of 18.02. kg/m2. The right foot has an average body mass index of 23.29 kg/m2, while the left foot has an average body mass index of 23.29 kg/m2. (Table 1)

Table 1. Characteristics of Research Subjects

Variables	n	(%)	SD of BMI
Gender			
Male	49	51	24,66 ± 4,55
Female	47	49	21,82 ± 2,43
Cabang Olahraga			
Fencing	11	11,5	22,82 ± 2,49
Athletic	29	30,2	22,86 ± 3,62
Basket	8	8,3	22,18 ± 1,72
Wrestling	15	15,6	27,64 ± 5,62
Handball	10	10,4	21,65 ± 1,47

Variables	n	(%)	SD of BMI
Hockey	10	10,4	22,76 ± 3,66
Gymnastic	3	3,1	18,02 ± 0,82
Wushu	10	10,4	22,96 ± 1,27
Foot dominant			
Right	87	90,6	23,23 ± 3,93
Left	9	9,4	23,68 ± 4,02

The average value, minimum value, maximum value, and standard deviation will be used to examine descriptively the study results in the form of age, weight, height, body mass index, CSI, and BHJMI index of the research subjects. The subjects in this study were on average 22.36 years old, with the youngest being 18 and the oldest being 32. The research respondents' average body weight was 64.92 kg, with the lowest weight being 41 kg and the highest being 131 kg. The research respondents' average height was 166.73 cm, with the lowest being 147 cm and the greatest being 185 cm. The research participants' average body mass index was 23.27, with the lowest being 16.97 and the highest being 41.11. The mean CSI of research respondents' right feet was 0.35, with the lowest value of 0.1 and the greatest value of 0.67, and the left foot's CSI was 0.34, with the lowest value of 0.12 and the highest value of 0.67. The research subjects' average BHJMI score was 2.18, with 0 being the lowest and 9 being the highest. (Table 2)

Table 2. Characteristics of Age, Height, Weight, Body Mass Index, BHJMI and Right and Left Foot Posture (CSI) of Research Subjects

Variables	N	Mean	Minimum	Maximum	Standard Deviation
Age (year)	96	22,36	18,00	32,00	3,71
Body Weight (kg)	96	64,92	41,00	131,00	15,13
Body Height (cm)	96	166,33	147,00	185,00	7,96
Body Mass Index (kg/m2)	96	23,27	16,97	41,11	3,93
CSI (right)	96	0,35	0,10	0,67	0,10
CSI (left)	96	0,34	0,12	0,67	0,10
BHJMI	96	2,18	0,00	9,00	1,98

2. Analysis of the Relationship between Body Mass Index, Type of Weight Bearing Activity and BHJMI with Pes Planus

The Binary Logistics Regression test will be used to examine the relationship between body mass index, kind of weight bearing exercise, and BHJMI with pes planus in research subjects. To assess the link between each independent variable and the dependent variable, as well as the odds ratio value, the Binary Logistics Regression Test can be utilized. If the P-value for the Binary Logistics Regression test is less than 0.05, it can be concluded that there is a significant relationship between body mass index, type of weight-bearing activity, and BHJMI with pes planus; however, if the P-value is greater than 0.05, it can be concluded that there is no significant relationship between body mass index, type of weight-bearing activity, and BHJMI with pes planus. The odds ratio, or Exp (B), is a component of the regression coefficient that is used to determine how much the independent variable influences the dependent variable.(Table 3).

Table 3. Binary Logistic Regression Test of Body Mass Index, Type of Weight Bearing Activity and BHJMI with pes planus

Variables	Pes Planus (Right)		Pes Planus (Left)	
	Significance	OR/CI	Significance	OR/CI
Body Mass Index	**0.042***	0.964 / 0,930-0,999	**0,000***	0,868 / 0,813-0,927
Type of Weight Bearing Activity	0.051	0.330 / 0,108-1,006	0.405	1,760 / 0,465-6,651
BHJMI	0.371	0.873 / 0,647-1,176	**0,032***	1.339 / 1,026-1,747

$p < 0.05$, OR 95% CI

The association between body mass index, type of weight bearing activity, BHJMI, and pes planus was shown in Table 3. Pes planus affects both the right and left feet and is strongly linked to BMI. According to the odds ratio (OR), every 1 kg/m2 rise in BMI increased the probability of developing pes planus by 0.964 times in the right leg and 0.868 times in the left leg. There was no link between the type of weight-bearing activity and pes planus. When compared to medium impact sports, the OR value of high impact sport weight bearing activity increased the probability of developing pes planus by 0.330 times on the right leg and 0.405 times on the left foot. In the left foot, BHJMI scores demonstrated a substantial connection with pes planus, but not in the right foot. According to the BHJMI's odds ratio (OR), every score of 1 in the evaluation raises the likelihood of developing pes planus in the left leg by 1.339 times, but only by 0.873 times in the right leg.

DISCUSSION

This study was conducted to assess the relationship between body mass index, type of weight bearing activity and BHJMI with pes planus in adult athletes. Based on secondary data in the form of screening data for Puslatda East Java athletes from the Sport Clinic RSUD Dr. Soetomo Surabaya, there are 96 athlete data representing the adult athlete population. The mean body mass index of adult male athletes in this study was higher than that of women. Zhang and colleagues (2019) found that the average body mass index in the general adult population was higher in men than women. Huebner and Perperoglou (2020) found that the mean body mass index in male adult athletes was also higher than that of women. This is also supported by a literature review study by Walsh et al (2018) that the average body mass index of male adult athletes is higher in men than women. Males basically have a higher composition of muscle mass so this affects a higher average body mass index in both the general population and adult athletes (Zhu et al., 2015).

The average body mass index of adult athletes in this study was the highest from wrestling, namely 27.64 kg/m2 and the lowest came from gymnastics, namely 18.02 kg/m2, while athletes from fencing, hockey, athletics, basketball and hand ball and wushu are included in the normal body mass index category.

Wrestling is a sport with varying body mass index, depending on body weight specifications for competition, however, the average body mass index of wrestling athletes is still higher when compared to other martial arts athletes/combat sports (Jonnalagadda et al., 2004; Dopsaj. et al., 2017).

The average body mass index of hockey athletes in this study was 22.76 kg/m2. This is also similar to research by Chiarlitti and colleagues (2018) where adult Hockey athletes have an average body mass index of 22.26 kg/m2. The average body mass index of athletic athletes in this study was 22.55 kg/m2. Research by Fatikasari and Hakim (2019) also found a normal average body mass index in adult athletic athletes, which is 21.56 kg/m2. The mean body mass index of basketball and hand ball athletes in this study were 22.26 kg/m2 and 21.7 kg/m2. This is also similar to the research conducted by Muratovic and colleagues (2014) where the average body mass index of basketball athletes is higher than handball athletes. Body mass index in athletes generally varies depending on genetic factors, diet, lifestyle, type of exercise and sport. An increase in body mass index in athletes can be caused by an increase in fat mass and muscle mass. Increased muscle mass in athletes is useful for improving physical performance such as athletic athletes, hockey, basketball, handball, fencing and wushu, however, some athletes require a high body mass index such as wrestling for sports activities in the form of high endurance. Certain sports require a body mass index as an initial assessment of sports involvement, for example in sports that prioritize aesthetic performance such as gymnastics (Jonnalagada et al., 2004).

1. Relationship between Body Mass Index and Pes Planus

The aim of this study is to see if there's a relationship between BMI and pes planus in adult athletes. The findings of this study show a link between BMI and pes planus in adult athletes, both on the left and right feet, as well as an increase in risk variables for pes planus as BMI rises. An increase in fat mass and muscle mass can lead to an increase in the load on the lower extremities, resulting in a rise in BMI. Increased lower extremity load can boost muscle cell renewal, but too much of it can lead to extrinsic and intrinsic muscle degeneration in the foot.

Greater lower extremity load can improve muscle cell regeneration in theory, but it can also promote extrinsic and intrinsic muscle degeneration in the foot, ligament sprains, and increased strain on the plantar fascia in extreme cases. Increased fat mass can lead to an increase in proinflammatory adipocytes, which inhibits the ability of injured muscle cells, tendons, and ligaments to regenerate (Abate, 2014; Kotja et al., 2020). An increase in adipocytes in the midfoot area is linked to an increase in fat mass (Wearing et al., 2004).

In a comprehensive review study, Franceschi and colleagues (2014) discovered that obesity raises the risk of tendon degeneration in general. In an adult population with early symptoms of posterior tibial tendon damage, Chung and colleagues (2010) discovered a rise in body mass index. In a cross-sectional investigation, Frey and Zomora (2007) discovered a strong link between overweight and obesity and an increased risk of Achilles tendon, tibialis posterior, and peroneal tendon degeneration. Balen and Helms (2001) discovered that an MRI sprain ligament spring was present in 92 percent of cases of posterior tibial tendon impairment. The occurrence of pes planus is also linked to the degeneration of the intrinsic muscles of the foot (Shree et al., 2018). Intrinsic muscle strengthening exercises, according to Unver and colleagues (2019), can improve the creation of the arch of the foot. Increased plantar pressure, notably in the 2nd and 3rd metatarsal areas and the calcaneus, coincides with an increase in BMI, stretching the plantar fascia structure related to that location (Hills et al., 2002). Pes planus is caused by the failure of the tissues that make up the arch of the foot, as well as the intrinsic and extrinsic muscles of the foot, the ligamentum spring, and the plantar fascia (Kirby et al., 2017).

2. Relationship between Type of Weight Bearing Activity and Pes Planus

The aim of this research is to see if there's a relationship between the type of weight-bearing activity and pes planus in adult athletes. The findings of this study revealed an inconsequential link between the type of weight bearing activity and pes planus in adult athletes, both on the left and right foot; however, the high impact sport type of weight bearing exercise was associated with a higher risk of pes planus. Increased weight-bearing exercise can result in mechanical overloading of the musculoskeletal components of the lower extremities, which can lead to injury, particularly in the feet. Pes planus is a condition caused by injury to the structures that make up the arch of the foot (Kirby et al., 2017).

Setiawati and colleagues (2021) discovered a link between pes planus and posterior tibial tendon dysfunction in athletes, with weightlifters having the highest frequency (high impact sports). Pes planus is linked to a weakness of the intrinsic muscles of the foot, according to a study by Boon and Harper (2003). In a literature review study, Burge and colleagues (2012) discovered that athletes who participate in high-impact sports exhibit radiographic signs of injuries to the spring ligament, posterior tibial tendon, tarsometarsal joint, and stress fractures of the tarsal and metatarsal bones. According to Murphy and colleagues (2013) and Bolga and Malone (2004), athletes who participate in high-impact sports have a higher risk of injury. Plantar fasciitis was reported to be common among athletes who participated in high-impact sports, according to Murphy and colleagues (2013) and Bolga and Malone (2004).

Several factors influence the occurrence of pes planus in adult athletes, including the type of weight-bearing activity as well as intrinsic and extrinsic factors found in these athletes. Anatomical factors such as stiffness and weakening of the gastrocnemius, soleus, and intrinsic muscles of the foot, as well as degenerative factors such calcaneal aging, heel pad atrophy, and plantar fascia stiffness, are examples of intrinsic factors. The degree of exercise and the mismatch of footwear worn by athletes during sporting activities are examples of extrinsic influences (Petraglia et al., 2017; Aicele et al., 2018). Several intrinsic and extrinsic factors were not included in the inclusion criteria in this study, which could explain why the association was insignificant; nonetheless, an increase in the type of weight bearing exercise could be a risk factor for pes planus occurrence.

3. Relationship between Beighton and Horan Joint Mobility Index and Pes Planus

The aim of this study is to see if there's a relationship between BHJMI and pes planus in adult athletes. On the left foot, there was a significant link between BHJMI and pes planus, but not on the right foot; however, an increase in BHJMI score may increase the likelihood of developing pes planus. A high score on the Beighton and Horan Joint Mobility Index is linked to generalized joint laxity, which can lead to ligamentous structural injury and other advanced pathologies (Decoster et al., 1999). Sueyoshi and colleagues (2016) discovered that a rising BHJMI score was linked to a higher risk of numerous ankle sprains. In addition, Pasapula and colleagues (2021) discovered a link between ankle injuries and ligament spring laxity.

Pes planus is uncommon in isolated ligament spring rupture cases in general. Orr and Nunley (2013) published six case reports on the occurrence of pes planus caused by the isolation of the ligament spring rupturing. Gerstner and colleagues (2020) discovered that correcting the ligamentum spring and posterior tibialis muscle resulted in a considerable improvement in pes planus. According to Sirlyn (2017), the occurrence of pes planus in adulthood is often linked to posterior tibial tendon failure. Balen and Helms (2001) discovered that an MRI sprain ligament spring was present in 92 percent of cases of posterior tibial tendon impairment. There was a difference in the correlation between BHJMI and pes planus in both foot in this investigation.

The left foot had a strong connection with BHJMI, whereas the right foot did not. Bahamonde and colleagues (2012) discovered that in people who have a dominant right hand, the left foot had more activity than the right foot. According to a literature review study by Semple et al (2009), increased lower extremity activity is linked to posterior tibial tendon impairment. Because the right hand dominance data in this study was higher than the left hand dominance data, it's possible that this is why the BHJMI was substantially related with pes planus of the left foot as compared to the right foot.

Pes planus is a condition in which the structures in the arch of the foot deteriorate. The arch of the foot is made up of both passive and active components that work together to keep the arch in place. In addition to the plantar fascia, the spring ligament is a passive component; yet, sufficient assistance from the active components of both the intrinsic and extrinsic muscles of the foot can keep the arch of the foot in shape (Kirby, 2017). Athletes are people who have a lot of muscle strength, but they also have a higher risk of chronic and recurrent injuries. Barber Foss and colleagues (2009) discovered a link between the BHJMI and an increase in midfoot area load, which was linked to the occurrence of pes planus in adolescent athletes to young adults. There was no information about other arch structures in this study, such as plantar fasciitis or plantar fasciitis, intrinsic and extrinsic muscular strength of the foot, therefore the results of the study, particularly for pes planus of the right foot, could not be greatly influenced.

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LIMITATION

Since this study is a non-reactive study using secondary data, therefore some confounding variables cannot be measured or excluded which might affect the results of the study.

CONCLUSION

A significant correlation has been found between body mass index and pes planus in adult athletes, both right and left foot. However, a significant relationship between BHJMI and pes planus in adult athletes, only on the left foot. In adult athletes, an increase in body mass index, type of weight bearing activity, and BHJMI values is associated with an increased risk of pes planus.

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Not Applicable

Ethics and consents

Ethical clearance was approved by the Ethics Committee of Dr. Soetomo General Hospital, Surabaya, Indonesia (No.0620/LOE/301.4.2/IX/2021) on 28 September 2021.

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