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Relationship between Flat Feet Shape and VO2Max of Pencak Silat Athletes Based On Length of Training

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Abstract

Flat feet can cause a reduction in the foot function resulting in fatigue when walking or running. This condition can result in a suboptimal intensity exercise required to improve VO2Max of Pencak Silat athletes. This study aimed to determine the relationship between the shape of foot and VO2Max based on training duration among Pencak Silat athletes at the provincial level of DKI Jakarta. The study used a cross-sectional design involving 46 athletes selected through a total sampling. The subject criteria for this study included athletes aged 17-24 years, healthy, and had no lower extremities problems. The study utilized footprint test and multistage fitness test instruments. The study found that 27 (58.7%) athletes had a normal foot shape, while 19 (41.3%) had flat feet. There were no differences in age, sex, body mass index, and training duration between the two groups of foot shape ($p > 0.05$). The maximum VO2 value was 45.0 (7.2) ml/kg/min in athletes with normal foot shape and 40.1 (70.5) ml/kg/min in athletes with flat feet. The independent t-test revealed a significant difference in VO2Max between the two groups of foot shapes ($p = 0.028$). The increase of VO2Max was in line with the duration of exercise, but this increase was not significant in subjects with flat feet compared to those with normal foot shape. It concludes that flat feet are negatively associated with VO2Max of athletes. Pencak Silat athletes with flat feet must exert extra effort to enhance their VO2Max, such as interval training and kinesio taping. Further research is recommended to explore the impact of these efforts on improving VO2Max.

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INTRODUCTION

Pencak Silat is a traditional martial art originating from the rich cultural legacy of Indonesia. Presently, Pencak Silat stands as a martial sport that has garnered notable accomplishments, evoking a sense of national pride within the Indonesian population. The acquisition of methods and tactics in Pencak Silat heavily relies on the athlete physical attributes (Sinulingga, 2022).

An essential physiological attribute is a high aerobic capacity, commonly referred to as VO2Max, which enables athletes to withstand prolonged physical exertion without departing to tiredness and facilitates expedited recovery during periods of rest. A suboptimal VO2Max in Pencak Silat athletes can lead to heightened susceptibility to fatigue, ultimately impairing their competitive performance. Hence, enhancing VO2Max holds significant importance in terms of physical performance (Chabibullah et al., 2021).

VO2Max refers to the upper limit of oxygen consumption, measured in milliliters, that an individual may utilize within a span of one minute per kilogram of their body weight. In a broader sense, the maximal oxygen uptake (VO2Max) is influenced by two primary factors, the supply of oxygen to the mitochondria in skeletal muscles through the combined efforts of the circulatory and respiratory systems and the utilization of oxygen by the mitochondria in skeletal muscles (Gifford et al., 2016).

To enhance aerobic capacity, it is imperative for athletes to adhere to an exercise program (MacInnis & Gibala, 2017). Body posture is a significant determinant in the context of training. The maintenance of proper posture contributes to the establishment of a bodily structure that is both symmetrical and balanced, hence facilitating the attainment of stability, balance, strength, endurance, and flexibility. These attributes enable athletes to effectively perform a wide range of physical activities (Supartono, 2015; Wardhani et al., 2020).

Postural abnormalities in soft tissue, obesity, injury, and high impact training like Pencak Silat have been identified as potential factors contributing to the development of flat feet, characterized by a reduction in the medial arch of the foot (arcus pedis), resulting in the sole of the foot nearly or fully contacting the floor and the outward displacement of the heel (Şahin et al., 2022; Wardhani et al., 2020).

Indeed, the lower extremities play a crucial role in human locomotion and serve as a fundamental weight-bearing structure. The structure of the foot arch serves the purpose of shock absorption, body weight transmission, and facilitating forward movement as a lever (Şahin et al., 2022). Flat feet can lead to a diminished lever function of the foot, resulting in increased fatigue during walking or running activities. This particular situation induces discomfort and diminishes the endurance of athletes throughout both their training and competition (Herianto & Aminoto, 2013; Supartono, 2015).

Recent study showed that athletes with flat feet exhibit diminished capacity to regulate foot motions, resulting in compromised balance and reduced leaping proficiency (Şahin et al., 2022). Another study found comparable outcomes in their study, indicating that children between the ages of 12 and 14 with flat feet had inferior physical performance in terms of running speed, jumping ability, and balance compared to children with typical normal foot arches (Sagat et al., 2023). The findings from another study indicated that the players with flat feet exhibited an average VO2Max falling within the moderate group, whereas individuals with normal arches demonstrated an average VO2Max falling within the good category (Ardian, 2018). The study conducted by Fardhany et al. (2014) showed comparable findings that students with flat feet had an average VO2Max that fell within the lower range.

As far as the existing literature is concerned, there is currently a lack of research investigating the potential correlation between flat feet and VO2Max in athletes practicing Pencak Silat. This study holds significance since it aimed to investigate the correlation between flat feet and VO2Max values in Pencak Silat athletes, with a focus on training length.

The outcome of this study is aimed to serve as valuable content for deliberation in the development of coaching and training programs tailored to the specific needs of athletes. By doing so, it is expected that these interventions will contribute to enhancing athlete performance during competitive events, ultimately leading to the attainment of notable accomplishments.

METHODS

This research is quantitative analytical research with a cross-sectional design. The research used data on

the shape of the soles of the feet and VO2Max taken directly at the same time.

Participants

The subjects of this research were Pencak Silat athletes who met the research criteria. The inclusion criteria for participants in this study consisted of Pencak Silat athletes at the Jakarta Province level and were enrolled at Jakarta State University. The participants were between the ages of 17 and 24, in good health, free from any lower extremity complaints or injuries, willing to participate in the research, and able to complete the research questionnaire in its entirety. The research included all 46 athletes involved in the Pencak Silat program at Jakarta State University, constituting a total sampling.

Instrument and Procedure

The assessment of foot sole morphology through the utilization of the footprint test involved dipping the soles of the feet into a container containing ink. Subsequently, the plantar surfaces of the feet were placed upon millimeter block paper in order to generate a representation of the footprints (see Figure 1). The foot size data was inputted into the formula B:(A+B+C). A positive diagnosis of flat feet was determined when the calculated value exceeds 0.26. (Supartono, 2015).

The measurement of VO2Max was conducted by the utilization of the Multistage Fitness Test. The participants of the study were instructed to engage in a running activity back and forth at 20 meters. They were required to synchronize their running pace with the auditory beep test rhythm until they reached their individual threshold, the point they were no longer able to follow the rhythm on level and return. The VO2Max value was determined using the Multistage fitness test norm table according to level and return (Zakiyuddin & Marsudi, 2016).

Procedure

Following the acquisition of Ethical Clearance from the Health Research Ethics Commission of the National Development University "Veteran" Jakarta, bearing the reference number 44/III/2023/KEPK, the researcher proceeded with the process of data collection.

Research subjects were asked to fill out a questionnaire encompassing inquiries regarding self-identity, demographic data, and medical background. Subsequently, the execution of the footprint test entailed the following steps for assessing the morphology of the plantar surfaces: 1) The subject was asked to remove all footwear and cleaned both soles of the feet, 2) The subject placed the soles of both feet on a container containing printing ink, followed by placing both inked feet onto a millimeter-sized block of folio paper, in a manner as they were creating a toe print. 4) After the toe print had dried, measurements were obtained by identifying the midpoint of the heel (referred to as point K) and drawing a direct line to the tip of the second toe (point J). Subsequently, a straight line was drawn tangent to the most anterior point of the foot (point L). Point A referred to the LK line, which was comprised of three distinct segments: the anterior, posterior, and medial portions. Point B represented the central one-third region of the foot, specifically the midfoot area, and point C corresponded to the posterior one-third region, specifically the hindfoot area. The measurement of the subject feet was obtained using a ruler in centimeters and afterwards inserted into the formula B: (A+B+C).

The Multistage Fitness Test, often known as the Bleep Test, was employed as a mean of assessing the subject maximal oxygen uptake (VO2Max) with the subsequent protocol: 1) The participants warmed up before carrying out the test. 2) The examiner instructed the subjects to run to the opposite end of the cone, which was 20 meters away, whenever a "beep" sound was heard. 3) If the study participant reached the designated location prior to the subsequent auditory signal, he or she was instructed to turn back and wait for the "beep" sound to return to the opposite end of the cone. 4) Upon attaining a one-minute interval referred to as level one, comprising of seven shuttles or iterations, the interval between "beep" sounds was reduced, requiring the study subject to run faster to complete the following level. 5) The research participants persisted in exerting maximal effort until they reached a point when they were no longer able to maintain synchronization with the auditory stimulus. If the study subject was unable to run at the audio test speed, the test was terminated under the following conditions: the research participant demonstrated consecutive failures in reaching the cone following the auditory cue. The data were documented based on the subject proficiency and feedback, and an estimation of the VO2Max value (ml/kg/min) was de-

rived using the Multistage Fitness Test norm table.

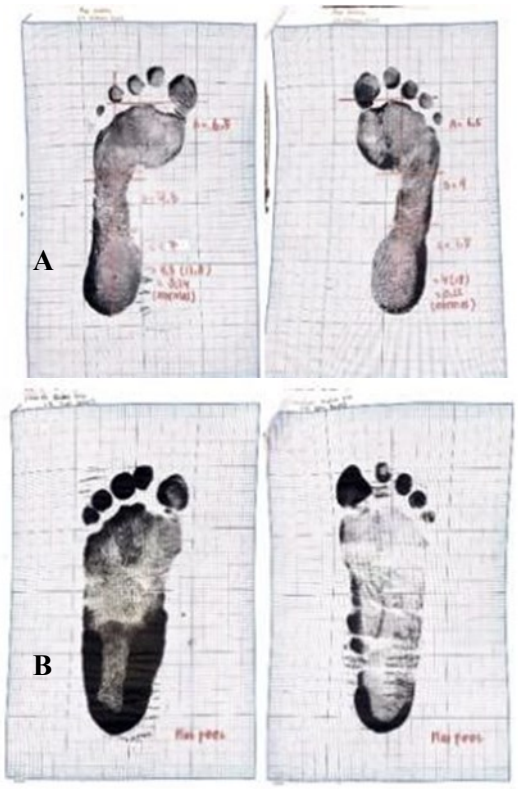

Figure 1. Normal footprint (A) and flat feet (B)

RESULT

The mean age of the research participants was 19 years, female, and the majority exhibited normal foot shapes. There were no differences in age, gender, body mass index, and length of exercise between the normal feet group and the flat feet group ($p > 0.05$) (Table 1).

Table 1. Characteristics of Research Subjects

Characteristic	Foot Shape Normal (n=27)	Foot Shape *Flat Feet* (n=19)	Value *P*
Age (*mean* ± SD)	19,7 ± 1,2	19,6 ± 1,3	0,991[a]
Sex, n (%)			
Male/Man	12 (66,7)	6 (33,3)	0,456[b]
Female/Woman	15 (53,6)	13 (46,4)	
IMT, n (%)			
Normoweight (< 23 kg/m²)	23 (62,2)	14 (37,8)	0,456[b]
Overweight (> 23 kg/m²)	4 (44,4)	5 (55,6)	
Length of Training, n (%)			
1-5 years	7 (58,3)	5 (41,7)	1,000[b]
6-10 years	20 (58,8)	14 (41,2)	

Note: [a]with Mann Whitney test
[b]with Chi-square exact test

Based on the data, it can be inferred that the variables of age, sex, body mass index, and length of training did not exhibit confounding effects on the VO2Max value.

The study revealed that a significant proportion (58.7%) of participants exhibited foot morphologies that were within the usual range. The findings from the independent t-test indicated a statistically significant difference in the mean of VO2Max between the groups with a training duration ranging from 1 to 10 years ($p = 0.028$).

Table 2.Correlation between foot shape and VO2Max

Foot Shape	Mean ± SD	p value
Length of training 1-10 years		
Normal (n = 27)	45,0 ± 7,2	0,028
Flat Feet (n = 19)	40,1 ± 7,5	
Length of training 1-5 years		
Normal (n = 7)	42,6 ± 8,7	0,460
Flat Feet (n = 5)	39,3 ± 5,1	
Length of training 6-10 years		
Normal (n = 20)	45,9 ± 6,6	0,039
Flat Feet (n = 14)	40,3 ± 8,3	

A comparative analytical test was conducted to examine the impact of length of training on VO2Max values in two distinct groups, categorized as 1-5 years and 6-10 years, according to the presence of shared characteristics among the research subjects. The findings of this study indicate that there was no statistically significant difference in the average VO2Max values between the two groups with training period of 1-5 years ($p = 0.460$). Nevertheless, a notable distinction was observed in the average VO2Max value between the two groups undergone a training period of 6-10 years ($p = 0.039$). Specifically, the mean of VO2Max value was recorded as 45.9 ± 6.6 ml/kg/min in the group with normal foot shape, whereas it was 40.3 ± 8.3 ml/kg/min in the group with flat feet (Table 2).

DISCUSSION

The average age of the research subjects was 19 years old. Flat feet spontaneously become normal during the initial decade of childhood. This condition is brought on by infant fat-induced closure of the developing foot arch or because the foot arch is not fully developed (Ueki et al., 2019). Flat feet can progress into adulthood without causing symptoms and are considered physiological unless the person becomes symptomatic (Flores et al., 2019). The transition from adoles-

cence to adulthood can experience a decrease in the arch of the foot due to weak muscles (Chougala et al., 2015).

Age is one of the factors that influences the VO2Max value. Physical inactivity declines with age, potentially leading to a decline in overall fitness. The VO2Max continues to increase in minors until they reach the age of 20 years; it reaches its maximum at the age of 30 years. In addition, VO2Max will decrease with age due to a decline in the function of organs involved in oxygen transportation and utilization (Wulandari, 2023). The Mann-Whitney test yielded no significant difference ($p = 0.991$) in the mean age between the two subject groups. From this study, it can be concluded that age has no effect on the VO2Max value.

The majority of the study participants with flat feet were female. This finding is consistent with studies that indicate women are more likely to have flat feet than men (Kachoosangy et al., 2013). According to additional studies, women are more likely to experience flat feet because of fat buildup that results in the collapse of the medial longitudinal arch (Amir et al., 2021).

The VO2Max value is not necessarily influenced by gender because lifestyle and physical activity are other important factors. Men tend to be more physically active and have larger muscle mass than women, hence they generally have higher VO2Max values (Akbar et al., 2017). According to the results of the Chi-square exact test, there were no gender differences between the groups ($p = 0.566$). It can be concluded that sex did not influence the variations in VO2Max values obtained in this study.

The findings of this study indicate a higher prevalence of flat feet among individuals who are overweight in comparison to those who have a normal weight. Specifically, 37.8% of individuals with a normal weight and 55.6% of individuals who are overweight were found to have flat feet, as presented in Table 1. The findings presented in this study are relevant with previous research, which indicates that individuals who are overweight have a 5.4-fold increased likelihood of developing flat feet in comparison to those who have a normal weight. The accumulation of fat will result in an increase in the body burden. The increase in fat mass is associated with an elevation in both static and dynamic plantar pressure. According to Chougala et al. (2015), an individual with a greater fat mass and weaker muscles will result in a reduction in the arch of the foot, known as the arcus pedis.

The body mass index has the potential to affect the VO2Max value. The greater the BMI, the lower the VO2Max value. The rationale behind this phenomenon lies in the fact that an increase in body fat can impose a greater strain on the cardiorespiratory system, impeding the uptake of oxygen for intracellular metabolism, particularly in the musculoskeletal system. Consequently, the musculoskeletal system may not be able to efficiently acquire oxygen during physical training or competition (Jalili et al., 2018). The findings from the Chi-square exact test indicate that there is no statistically significant variation in BMI across the different foot shape groups in this study ($p = 0.456$). Therefore, it can be concluded that the BMI factor did not have an impact on the observed differences in VO2Max values in this study.

The length of training of this research subjects ranged from 1-10 years. The majority of participants (73.9%) underwent a training period ranging from 6 to 10 years. According to a study conducted by Wardhani et al. (2020), there is a correlation between the duration of training and the prevalence of flat feet among athletes, which can be attributed to excessive flexibility in the foot ligaments. Physical exercise is undertaken with the aim of enhancing productivity and preserving bodily well-being to facilitate optimal muscular functioning in response to various activities. Good posture is a crucial element in the training process. According to Ambarsarie et al. (2016), suboptimal aerobic exercise intensity in athletes with flat feet is associated with suboptimal values of VO2Max. The Chi-square exact test findings indicated that there was no statistically significant difference in the length of training between the participant groups ($p = 1{,}000$) (see Table 1). Hence, it can be ascertained that the variable of training length, ranging from 1 to 10 years, does not exert any apparent impact on the difference observed in VO2Max values within the context of this research.

In this study it was observed that 27 participatns, accounting for 58.7% of the sample, exhibited normal foot shape demonstrating a mean of VO2Max value of 45.0 ± 7.2 ml/kg/min, which falls into the good group. Conversely, those with flat feet displayed a mean of VO2Max value of 40.1 ± 7.5 ml/kg/min, placing them in the moderate category. The findings shown here are

consistent with prior research conducted on soccer players, indicating that those with flat feet exhibit an average VO2Max value falling below the medium range, whereas individuals with normal foot arches have an average VO2Max value falling within the good range (Ardian, 2018). Furthermore, a study conducted by Fardhany et al. (2014) reports that students with flat feet have a significantly lower average of VO2Max.

The results of the independent t-test showed that there was a relationship between the shape of foot soles and the VO2Max value ($p = 0.028$) (Table 2). Research results show that flat feet can have a significant impact on a person ability to engage in various daily activities, such as exercising, standing for extended durations, and walking (Açak, 2020). The relationship between the shape of foot soles and VO2Max is related to the quality of an athlete training in developing physical fitness. Exercises carried out systematically with high intensity has a good impact on increasing VO2Max and improving athlete skills (Mubarok & Ramadhan, 2019). Flat feet might lead to a decrease in the foot lever function, resulting in feelings of exhaustion (Supartono, 2015). This finding aligns with previous research conducted by Djaali et al. (2018), which demonstrates that individuals with flat feet exhibit higher energy expenditure during walking compared to those with a normal foot shape. The results of other studies show that exercise intensity determines mitochondrial biogenesis and increases aerobic capacity (VO2Max) (MacInnis & Gibala, 2017). This is what causes the VO2Max of athletes with flat feet to be less than optimal. A suboptimal VO2Max can result in a decline in the effectiveness of mastered methods and tactics, as it leads to reduced endurance and performance following the duration of the match. This can manifest as diminished power in kicks and punches, ultimately impacting the scoring outcomes of the fight (Patria, 2017).

The anatomical structure, proportions and posture of the athlete body must be considered. The primary requisite for athletes to attain accomplishments in their future training is a commendable state of physical fitness (Supartono, 2015). The capacity to adjust to diverse ground surfaces enables the feet to operate as lever mechanisms that propel the body during physical exertion. Flat feet cause the plantar fascia to become overstretched, increases pressure on the dorsal part of the midfoot, decreases movement of the posterior tibial tendon, and causes muscular stiffness (Herianto & Aminoto, 2013).

The findings of the study indicate exercise intensity plays a significant role in determining the extent of the rise in maximal aerobic capacity, also known as VO2Max. This is associated with central adaptation, which involves an augmentation in blood volume and cardiac output. This is accompanied by peripheral adaptation, characterized by an increase in the number of mitochondria and skeletal muscle capillary density (MacInnis & Gibala, 2017). The increase of cardiac output during aerobic activity leads to an elevation in pulmonary blood flow, hence facilitating enhanced oxygen diffusion through the pulmonary capillary blood flow for subsequent distribution to active muscles. Furthermore, engaging in aerobic exercise leads to an elevation in respiratory rate, so enhancing the intake of oxygen and the elimination of carbon dioxide. The VO2Max value may exhibit a significant increase due to the proper functioning of the circulatory, respiratory, and muscular systems. This maximum aerobic capacity will support the availability of ATP needed so that athletes are more resistant to fatigue (Hall & Hall, 2021; MacInnis & Gibala, 2017).

The restricted mobility experienced by athletes with flat feet leads to suboptimal training intensity, hence hindering the body central and peripheral adaptations. Consequently, athletes with flat feet exhibit lower VO2Max values in comparison to those with a normal foot structure (Kalangi, 2014).

An athlete who has a high VO2Max value does not easily experience fatigue. Consequently, it is imperative for athletes to engage in trainings that focus on enhancing the strength and endurance of their lower limbs in order to augment their VO2Max value (Said et al., 2015). According to Saprian et al. (2022), good physical endurance and muscle strength in Pencak Silat athletes will support enhancing their combat effectiveness against opponents. If an athlete possesses a lower VO2Max capacity, they will encounter challenges in achieving victory during a match. Athletes may experience a depletion of energy throughout the match, leading to a disruption in concentration and the onset of fatigue. Consequently, this might result in a decline in physical performance (Samodra & Mashud, 2021).

The results of the study showed that there was no difference in the mean of VO2Max value in the two

groups following a training period of 1-5 years. In subjects with a training time of 6-10 years, however, there was a difference in the mean of VO2Max value between the subject groups. It demonstrates that the length of training influences the growth in VO2Max values. This study discovered that after 6-10 years of training, the VO2Max value in athletes with normal foot shape was 45.9 ml/kg/min and 40.3 ml/kg/min in athletes with flat feet. It can be concluded that the longer the length of training, the greater the increase in VO2Max value in subjects with normal feet compared to athletes with flat feet. According to Mubarok and Kharisma (2022), engaging in aerobic training programs characterized by moderate to high intensity and prolonged duration might induce muscular adaptations that enable the muscles to withstand intense exertion and heavy loads during both training sessions and competitions. It occurs because, as the duration of the aerobic exercise increases, red muscle develops more dominantly than white muscle, resulting in an increase in muscle O2 consumption and ATP production over a longer period of time to avoid significant fatigue, resulting in an increase in VO2Max values (Bacon et al., 2013). Flat feet lead to a decline in the strength of the plantar flexor muscles, resulting in stiff muscles and diminished postural stability due to excessive mobility of the feet while bearing weight. Consequently, athletes with flat feet experience accelerated fatigue during training sessions and a decrease in endurance during both training and matches (Supartono, 2015). Suboptimal aerobic exercise hinders the proper development of red muscle and impairs the optimal utilization of oxygen by the muscles, resulting in a suboptimal value of VO2Max (Kalangi, 2014).

The limitation of this study is the absence of data regarding spirometry or electrocardiogram examinations to verify the heart and lung function of the research participants. Additionally, more precise assessments such as radiography (bone scan) to evaluate the arch of the foot (arcus pedis) and laboratory test method (treadmill) to determine the VO2 max value are not available to support the findings. Suggestions for further investigation encompass the comprehensive evaluation of cardiac performance, pulmonary capacity, and muscle strength, with the aim of enhancing the overall validity and reliability of research outcomes.

The implication of the research results suggests that Pencak Silat athletes who have flat feet can still pursue their athletic career. However, it is recommended that they engage in certain practices, including longer warm-up and cool-down periods compared to athletes with typical normal foot arches, incorporating interval training into their training regimen, and engaging in high-intensity aerobic exercises. Athletes with flat feet typically undergo an extended training period in comparison to those with a normal foot shape. Flat feet athletes are expected to be disciplined in training in order to achieve optimal VO2Max values. An additional recommendation involves the utilization of kinesio tape on the posterior tibial region during activities or exercises that target the mitigation of foot eversion. This intervention aims to facilitate the realignment and balance of the foot, thus enhancing overall body posture.

CONCLUSION

In conclusion, it can be inferred that there is a correlation between the morphology of the plantar surface of the feet and the maximal oxygen consumption (VO2Max) value. The length of training does not significantly enhance the VO2Max value in athletes with flat feet in comparison to athletes with typical normal feet. To clarify, it can be stated that flat feet exert an adverse impact on the attainment of optimal VO2Max levels among Pencak Silat athletes.

The findings of this study suggest that Pencak Silat athletes who have flat feet should undertake extra efforts to enhance their VO2Max performance. These measures include extending the duration of warm-up and cool-down periods during training sessions, incorporating interval training into their regimen, and utilizing kinesio taping techniques.

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