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The Relationship of Body Composition and Sleep Quality with VO_2max in Adolescent Athletes at Sidoarjo Sports High School and Sewon 1 High School

Hubungan Komposisi Tubuh dan Kualitas Tidur dengan VO_2max pada Atlet Remaja di SMAN Olahraga Sidoarjo dan SMAN 1 Sewon

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ABSTRACT

Background: Body composition and sleep quality are body components that need to be considered in adolescent athletes. Both components can affect the level of maximum oxygen volume (VO_2max) and become factors in increasing physical performance in adolescent athletes.
Objectives: To determine the relationship between body composition and sleep quality with VO_2max in adolescent athletes at Sidoarjo Sports High School and Sewon 1 High School.
Methods: This cross-sectional study was conducted with 106 athletes selected by purposive sampling. Quantitative data were obtained using Bioelectrical Impedance Analysis (BIA), the Pittsburgh Sleep Quality Index (PSQI) questionnaire, and the Multistage Fitness Test. The statistical tests used were the Pearson Product Moment and Spearman Rank.
Results: There was a significant negative relationship between the percentage of fat mass and VO_2max in both combined subjects (r=-0.669, p-value<0.001), male (r=-0.295, p-value=0.026), and female (r=-0.486, p-value<0.001). There was a significant positive relationship between the percentage of muscle mass and VO_2max both with combined subjects (r=0.628, p-value<0.001) and women (r=0.492, p-value<0.001). There was no significant relationship between sleep quality and VO_2max but there was a relationship in the components of sleep quality, namely subjective sleep quality (r=-0.34, p-value=0.01) and sleep efficiency (r=-0.29, p-value=0.03) with VO_2max in female athletes.
Conclusions: Adolescent athletes with a low percentage of fat mass tend to have high VO_2max, while adolescent athletes with a low percentage of muscle mass tend to also have low VO_2max. There was no significant relationship between sleep quality and VO_2max.

INTRODUCTION

Young athletes are the future of the nation in sports and have numerous opportunities to achieve success at both regional and international levels. Indonesia's level of achievement in the field of sports still needs to be improved in terms of coaching and training patterns[1]. One essential component an athlete must possess is good cardiorespiratory endurance, measured by maximal oxygen volume (VO_2max)—an indicator of the body's maximum capacity to absorb oxygen through the lungs, cardiovascular system, and muscles within one minute[2,3]. VO_2max plays an important role in determining an athlete's performance during a match and serves as an indicator of the effectiveness of aerobic exercise and how efficiently oxygen from the air is supplied to the muscles. Another factor that affects VO_2max is body composition, which includes the proportion of fat and fat-free mass[4,5]. Athletes with higher muscle mass tend to have higher VO_2max during aerobic exercise compared to those with more body fat[4]. A comparison of VO_2 levels during submaximal efforts between male bodybuilders (%body fat=8%) and non-athletes (%body fat=24%)—both groups having the same body weight—showed that bodybuilders exhibited significantly higher VO_2 during motor tasks[6]. Body composition measurements are better focused on muscle mass rather than adiposity or body fat[7]. Athletes with a higher Body Mass Index (BMI) do not necessarily have more body fat, because a high BMI can also be caused by large muscle mass[4].

After competing, athletes need to pay attention to physical and mental recovery, including good sleep quality, to improve performance and recovery processes[8–10]. Sleep duration of less than 8 hours can increase the risk of injury in adolescent athletes.

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Research shows that sports teams with longer sleep duration tend to achieve higher rankings[11]. Good sleep quality is also associated with higher VO_2max and better athlete performance. Other studies indicated that better sleep quality was associated with improved performance, as evidenced by higher maximum power output (Wmax) and maximal oxygen uptake (VO_2max) as well as a lower maximal heart rate (HRmax)[12]. Endurance training aimed at increasing VO_2max is utilized in various sports including basketball, soccer, running, and combat sports, because it enhances cardiorespiratory efficiency[8,13]. Accordingly, this study aimed to determine the relationship between %fat mass, %muscle mass, and sleep quality with VO_2max values in adolescent athletes at Sidoarjo Sports High School and Sewon 1 High School.

METHODS

Study Design and Participants

This cross-sectional study involved a total of 106 athletes from various sports in selected schools using purposive sampling. This study was conducted on adolescent athletes from various sports disciplines in high schools that offer specialized sports programs aimed at developing high-performing athletes alongside general education. Both schools, Sidoarjo Sports High School and Sewon 1 High School, have achieved numerous national and international sports achievements. The inclusion criteria in this study were: all athletes of any sports who completed all data collection, aged 15-18 years, and physically and mentally fit. Participants who smoke, consume alcohol, follow any specific diet program, and were absent during data collection were excluded. The research protocol was approved on December 4, 2023, by the Ethics Committee of the Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada (Ethics No. KE/FK/1894/EC/2024).

Data Collection

Primary data were collected on sleep quality, body composition, and VO_2max. Bioelectrical Impedance Analysis (BIA) was used to measure the percentage of fat mass and the percentage of muscle mass. After taking these measurements, athletes were categorized based on their body fat percentage and muscle mass. For women, body fat mass is classified as follows: < 20% = low, 20-30% = normal, 30-35% = high, and >35% = very high. For men, the cut-offs are: <10% is low, 10-20% = normal, 20-25% = high, and >25% = very high. Meanwhile, women's muscle mass is categorized as: <24.3% = low, 24.3-30.3% = normal, 30.4-35.3% = high, and >35.4% = very high. For men, muscle mass is categorized as: <33.3% = low, 33.3%-39.3% = normal, 39.4%-44.0%, and >44.1% = very high[8].

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI) questionnaire, which is a self-rated tool. Respondents were asked to honestly report their sleep habits over the past 15 days. The PSQI includes seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component was scored on a scale from 0 to 3, where 0 indicated no difficulty sleeping and 3 represented the highest level of dysfunction. The scores for each component were summed to yield a total score that ranged from 0 to 21. Athletes were considered to have good sleep quality if their total score was less than 5, while a score greater than 5 indicated poor sleep quality. This questionnaire was adapted into Indonesian and contained 19 valid items, with a reliability coefficient (α) of 0.914[14].

VO_2max value was estimated from Multi-Stage Fitness Test results using a conversion table. During the Multistage Fitness Test, the participants run back and forth on a 20-meter track, following a pace set by a pre-recorded audio. The estimated VO_2max values are categorized from very poor to superior. For women, the categories were: <25.0 = very poor, 25.0-30.9 = poor, 31.0-34.9 = fair, 35.0-38.9 = good, 39.0-41.9 = very good, and >41.9 = superior. For men, the categories are: <35.0 = very poor, 35.0-38.3 = poor, 38.4-45.1 = fair, 45.2-50.9 = good, 51.0-55.9 = very good, and > 55.9 is superior[15].

Data Analysis

The complete data were collected and compiled in Excel, then checked, cleaned, coded, and analyzed. Data were presented as means, standard deviations (SD), and frequency tables. The data analysis involved statistical association tests to examine the relationship between body composition, sleep quality, and VO_2max. Normality tests were conducted on all variables before analysis. For normally distributed data, the Pearson correlation test was used, while the Spearman Rank correlation test was applied to non-normally distributed data. All statistical analyses were conducted using SPSS version 25 (IBM Corp., Chicago, USA), with the level of significance set at p-value<0.05.

RESULTS AND DISCUSSIONS

This study aimed to determine the relationship between body composition and sleep quality with VO_2max values in adolescent athletes at Sidoarjo Sports High School and Sewon 1 High School. The study found that body composition in terms of both %fat mass and %muscle mass had a relationship with VO_2max in boys, girls, and both groups combined, except for %muscle mass in boy athletes. Meanwhile, there was generally no relationship between sleep quality and VO_2max in boys, girls, or both groups combined. However, a relationship was found between specific components of sleep quality, including subjective sleep quality and sleep efficiency with VO_2max in girl athletes.

Characteristics of Participants

A total of 106 athletes participated in this study. Table 1 shows the distribution of athletes based on sex, age, and types of sports. In this study, most of participants were boys (53.7%), aged 16 and 17 years (37.8% each). The highest number of participants came from *sepak takraw* (11.3%) followed by *pencak silat* (10.4%) and athletics (9.4%).

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Table 1. Distributions of participants

Characteristics of Respondents	n	%
Sex		
Girls	49	46.3
Boys	57	53.7
Age		
15 years	13	12.3
16 years	39	37.8
17 years	39	37.8
18 years	15	14.1
Type of Sports		
Athletics	10	9.4
Volley	8	7.5
Swimming	9	8.5
Diving	6	5.7
Roller Skating	3	2.8
Sepak Takraw	12	11.3
Pencak Silat	11	10.4
Fencing	7	6.6
Karate	8	7.5
Judo	4	3.7
Taekwondo	6	5.6
Rock Climbing	5	4.7
Basketball	3	2.8
Football	1	1
Cycling	2	2.8
Table Tennis	8	7.5
Tennis Court	2	1.8
Total	106	100

Pencak Silat, martial arts*; Sepak Takraw,* volley football*.*

Table 2 presents the average age of the participants and component variables, including the percentage of fat mass, percentage of muscle mass, sleep quality, and VO_2max. The average age of participants was 16.5 years old and %fat mass was higher in girls (22.7%) than in boys (9.2%), while the percentage of muscle mass was higher in boys (37.4%) than in girls (28.4%). Sleep quality in all subjects had a poor average (Score >5). In terms of VO_2max, boys had a higher level (50.6) compared to girls (39.9).

Table 2. Average of age, body composition, sleep quality, and VO_2max

Variable	Mean ± SD		
	Combine (n = 106)	Boys (n = 57)	Girls (n= 49)
Age (year)	16.5 ± 0.88	16.3 ± 0.89	16.7 ± 0.83
%Fat mass	15.4 ± 7.5	9.2 ± 2.4	22.7 ± 4.0
%Muscle mass	33.2 ± 4.9	37.4 ± 2.1	28.4 ± 2.0
Sleep quality	7.3 ± 3.2	7.2 ± 2.9	7.5 ± 3.6
VO_2max	45.6 ± 9.1	50.6 ± 7.4	39.9 ± 7.2

n: frequencies, SD: standard deviation, VO_2max: maximal oxygen volume.

Distribution of Body Composition Differentiated by Sex

Table 3 describes the distribution of body composition, specifically the percentages of fat mass and muscle mass, based on sex, including both combined data and separate data for boys and girls. Most athletes had %fat mass within the normal (48.1%) or low (51.9%) categories, with boys (70.2%) having a lower %fat mass compared to girls (28.6%). Boys generally have a lower percentage of body fat due to factors such as gender and physical activity. Boys typically have lower fat mass and higher lean muscle mass compared to girls[16]. Boys tend to build more muscle, while girls accumulate more fat. Additionally, high physical activity levels in men often result in reduced body fat, which is replaced by increased muscle mass[5]. For athletes, maintaining a normal body fat percentage supports efficient movement, helps regulate body temperature, and delays fatigue[17].

In terms of muscle mass percentage, boys (86%) had a %muscle mass that was not significantly different from girls (77.6%), with both groups being largely within the normal category. Adolescent athletes experience a greater increase in muscle mass compared to individuals in other age groups. For adolescent athletes, high-intensity strength training can significantly enhance musculoskeletal outcomes and improve metabolism, particularly in girls. The peak in muscle strength usually coincides with the peak in muscle mass, occurring approximately 12 months apart[18].

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Table 3. Distribution of body composition differentiated by sex

Variable	Category	n	%
%Fat mass			
Combine (n = 106)	Very high	0	0
	High	1	1
	Normal	51	48.1
	Low	54	51.9
Boys (n = 57)	Very high	0	0
	High	0	0
	Normal	17	29.8
	Low	40	70.2
Girls (n = 49)	Very high	0	0
	High	1	2
	Normal	34	69.4
	Low	14	28.6
%Muscle mass			
Combine (n = 106)	Very high	0	0
	High	16	15.1
	Normal	87	82
	Low	3	2.6
Boys (n = 57)	Very high	0	0
	High	6	10.5
	Normal	49	86
	Low	2	3.5
Girls (n = 49)	Very high	0	0
	High	10	20.4
	Normal	38	77.6
	Low	1	2

Distribution of Sleep Quality Differentiated by Sex

Table 4 describes the distribution of sleep quality, based on sex including both combined data and separate data for boys and girls. From these results, boy athletes (70.2%) had worse sleep quality than girl athletes (61.2%). Overall, 70 research subjects (66%) had poor sleep quality. When examining the sleep quality component of the PSQI questionnaire, 88 out of 106 subjects (83%) had never used sleeping pills. Additionally, over 70% of the study subjects had very good sleep efficiency, and this was evenly distributed between boys and girls. In terms of sleep duration, 43 out of 106 subjects (40.6%) had very poor sleep duration, though the results were fairly close since 39 subjects (36.9%) had good sleep duration. Regarding sleep disorders, half of the study subjects (50%) did not experience any sleep disorders.

Table 4. Distributions of sleep quality differentiated by sex

Variable	Category	n	%
Sleep Quality			
Combined (n = 106)	Good	36	34
	Bad	70	66
Boys (n = 57)	Good	17	29.8
	Bad	40	70.2
Girls (n = 49)	Good	19	38.8
	Bad	30	61.2
Sleep Quality			
Combined (n = 106)	Very good	18	17
	Good	67	63.2
	Bad	20	18.9
	Very bad	1	0.9
Boys (n = 57)	Very good	11	19.3
	Good	32	56.1
	Bad	13	22.8
	Very bad	1	1.8
Girls (n = 49)	Very good	7	14.3
	Good	35	71.4
	Bad	7	14.3
	Very bad	0	0
Sleep Latency			
Combined (n = 106)	Very good	19	17.9

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Variable	Category	n	%
	Good	42	39.6
	Bad	36	34
	Very bad	9	8.5
Boys (n = 57)	Very good	12	21.1
	Good	21	36.8
	Bad	21	36.8
	Very bad	3	5.3
Girls (n = 49)	Very good	7	14.3
	Good	21	42.9
	Bad	15	30.6
	Very bad	6	12.2
Sleep Duration			
Combined (n = 106)	Very good	23	21.7
	Good	39	36.8
	Poor	1	0.9
	Very poor	43	40.6
Boys (n = 57)	Very good	14	24.6
	Good	17	29.8
	Poor	0	0
	Very poor	26	45.6
Girls (n = 49)	Very good	9	18.4
	Good	22	38.6
	Poor	1	2
	Very poor	17	34.7
Sleep efficiency			
Combined (n = 106)	Very good	77	72.6
	Good	11	10.4
	Bad	7	6.6
	Very bad	11	10.4
Boys (n = 57)	Very good	42	73.7
	Good	6	10.5
	Bad	4	7
	Very bad	5	8.8
Girls (n = 49)	Very good	35	71.4
	Good	5	10.2
	Bad	3	6.1
	Very bad	6	12.2
Sleep disturbances			
Combined (n = 106)	Very good	0	72.6
	Good	53	10.4
	Bad	47	6.6
	Very bad	6	10.4
Boys (n = 57)	Very good	0	73.7
	Good	31	10.5
	Bad	25	7
	Very bad	1	8.8
Girls (n = 49)	Very good	0	71.4
	Good	22	10.2
	Bad	22	6.1
	Very bad	5	12.2
Use of sleep medications			
Combined (n = 106)	Never	88	83
	<1x	8	7.5
	2-3x	6	5.7
	>3x	4	3.8
Boys (n = 57)	Never	47	82.5
	<1x	5	8.8
	2-3x	4	7
	>3x	1	1.8
Girls (n = 49)	Never	41	71.9
	<1x	3	5.3
	2-3x	2	3.5

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Variable	Category	n	%
	>3x	3	5.3
Daytime dysfunction			
Combined (n = 106)	Very good	34	32.1
	Good	44	41.5
	Bad	25	23.6
	Very bad	3	2.8
Boys (n = 57)	Very good	19	33.3
	Good	24	42.1
	Bad	13	22.8
	Very bad	1	1.8
Girls (n = 49)	Very good	15	30.6
	Good	20	40.8
	Bad	12	24.5
	Very bad	2	4.1

Many factors caused poor sleep quality in the research subjects. Previous research identified two main factors influencing sleep quality in adolescents: intrinsic and extrinsic factors[19]. Intrinsic factors include stress, excessive worry, nervousness, and tension. Worry and nervousness, in particular, significantly contribute to cognitive arousal before bedtime, which can lead to sleep disorders. A study on Australian elite swimmers found that sleep duration decreased to an average of 5.4 hours during competition periods and intense training, while rest days showed an average of 7.1 hours of sleep[20]. Extrinsic factors impacting sleep quality include food and drink intake (especially caffeine), body temperature, exercise intensity, and external pressures, such as family commitments, coaching demands, and balancing academic and social life[19]. Additionally, insufficient sleep duration, prolonged sleep latency, and low sleep efficiency are among the most significant contributors to poor sleep quality. Adolescents often experience better sleep quality when they are under parental supervision or living with their parents[21]. In this study, most participants lived in school dormitories, away from their parents, and lacked direct supervision over their sleep schedules, which may contribute to poor sleep quality.

Distributions of VO_2max differentiated by sex

Table 5 described the distribution of VO_2max based on sex, including both combined data and separate data for boys and girls. The results showed that the combined data were predominantly in the superior category, with 32 subjects (30.2%) falling into this range. When examined by sex, 14 boys (24.6%) and 18 girls (36.7%) had superior VO_2max results. In contrast, only 1 boy (1.8%) and 2 girls (4.1%) had VO_2max results in the very poor category. Various factors can influence VO_2max, including gender, type of sport, training patterns, and others. Sports research found that male athletes generally have higher VO_2max levels than female athletes[22].

Table 5. Distributions of VO_2max differentiated by sex

Variable	Category	n	%
VO_2max			
Combine (n = 106)	Superior	32	30.2
	Very good	24	22.6
	Good	25	23.6
	Enough	16	15.1
	Poor	6	5.7
	Very poor	3	2.8
Boys (n = 57)	Superior	14	24.6
	Very good	17	29.8
	Good	12	21.1
	Enough	10	17.5
	Poor	3	5.3
	Very poor	1	1.8
Girls (n = 49)	Superior	18	36.7
	Very good	7	14.3
	Good	13	26.5
	Enough	6	12.3
	Poor	3	6.1
	Very poor	2	4.1
Sleep Quality			
Combine (n = 106)	Very good	18	17
	Good	67	63.2
	Bad	20	18.9
	Very bad	1	0.9

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Variable	Category	n	%
Boys (n = 57)	Very good	11	19.3
	Good	32	56.1
	Bad	13	22.8
	Very bad	1	1.8
Girls (n = 49)	Very good	7	14.3
	Good	35	71.4
	Bad	7	14.3
	Very bad	0	0

Correlation of Variables

Table 6 presents the results of the association between body composition (%fat mass and %muscle mass) and sleep quality with VO_2max. A significant relationship was found between all percentages of fat mass and muscle mass with VO_2max, except for the percentage of muscle mass in boy athletes. A significant relationship (p-value<0.05) was observed in all body composition variables, including both %fat mass and %muscle mass with VO_2max, whether analyzed by sex separately or combined except for %muscle mass in men (Table 6). The relationship between %fat mass and VO_2max was negative, whereas the relationship between %muscle mass and VO_2max was positive. These results mean that as %fat mass increases, VO_2max tends to decrease, while as %muscle mass increases, VO_2max tends to increase. In %fat mass, similar results were found in previous studies on football and judo athletes showing that the %fat mass was significantly negatively related (p-value<0.05) to VO_2max values[23]. These results were supported by other studies, which indicated that individuals who were obese or had a high percentage of fat mass experienced difficulties in their muscles absorbing adequate oxygen, leading to reduced aerobic capacity as reflected by lower VO_2max values[24]. An athlete typically had a lower percentage of fat mass and a higher VO_2max or aerobic capacity compared to a non-athlete, as a lower fat mass and higher aerobic capacity effectively determined the athlete's endurance, thereby enhancing performance during training and competitions[25]. An athlete with greater endurance was likely to have more power during matches, increasing the chances of winning. In terms of sex, boys generally had higher aerobic capacity (VO_2max) than girls, due to lower fat mass in boys, which facilitated better oxygen regulation to active muscles, along with factors related to heart size and oxygen transport capacity, such as HRmax[18,26]. Adolescent athletes typically experience a more significant increase in muscle mass compared to other age groups, with males start to gain muscle earlier, around age 13, compared to females at age 15. This difference is attributed to androgenic effects, which are hormones that promote male characteristics[18]. Men generally have a lower percentage of body fat due to factors such as sex and physical activity. Sex differences often lead to variations in body composition, with men typically having less body fat and higher lean muscle mass compared to women. Additionally, high levels of physical activity in men can result in reduced body fat and increased muscle mass[5]. Therefore, an athlete needs to have a lower percentage of body fat mass than a non-athlete so that there is no accumulation of fat which can increase endurance for high intensity sports.

Meanwhile, there was a significant positive relationship (p-value<0.001) between the percentage of muscle mass and VO_2max in both combined groups of athletes and in girls, while no such relationship (p-value>0.05) was found in boys. In sports, athletes typically have greater muscle mass due to the higher intensity of their physical training compared to non-athletes. Therefore, the percentage of muscle mass in athletes should be higher than in non-athletes. Previous studies have shown that male sprinters in Poland had an average muscle mass percentage of 47.4%[27] while female volleyball players from the 2016 Rio Olympics had an average skeletal muscle mass of 48.95%[28] and male volleyball players had an average of 53.31%[29]. Additionally, exercise patterns are crucial for muscle development. When muscle mass is exposed to higher intensity training, it consumes more oxygen, which increases the percentage of muscle mass, leading to greater oxygen uptake and a higher VO_2max[26]. Thus, a high percentage of muscle mass in athletes is crucial for achieving a high VO_2max.

In boys, there was no significant relationship (p-value>0.05) between muscle mass percentage and VO_2max. Several factors may have contributed to the lack of this relationship, including data distribution, training factors, and the types of sports. The data for muscle mass percentage were not normally distributed and showed relatively narrow variance. Additionally, differences in training frequency and routines among various sports could have influenced the results. The study did not account for the specific types of sports played by the subjects, which could affect the relationship between muscle mass percentage and VO_2max. The types of sports might have contributed to the lack of correlation between muscle mass percentage and VO_2max, because the sport could have influenced the outcomes of the endurance test or VO_2max, as well as the percentage of muscle mass. For example, endurance sports typically result in higher VO_2max, while weightlifting is associated with higher muscle mass percentages.

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Table 6. The correlation of %fat mass, %muscle mass, sleep quality, and component of sleep quality with VO_2max

Variable	Category	VO_2max	
		r	p-value
%Fat Mass	Combined (n = 106)	-0.669	<0.001[b]
	Boys (n= 57)	-0.295	0.026 [a]
	Girls (n = 49)	-0.486	<0.001[a]
%Muscle Mass	Combined (n = 106)	0.628	<0.001[b]
	Boys (n = 57)	0.236	0.077 [b]
	Girls (n = 49)	0.492	<0.001[a]
Sleep Quality	Combined (n = 106)	-0.121	0.216 [b]
	Boys (n = 57)	-0.095	0.483[b]
	Girls (n = 49)	-0.227	0.118 [b]

[a]Pearson correlation test, significant if p-value<0.05.
[b]Spearman correlation test, significant if p-value<0.05.

Regarding sleep quality, no significant relationship was observed except for the components of sleep quality, namely subjective sleep quality and sleep efficiency, with VO_2max in female athletes. The sleep quality of all research subjects, both when combined and differentiated by gender, did not show a significant relationship (p-value>0.05) with VO_2max levels. Research conducted on 12 taekwondo athletes revealed a similar finding, that there was no relationship between sleep quality, especially sleep efficiency, and physical performance results[30]. Several factors may contribute to the absence of a significant relationship between the two variables, particularly those that were not measurable by the instruments used in this study, such as lifestyle, environmental factors, food intake, and health conditions. Additionally, the impact of the data's normality test results, where the sleep quality variable was not normally distributed, could also be a factor since there was no consistent pattern between sleep quality and VO_2max. The differing outcomes for each variable, such as poor sleep quality and good VO_2max, could also play a role in the lack of a relationship between them. However, the findings of this study contradict those of other research, such as a study involving 100 teenage soccer athletes, which found a significant relationship (p-value<0.05) between sleep quality and VO_2max values[31].

Table 7. The correlation of component of sleep quality with VO_2max

Variable	Category	VO_2max	
		r	p-value
Subjective sleep quality	Combined (n = 106)	-0.13	0.15
	Boys (n = 57)	-0.12	0.35
	Girls (n = 49)	-0.34	0.01 [b]
Sleep latency	Combined (n = 106)	-0.06	0.50
	Boys (n = 57)	0.12	0.36
	Girls (n = 49)	-0.23	0.10
Sleep duration	Combined (n = 106)	-0.00	0.96
	Boys (n = 57)	0.00	0.96
	Girls (n = 49)	-0.14	0.31
Sleep efficiency	Combined (n = 106)	-0.15	0.11
	Boys (n = 57)	-0.12	0.45
	Girls (n = 49)	-0.29	0.03 [b]
Sleep disturbances	Combined (n = 106)	-0.03	0.71
	Boys (n = 57)	-0.10	0.45
	Girls (n = 49)	0.24	0.09
Use of sleep medication	Combined (n = 106)	-0.10	0.29
	Boys (n = 57)	-0.14	0.29
	Girls (n = 49)	-0.13	0.35
Daytime dysfunction	Combined (n = 106)	-0.11	0.23
	Boys (n = 57)	-0.16	0.21
	Girls (n = 49)	-0.05	0.72

[a]Pearson correlation test, significant if p-value<0.05.
[b]Spearman correlation test, significant if p-value<0.05.

When analyzing the components of sleep quality, a relationship was identified between certain sleep quality components—specifically subjective sleep quality and sleep efficiency—with VO_2max in girl athletes. For subjective sleep quality, it was found that the better the subjective sleep quality, the higher the VO_2max results. This finding aligns with a previous study where 13 weeks of high-dose aerobic training improved sleep duration and tended to enhance subjective sleep quality in sedentary boys[32]. Regarding sleep efficiency, higher sleep efficiency was linked to better VO_2max results. Previous research showed that engaging in High-Intensity Interval

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Training (HIIT) for six months could decrease sleep efficiency scores, which could result in weight loss and reduced waist circumference[33]. Good sleep efficiency is strongly associated with overall health benefits, such as improved cognitive performance, faster muscle recovery, a stronger immune response, and, for athletes, enhanced performance in specific sports[30]. The relationship between subjective sleep quality and VO_2max found only in girl athletes could be explained by the global score of the PSQI questionnaire, which showed that girls generally had better sleep quality than boys. Girls tended to have better sleep quality than boys, as demonstrated by going to bed earlier, experiencing better quality dreams, and maintaining better sleep hygiene, all of which indicated that girls generally had healthier sleep habits. However, previous studies indicated that teenage girls experienced poorer sleep quality or were more frequently disturbed compared to teenage boys[34]. This issue requires further investigation to achieve more accurate results.

These findings can be useful for athletes, coaches, teachers, and other parties involved in sports to help improve performance, especially for adolescent athletes. This research can be developed further with more variables so that other factors that can support athlete performance besides training can be identified. The limitation of this study is that it does not take into account other factors that can affect the results, such as type of training, food intake, or training. Overall, the results indicate that optimizing body composition, including percentage of fat mass and muscle mass, is very important to improve the performance of adolescent athletes.

CONCLUSIONS

Athletes with a low percentage of fat mass tend to have a high VO_2max, while athletes with a low percentage of muscle mass also tend to have a low VO_2max. There was no significant overall correlation between sleep quality and VO_2max; however, specific aspects of sleep quality, such as subjective sleep quality and sleep efficiency, were linked to VO_2max in female athletes. In other words, better subjective sleep quality and sleep efficiency were associated with higher VO_2max levels. Therefore, further optimization of body composition, including fat mass and muscle mass percentages, can be pursued to enhance athlete performance. Additionally, greater attention should be given to improving sleep quality among athletes at both SMAN Olahraga Sidoarjo and SMAN 1 Sewon to promote better rest.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors have no conflict of interest in this article. Funding for this research was obtained independently with the researcher's personal funds and assisted by the lecturer.

AUTHOR CONTRIBUTIONS

FM: conceptualization, formal analysis, project administration, software, methodology, roles/writing-original draft RM: data curation, supervision, validation, methodology, writing-review & editing, funding acquisition, investigation MH: supervision, validation, resources, writing-review & editing, funding acquisition, and investigation.

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