Sarcopenia markers, physical performance and sleep quality among high-risk students

Marcadores de sarcopenia, rendimiento físico y calidad del sueño en estudiantes de alto riesgo

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Abstract

Introduction: Sarcopenia, once primarily associated with the older population, is now also affecting younger population. Early identification of individuals at risk presents a critical opportunity for better prevention. To date, there has been an absence of sarcopenia risk assessments conducted among students in Indonesia, thus rendering the pertinent risk factors largely unexamined.
Objective: This study aimed to compare characteristics, skeletal muscle mass index, muscle strength, physical performance, and sarcopenia risk between students aged 15–25 years with high and low-moderate levels of physical activity.
Methodology: A comparative study was conducted involving 44 matched students, divided into two groups: those with high and those with low-to-moderate physical activity levels. Evaluation encompassed skeletal muscle mass measurement, handgrip strength assessment, sit-to-stand test, sleep quality evaluation, and screening for sarcopenia risk.
Results: Students with higher physical activity levels displayed higher skeletal muscle mass index, greater handgrip strength, and faster sit-to-stand test performance compared to their low-moderate physical activity levels peer. Furthermore, sleep quality was notably better among students in the high level of physical activity group.
Discussion: These findings are consistent with the current academic literature, which accentuates the importance of physical training in preserving muscle mass and enhancing muscle performance. The physiological and psychological changes identified in individuals who engaged in training may be related to the improvement of hormonal responses, including an increase in growth hormone and endorphins.
Conclusions: Engaging in high physical activity may contribute to reduce the risks associated with sarcopenia development. Notably, the incidence of sarcopenia was absent among all individuals who had training.

Keywords

Physical activity; sarcopenia; skeletal muscle mass; students; sleep habits.

Resumen

Introducción: La sarcopenia, antes atribuida principalmente a la población de edad avanzada, afecta cada vez más a la población más joven. La identificación temprana de las personas en riesgo supone una oportunidad fundamental para mejorar la prevención. Hasta la fecha, no se han realizado evaluaciones del riesgo de sarcopenia entre los estudiantes de Indonesia, por lo que los factores de riesgo pertinentes no se han examinado en gran medida.
Objetivo: El objetivo de este estudio fue comparar las características, el índice de masa muscular esquelética, la fuerza muscular, el rendimiento físico y el riesgo de sarcopenia entre estudiantes de entre 15-25 años con un nivel de actividad física alto y bajo-moderado.
Metodología: Se realizó un estudio comparativo en el que participaron 44 estudiantes emparejados, divididos en grupos de actividad física alta y baja-moderada según sus niveles de actividad física. La evaluación abarcó la masa muscular esquelética, la fuerza de prensión manual, la prueba de sentarse y levantarse, la calidad del sueño y la detección del riesgo de sarcopenia.
Resultados: Los estudiantes con un mayor nivel de actividad física mostraron un índice de masa muscular esquelética más alto, una mayor fuerza de prensión manual y un rendimiento más rápido en la prueba de sentarse y levantarse en comparación con sus compañeros con actividad física baja-moderada. Además, la calidad del sueño fue notablemente mejor entre los estudiantes del grupo con alto nivel de actividad física.
Discusión: se deben contrastar los resultados de la investigación con los de otras investigaciones publicadas en la literatura.
Conclusiones: La realización de una actividad física intensa puede contribuir a reducir los riesgos asociados al desarrollo de la sarcopenia. Cabe destacar que la incidencia de sarcopenia fue nula entre todas las personas que realizaban entrenamiento.

Palabras clave

Actividad física; estudiantes; hábitos de sueño; masa muscular esquelética; sarcopenia.

Introduction

Sarcopenia is evolving from being prevalent in older people to younger age groups. Early detection of sarcopenia risk can provide an opportunity for better prevention. The shifting in the prevalence of sarcopenia at a younger age (18–39 years) has been recorded in studies conducted in several countries, namely in Thailand in 2013, the prevalence was 26.4%(Pongchaiyakul et al., 2013), in the United States, in 2018, the rates among non-Hispanic whites were 6.32% and 26.1%(Du et al., 2018) among Hispanics; in China was 11.3–14.9%(Lin & Li, 2021); and in Korea was 8–21%, in 2017 to 30%, in 2022(Bae & Kim, 2017; Park et al., 2022). The prevalence of sarcopenia among Indonesians in 2016 were around 9.1% in men and 7.4% in women, based on AWGS, with the highest prevalence found in the city of Surabaya at 13.9% in men and 27.9% in women (Vitriana et al., 2016). In Surabaya, possible sarcopenia among Indonesians aged 15 – 19 years was 32.4% and among those aged 20 – 23 years was 33.3%(Arisanti et al., 2025).

To this day, sarcopenia risk screening among students in Indonesia has never been done; therefore, the associated risk factors are still unknown. Physical inactivity is believed to be a significant risk factor for sarcopenia. In many countries, the sport participation index peaks at 12-13 years of age and progressively declines starting at 17 years of age. (Eime et al., 2016). More than 80% of adolescents worldwide do not meet the WHO's physical activity recommendations, 74% of adolescents in Southeast Asia are classified as inactive, and 65% of adolescents in Indonesia are inactive (Mutohir et al., 2021, 2023; WHO, 2021). In the post COVID-19 era, there was a significant decrease in the participation index of physical activity among students in Indonesia (Wijaya et al., 2025). During 2022, the participation index of physical activity among Indonesians was only 30,93%. It was lower than a year before (Mutohir T. C. et al., 2022).

Physical training, particularly resistance exercise, is a key non-pharmacological strategy to lower the risk of sarcopenia by enhancing muscle mass, strength, and physical performance (Lu et al., 2021; Papadopoulou et al., 2021; Shen et al., 2023). It stimulates muscle hypertrophy, activates satellite cells, and engages molecular pathways such as mTOR and Hippo-YAP that regulate muscle protein synthesis and mechano-transduction (Dupont et al., 2011). While resistance training is the most effective in promoting muscle growth, combining it with aerobic and functional exercises to improve cardiovascular health, oxidative capacity, and mobility (Bori et al., 2012; Csapo & Alegre, 2016; Jun-Won et al., 2017; Peterson et al., 2011; Yoo et al., 2018). Early and consistent training is crucial for maintaining musculoskeletal function and reducing the risk of muscle loss in at-risk populations.

Students with regular physical training routines, such as athletes, consistently demonstrate superior lifestyle habits compared to their low-moderate physically active peers, including higher physical performance, improved sleep quality, and enhanced dietary habits, all of which contribute to better physical and mental health outcomes (Li & Huang, 2025). In contrast, other students commonly report insufficient physical activity, elevated academic stress, and compromised well-being, with nearly half of university populations failing to meet the recommended activity levels (Donnelly et al., 2024). This study aimed to compare skeletal muscle mass index, muscle strength, physical performance, and sarcopenia risk between students with high versus low-to-moderate levels of physical activity.

Method

Study design

This was a comparative cross-sectional study comparing two groups of students: those with high-level physical activity versus those with low to moderate levels of physical activity. The International Physical Activity Questionnaire (IPAQ), adapted for Indonesians, was used to distinguish between high levels of physical activity and low-to-moderate levels of physical activity in students. Students with an IPAQ score of 3000 METs or higher, were grouped as high level of physical activity. A low-to-moderate level of physical activity was categorized as students who had an IPAQ score of under 3000 METs min/week (Craig, 2003; Dharmansyah & Budiana, 2021; World Health Organization, 2020). Between groups, students

were matched for domicile, age, gender, weight, and height. The skeletal muscle mass index, muscle strength, physical performance test, and risk of sarcopenia were compared between groups.

Participants

Subjects were forty-four matched students, registered from the Surabaya and Malang regions of East Java Province, Indonesia, consisting of 22 high-level physical activity participants and 22 low-to-moderate level of physical activity participants. The inclusion criteria were age 18–22 years old and voluntary participation in the study with informed consent. Exclusion criteria included musculoskeletal limitations, a history of injury, chronic diseases, and menstruation.

Students and parents were provided with an explanation regarding the study objectives, benefits, and procedures, both orally and in writing. All participants voluntarily agreed to participate in the study, having given their informed consent. This study was conducted in accordance with the principles outlined in the Declaration of Helsinki of the World Medical Association. It was approved by the Health Research Ethics Committee, School of Medicine, Universitas Ciputra Surabaya, East Java, Indonesia, under approval number 182/EC/KEPK-FKUC/XI/2024.

Procedure

Subjects were characterized by domicile, age, gender, weight, and height to ensure matching between groups. Each was joining in three sessions of the procedure. In the first session, students completed questionnaires of strength, assistance with walking, rise from a chair, climb stairs, and Falls (SARC-F) to screen for the risk of sarcopenia, as well as the Pittsburgh Sleep Quality Index (PSQI) questionnaire. The second session was measuring skeletal muscle mass index using bioimpedance analyzer tools – BIA (InBody-970). At last, the students performed a test using the handgrip dynamometer to measure muscle strength and completed five sit-to-stand repetitions to assess physical performance. All data were collected and tabulated for statistical analysis.

Instrument

The validity of the instruments used was excellent. The high-frequency (HF) BIA results showed a high correlation with the DEXA results for assessing appendicular lean mass – ALM (standard coefficient beta (β) ≥ 0.95), fat-free mass-FFM (β ≥ 0.98, coefficient of determination (R2) ≥ 0.95), and percentage of body fat – PBF (β ≥ 0.94, R2 ≥ 0.89). Body composition measured by HF-BIA demonstrated good agreement with DEXA in Korean adults (Yi et al., 2022). The IPAQ questionnaire has been tested for validity and reliability in 14 locations across 12 countries, yielding validity and reliability values of 0.30 and 0.80, respectively. It has also been translated into Indonesian, with a test-retest reliability of 0.884. The Indonesian version of the International Physical Activity Questionnaire has been adopted with a good validity and reliability score (Dharmansyah & Budiana, 2021). The reliability of the handgrip dynamometer was excellent (ICC: Smedley = 0.92, $p < 0.001$) (Benton et al., 2022). The reliability data showed that both inter (ICC=0.92, CI95% 0.89–0.94) and intra-rater (ICC=0.95, CI95% 0.93–0.96) reliability for this application of the five times sit-to-stand test with these patients were excellent, according to ICC cut-off values (de-Melo et al., 2023; Koo & Li, 2016).

Data analysis

Characteristics were compared between groups to evaluate matching procedures. The comparison data of age, weight, height, and IPAQ score were presented as mean ± SD. The gender was presented as the frequency of males versus females within each group. A p-value of less than 0.05 indicated a significant difference between groups for a two-tailed test.

An independent t-test was performed to compare skeletal muscle mass index (SMMI), handgrip strength test results, and the five-times sit-to-stand test results between groups. Chi-square test was performed to compare the SARC-F category of sarcopenia risk between groups. A significant difference between groups was indicated by a p-value<0.05.

Results

The subjects participating in this investigation exhibited no significant differences in age, gender, weight, or height parameters. Indifferent data of age, gender, weight, and height were obtained from successfully matching criteria between high-level and low-moderate level of physical activity. The matched criteria resulted in the homogeneity of variances between groups. A salient characteristic that differentiates high-level physical activity participants from those with low-to-moderate level of physical activity is the physical density, as measured by the International Physical Activity Questionnaire (IPAQ).

Subjects were all active individuals, as shown in the results of the IPAQ, with no one having a METs-min/week below 600. Among the high-level physical activity participants, the average physical density was recorded at 7234.41, whereas the average physical density observed in the low-moderate level of physical activity participants was 2576.10. These findings substantiate that participants with a high-level of physical activity possess a physical density exceeding 3000 MET-min/week, categorizing them in the high-level of physical activity. High-level physical activity participants performed a structured activity in a periodization as an athlete does. They had done the activity as a daily routine task to achieve competitiveness in sports (Dharmansyah & Budiana, 2021). A comprehensive delineation of the subjects' characteristics is provided in Table 1.

Table 1. Subject characteristics between groups

Characteristics		Level of physical activity		p (sig.)
		High to ≥3000 METs.min/week	Low -moderate <3000 Mets.min/week	
Gender	(Male)	12	12	1
	(Female)	10	10	
Age (year)		19.54 ± 2.07	20.32 ± 0.84	0.49
Weight (kg)		68.12 ± 16.90	62. 35 ± 17.16	0.13
Height (m)		1.67 ± 9.76	1.66 ± 9.52	0.30
IPAQ (MET-min/week)		7234.41 ± 2883.41	2576.10 ± 2370.80	<0.001

The Skeletal Muscle Mass Index (SMMI) among individuals engaged in a high-level of physical activity was significantly higher than the participants in low-to-moderate level of physical activity. Participants in a high-level of physical activity group also showed higher muscle strength and physical performance. As seen in the Table. 2, the high-level of physical activity participants were stronger than the low-moderate level of physical activity participants. They also need a shorter duration to perform the five-times sit-stand test.

Table 2. Comparison of variables between high physical activity and low-moderate physical activity

Variables	Level of physical activity		p (sig.) *	Effect size (95%CI)
	High to 000 ≥3000 METs.min/week	Low-moderate <3000 Mets.min/week		
SMMI (kg/m2)	7.62 ± 1.51	6.63 ± 1.19	0.01	0.73 (0.11– 1.33)
Handgrip test (kg)	36.65 ± 9.54	30.66 ± 10.54	0.03	0.60 (-0.12 – 1.20)
Five times sit-stand test (sec.)	4.50 ± 0.94	7.96 ± 2.37	<0.01	-1.92 ((-2.63) – (-1.18))

*Independent t-test result.
SMMI: Skeletal Muscle Mass Index;

The comparison results (as shown in Table 2) revealed an impairment in skeletal muscle mass, muscle strength, and performance among participants with low-to-moderate level of physical activity compared to those with high-level of physical activity (Setiati et al., 2025; Setyowati & Chung, 2021). The low-to-moderate level of physical activity proposed had a higher risk of suffering from sarcopenia in the future. The SARC-F questionnaire was used to assess sarcopenia risk among students to confirm the hypothesis. Unfortunately, until now, we have not found any references that have used the SARC-F questionnaire among Indonesian Youth. The SARC-F questionnaire was limited in use among 3 – 20-year-olds diagnosed with carcinoma (Verwaaijen et al., 2023).

Students who engaged in a high-level of physical activity did not exhibit in high-risk category for developing sarcopenia. Conversely, the high-risk category of sarcopenia was found in 20.45% with low-to-

moderate level of physical activity. The comparison of the SARC-F score between groups is shown in Table 3.

Table 3. Comparison of variables between high physical activity and low to moderate physical activity

Variables	Category	Level of physical activity		p (sig.) *	Effect size (95%CI)
		High ≥3000 METs.min/week	Low-to-moderate <3000 Mets.min/week		
PSQI	Good	21(47.7%)	7 (15%)	0.04	0.10 (0.01 – 0.92)
	Poor	1 (2%)	15 (34%)		
SARC-F	Low risk	22 (50%)	13 (29,54%)	0.01	0.37 (0.24 – 0.57)
	High risk	0	9 (20.45%)		

*. Chi-square test

In addition to asses sarcopenia risk, the quality of sleep was also evaluated to investigate the influence of physical activity among students. The Pittsburgh Sleep Quality Index (PSQI) was used to determine the quality of sleep. The results of the PSQI showed that students with a high-level of physical activity have a better quality of sleep compared to those with low-to-moderate level of physical activity. Among the high-level of physical activity students, 47.7% exhibited good quality of sleep, in stark contrast to only 2% who demonstrated poor sleep quality. Analogous findings were observed in the low-moderate levels of physical activity group, where the percentage of individuals with good quality of sleep was only 15% markedly lower than that of those with poor quality of sleep (34%). The comparison of PSQI between groups is seen in Table 3.

As shown in Figure 1. The Skeletal Muscle Mass Index (SMMI) was significantly higher in the normal group (7.50 ± 1.31; p <0.001) compared to the Pre-Sarcopenia group (5.64 ± 0.80; p <0.001). Figure 2 demonstrates that Handgrip Strength in the normal group was markedly greater (36.40 ± 9.54; p <0.001) than in the Pre-Sarcopenia group (22.96 ± 5.60; p <0.001). In Figure 3, participants in the normal group performed the five-times sit-to-stand test faster (5.53 ± 2.13; p<0.001) than those in the Pre-Sarcopenia group (8.95 ± 1.97; p<0.001).

Figure 1. Comparison of mean SMMI in Normal group and Pre-Sarcopenia group.

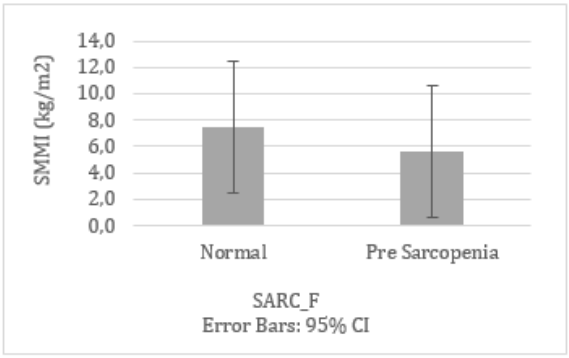


Figure 2. Comparison of mean Handgrip Strength in Normal group and Pre-Sarcopenia group

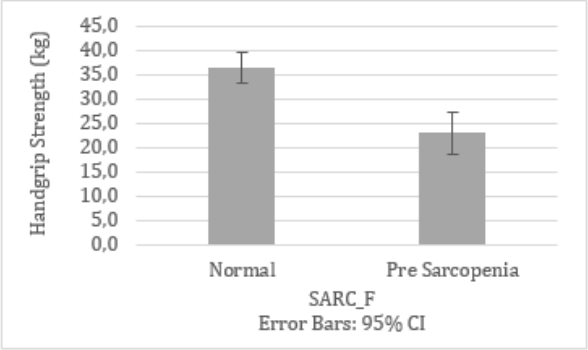
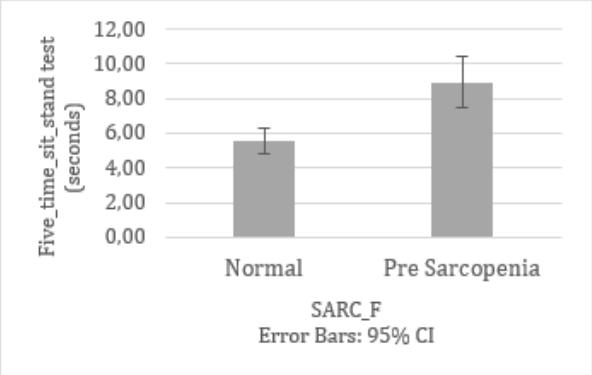


Figure 3. Comparison of mean ± SD Five Times Sit to Stand Test in Normal group and Pre-Sarcopenia group



Discussion

Youth Pre-Sarcopenia among Indonesian students

Sarcopenia is changing from being mainly attributed to the older population to increasingly impacting the younger population. The prevalence of sarcopenia in the 20–39 age group in Korea according to the Korean National Health and Nutrition Examination Survey (K-NHANES) from 2008–2011 was 18–21% and other studies in 2017 and 2022 reported the prevalence of sarcopenia in individuals aged 20–30 years to be 15–25% and 30%, respectively (Bae & Kim, 2017; Park et al., 2022).

The prevalence of sarcopenia among Indonesians in 2016 is around 9.1% in men and 7.4% in women, based on AWGS, with the highest prevalence found in the city of Surabaya at 13.9% in men and 27.9% in women (Vitriana et al., 2016). Our findings in Surabaya showed that possible sarcopenia among Indonesians aged 15 – 19 years was 32.4% and among those aged 20 – 23 years was 33.3% (Arisanti et al., 2025).

High level of physical activity limited the risk of sarcopenia among students.

Student with structured activity higher than 3000 METs/min/week was categorized as a high-level physical activity individual (Dharmansyah, 2021). They had incorporated intense physical exercise into their daily routine to achieve competitiveness in sports, as junior handball athletes. Intense physical exercise elicits a physiologic response more adapted to physical loads in daily activities. It improves skeletal muscle mass, muscle strength, and the ability to perform activities. Our study confirmed that muscle mass, strength, and performance among students with high-level of physical activity were higher than those of students with low-to-moderate levels of physical activity.

Intense physical exercise stimulates surge pulsatile Growth Hormone (GH) secretion into the circulation. The intensity of exercise has a positive correlation with the circulatory level of GH in the blood (Wideman, 2002; Pritzlaff-Roy, 2002). Growth Hormone stimulates anabolic signaling via GH receptor activation at sarcolemma. The anabolic signaling resulted in protein synthesis, satellite cell activation, and myotube fusion. These are important for improving muscle mass, in terms of both size and number of fibers (Sotiropoulos, 2006).

High level of physical activity revealed better quality of sleep

Intense physical exercise also induces endorphin secretion (Bonilla et al., 2024; Saanijoki et al., 2017). Endorphins are peptides produced in the brain that act as natural painkillers and mood boosters. They are released in response to stress, pain, and pleasurable activities, helping to reduce pain and create feelings of well-being. Endorphins are also known to mimic the effects of opioids, like morphine, by binding to opioid receptors in the nervous system. Endorphin helps athlete sleep and relax better than others (Alnawwar et al., 2023). The comparison Table. 3 showed that the high-level physical activity group experienced better sleep quality compared to the low-to-moderate level physical activity group.

Sleep quality is affected by the circadian rhythm, the body's 24-hour internal cycle. It plays a vital role in regulating various physiological processes, including skeletal muscle function. Circadian rhythm disorders affect muscle metabolism, protein synthesis, and overall muscle health. The circadian rhythm is essential to maintain and preserve as we age, because changes in it can disrupt physiological processes, metabolism, and the repair of skeletal muscle cells. If this disruption occurs, it will have a negative impact on protein synthesis and overall muscle health, leading to a higher risk of falls and mortality (Ancoli-Israel & Cooke, 2005; Buchmann et al., 2016; Hirshkowitz et al., 2015; Vitale et al., 2019).

Sleep has an important role in biological processes and mental regeneration. A good sleep is essential for developing muscle mass. Sleep plays a vital role in maintaining the balance between muscle anabolism and catabolism (Alarcón-Rivera et al., 2025). Growth Hormone is mainly secreted during the slow-wave sleep stage. This contributes to maintain the level of basal GH in the blood. Any disturbance during the slow-wave sleep stage increases the risk of muscle mass loss through the decrease of anabolic hormones, such as testosterone and GH (Dattilo et al., 2011; Dáttilo et al., 2020).

Poor sleep quality or lack of sleep also affects muscle physiological processes by causing increased protein degradation, decreased muscle protein synthesis, and muscle atrophy. Sleep disturbances cause a shortening of the REM (Rapid Eye Movement) phase, which can alter the body's hormonal system (HPA axis) to a catabolic state characterized by increased cortisol, decreased testosterone, GH, and IGF-1. These hormonal changes result in disturbances in muscle maintenance and growth (Rubio-Arias et al., 2019). Research on gadgets used and sleep quality among Indonesian high school students in 2021 found that 47% of teenagers are heavy gadget users and 86.4% have poor sleep quality (Kant et al., 1984).

Risk of sarcopenia among students was characterized by low muscle mass, strength, and performance. Low index of skeletal muscle mass (SMMI) was used as a sensitive marker of youth sarcopenia. Until now, there has been no cut-off value for the Indonesian youth population. According to AWGS (2019), the cut-off of SMMI was between 5.7 and 7 kg/m^2 (Chen et al., 2020). We found that one out of five subjects had an SMMI value lower than the cut-off. The index of skeletal muscle mass among the sarcopenia group was significantly lower than that of the normal group. It was the first finding limited to students aged 18-22 years old at Surabaya and Malang.

Physical activity, muscle mass, muscle strength, and performance

Low muscle mass limits the recruitment of muscle fibers during contraction. The number of fibers recruited determines the force generated and muscle strength. A lower mass of skeletal muscle is provided in a lower number of muscle fibers that are awaiting recruitment by a motor neuron. More recruited fibers produced a greater force of muscle to resist physical load (Conwit et al., 1999; Ross & Wakeling, 2021). Since lower muscle mass was found in sarcopenia subjects, the strength was also evaluated using the hand grip dynamometric test. The test result confirmed that the grip strength of the sarcopenia group was significantly lower than that of the normal group. We also found that low to moderate levels of physical activity were less intense than high levels of physical activity.

Grip strength represented the entire body strength. The effect of high-level activity was not only localized in the loaded muscle but also altered in other muscles. During activity, the loaded muscle secretes chemical substances, known as myokines, that travel into the circulation. Some myokines, like IL-6, IL-15, and irisin, have been shown to promote muscle hypertrophy in general (Lee & Jun, 2019).

Once a particular muscle was loaded, it generally grew and gained mass. To support this idea, we conducted five sit-stand tests. Performing the sit-stand test five times requires the contribution of interregional muscle strength, including the core, upper body, and lower body. No subject completed the test above the limit (12 seconds). Sarcopenia among students had yet to be followed by a physical performance decrement. The comparison revealed that the sarcopenia group required more time to complete the test than the normal group, and individuals with low to moderate levels of physical activity also took longer to finish the test compared to those with high levels of physical activity.

Overall, the ability to perform a physical task was limited among students with sarcopenia risk. Those who engage in more intense physical activity tend to find it easier to complete any task. Engaging in a high level of physical activity is crucial for maintaining musculoskeletal function and reducing the risk

of muscle loss in populations at risk. Earlier intervention is beneficial to limit the progression of sarcopenia among youth (D'Onofrio et al., 2023; Graham et al., 2021).

Strength, Assistance with walking, Rise from a chair, climb stairs, and Falls (SARC-F) was employed to examine the risk categorization for prospective sarcopenia (Malmstrom and Morley, 2013). The categories of SARC-F are high and low risk. Students who underwent high-level of physical activity exhibited a lower risk of developing sarcopenia compared to low-to-moderate level of physical activity. Engaging in a high level of physical activity may mitigate the risk of sarcopenia in active individuals in the future. Low-moderate levels of physical activity were not enough for sarcopenia prevention among adolescents. The student required more intense physical activity to alleviate stress, sleep disturbances, loss of skeletal muscle mass, and reduced strength. The participation index of physical activity among students needs to be elevated. Furthermore, this study should compare the effect of training variation on sarcopenia markers.

Study strengths and limitations

This study provides the very first evidence of youth sarcopenia in Indonesia. Being active was not enough to lower the risk of sarcopenia in youth. Physical activity and quality of sleep were two factors related to the risk of youth sarcopenia. Our findings were limited to the endocrine, nutritional, and stress aspects. Evaluation. In the future, the level of hormones, nutritional intake, and stress needs to be measured.

Conclusions

Lower skeletal muscle mass, strength, and performance were concomitant with an increased susceptibility to the onset of sarcopenia in later life. Engaging in physical training helps mitigate the risk of developing sarcopenia. Notably, the incidence of sarcopenia was absent among all individuals who had received training.

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