International Journal of Modern Education
EISSN: 2637-0905
IJMOE

Volume 6 Issue 21 (June 2024) PP. 382-391
DOI: 10.35631/IJMOE.621028

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.ijmoe.com

GLOBAL ACADEMIC EXCELLENCE

RELATIONSHIP BETWEEN BODY MASS INDEX AND FLEXIBILITY OF TRUNK AND HAMSTRING MUSCLES AMONG SCHOOL ADOLESCENTS

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Article Info:

Article history:
Received date: 18.04.2024
Revised date: 13.05.2024
Accepted date: 15.06.2024
Published date: 30.06.2024

To cite this document:

Rahman, R. A. A., Meilani, E., Shipah, N. A. M., Seman, M. H. A., & Jamaludin, N. A. (2024). Relationship Between Body Mass Index And Flexibility Of Trunk And Hamstring Muscles Among School Adolescents.

Abstract:

Background: The childhood obesity has led to a decrease in physical activity, which may have detrimental effects on overall well-being, including impairment in musculoskeletal flexibility. Joint flexibility, often known as range of motion, is and a component of muscular fitness that essential for performing daily tasks. Considering the major physiological changes that occurs during adolescence have substantial impact on long-term health, this study aimed to investigate the relationship between body mass index (BMI) and the flexibility of the trunk and hamstring muscles among school adolescents. **Methods:** A total of 143 school adolescents were recruited using a convenience sampling method. The participants' body composition was measured using the BMI, while the flexibility of the trunk and hamstring muscles was evaluated using the fingertip-to-floor test and the sit-and-reach test, respectively. The Spearman's correlation coefficient was utilised to examine the relationship between BMI and muscle flexibility. **Results:** Most of the participants (n = 64, 44.8%) were underweight, with a mean BMI of 20.2

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International Journal of Modern Education, 6 (21), 382-391.

DOI: 10.35631/IJMOE.621028

± 5.2 kg/m2. There were no significant correlations between BMI and muscle flexibility (trunk, p = 0.965; hamstring, p = 0.829). Additionally, there were significant differences between males and females in trunk flexibility (p = 0.04), but not in hamstring flexibility (p = 0.135). **Conclusion:** There was no association between BMI and muscle flexibility in this study However, male students demonstrate significantly greater trunk flexibility compared to their female peers.

Keywords:

Adolescents; Body Mass Index; Flexibility; Hamstring; Trunk

Introduction

According to the World Health Organization (WHO), the number of overweight children and adolescents aged 5-19 exceeded 390 million in 2022, marking a significant increase from a mere 8% in 1990 to 20% in 2022. The National Health and Morbidity Survey (NHMS) conducted in 2019 found that the rate of childhood obesity in Malaysia has significantly risen to 14.8% (Institute of Public Health, 2019). The rising prevalence of obesity in childhood and adolescence is a worldwide health issue that has substantial consequences for physical well-being, particularly in terms of growth and preservation of musculoskeletal flexibility (World Health Organization, 2023). Musculoskeletal flexibility is an integral aspect of physical fitness that pertains to the extent of movement achievable at a joint or group of joints and is vital for executing a diverse range of everyday tasks and upholding physical well-being (PK & Shaikh, 2022). The significance of flexibility, specifically in the trunk and hamstring muscles, should be emphasized during adolescence to prevent orthopaedic problems later in life, mainly back pain (Arora, D' Souza, & Yardi, 2016).

Literature Review

Obesity is a global health problem that can be affected by genetics, social circumstances, lifestyle choices, dietary habits, levels of physical activity, and environmental factors (Toriola et al., 2018). Adolescents who lead a sedentary lifestyle or lack physical activity often spend a significant amount of time sitting at work, in front of laptops or televisions, or lounging on the couch. Prolonged sitting or lack of movement leads to muscle shortening and tightness, particularly in the hip flexors, hamstrings, and lower back muscles (Arora et al., 2016). A gradual reduction in flexibility occurs as these muscles adjust to the shortened position. Physical activity levels among children and adolescents worldwide are generally below the recommendations provided by evidence-based guidelines, especially in low- and middle-income countries including Malaysia (Reilly et al., 2022; Shahril et al., 2023). According to data from the NHMS in 2017, the prevalence of sedentary behaviours among adolescents in Malaysia shown a progressive incline, rising from 47.3% in 2012 to 50.1% in year 2017 (Institute of Public Health, 2017). In addition to this, a recent report card from 2022 indicated that the "inactivity epidemic" continues to affect children and adolescents in Malaysia (Shahril et al., 2023).

Childhood and adolescence are crucial periods for the development and improvement of physical fitness. The habits that develop during these phases can continue into adulthood and have a long-term impact on their health. In addition, the physiological changes that occur throughout puberty, such as a rise in body fat and changes in body composition, can affect physical ability, especially flexibility (Jarral et al., 2021; Teju & Sinawang, 2023). The

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IJMOE
Volume 6 Issue 21 (June 2024) PP. 382-391
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increasing body fat in adolescents is caused by decreased physical activity and a rapid growth and development phase, which could negatively impact the flexibility of the hamstring and back muscles (Jarral et al., 2021). The Body Mass Index (BMI) indicates the level of body fat, which has been associated with different health outcomes (World Health Organization, 2023). It is a commonly used outcome measure that categorizes individuals as underweight, normal weight, overweight, or obese based on comparing weight to height.

Recently, a focus has been on the relationship between BMI and various aspects of physical fitness, such as flexibility among adolescents. However, the research findings on this topic have been inconsistent. Several studies have shown adverse associations between increased BMI and diminished flexibility (Thompson et al., 2021; Toriola et al., 2018). However, other studies have indicated insignificant or conflicting relationships (Arora et al., 2016; PK & Shaikh, 2022). It is crucial to comprehend the relationship between BMI and flexibility during this critical period of growth to guide treatment options that target the enhancement of health results. Hence, this study aims to explore the relationship between BMI and the flexibility of the trunk and hamstring muscles among school adolescents. By focusing on these specific muscle groups, the research seeks to provide targeted insights to inform the development of tailored physical activity and health promotion programs for this demographic. Furthermore, the study examines gender differences in flexibility outcomes, contributing to a more nuanced understanding of how BMI-related factors intersect with sex-specific physiological characteristics during adolescence.

Methods

Study Design
The design of this study was a cross-sectional of school adolescents from a government secondary school in Penang, Malaysia. The data collection was conducted over the course of one day on January 9, 2024, and included a one-time assessment. A total of 143 students participated in this assessment-based study. The participants were selected through convenient sampling within the age group of 13-16 years. Participants were excluded if they had experienced any musculoskeletal injury or any form of back or knee pain within the past three months (Figure 1). Following an explanation of the procedures and objectives of the study, written informed consent was acquired from the parent or guardian of each participant, and written assent was obtained from the participant.

Measurement and Procedure
Body composition was measured using BMI, while the flexibility of the trunk and hamstring muscles was assessed using the fingertip-to-floor test and the sit-and-reach test, respectively.

Body Mass Index (BMI)
The height was measured with a measuring tape while the person was barefoot, with the measurement being rounded to the nearest centimetre. Weights were determined to the nearest kilogramme using a standard portable weighing scale while barefoot. The BMI of each participant was calculated by dividing their body weight (in kilogrammes) by the square of their height (in metres). The BMI cut-offs for overweight and obesity in Asian children and adolescents are 23 and 27 kg/m^2, respectively (Cole & Lobstein, 2012; Qian et al., 2020). We applied these cut-offs for Asian populations in this study.

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EISSN: 2637-0905
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$$\text{BMI} = \frac{\text{Bodyweight (kg)}}{[\text{Height (m)}]^2}$$

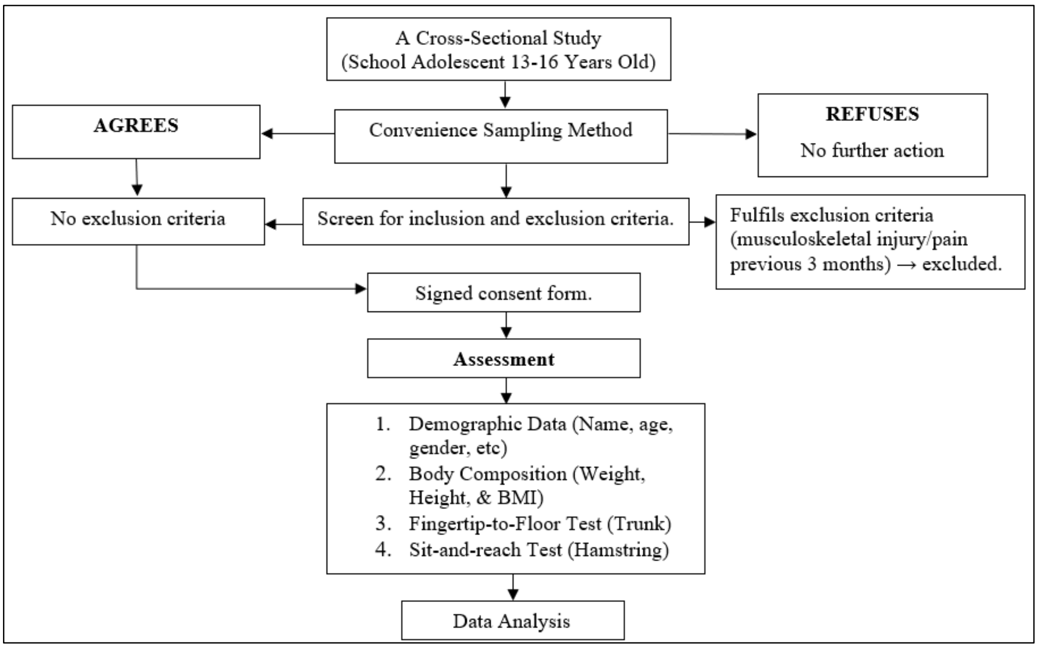

Figure 1: Flow Chart

Fingertip-to-Floor Test

The participant was asked to stand on the floor without shoes, with their feet at shoulder width. They were then instructed to bend their body forward while keeping their knees straight and placing their dominant hand over the other hand (Merritt, Mclean, Erickson, & Offord, 1986; Perret et al., 2001). The intention was to reach for their toes, but they were told to stop if they felt any discomfort. A tape measure was utilised to assess the vertical distance in centimetres between the floor and the tip of the middle finger on the hand that is predominantly used (Figure 2). A zero measurement indicated that the fingertip was in contact with the floor, whereas a positive value indicated that the fingers not contacted the floor (Allam et al., 2023). This test was carried out three times, and the final score was calculated as the mean. The FTF test is suitable for clinical practice and therapeutic trials because of its excellent validity, reliability, and responsiveness (Ekedahl, Jönsson, & Frobell, 2012; Perret et al., 2001).

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DOI: 10.35631/IJMOE.621028

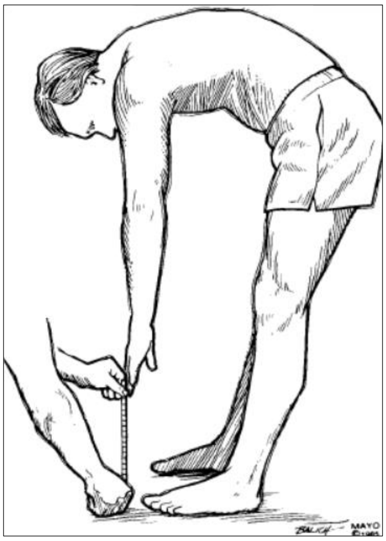

Figure 2: Fingertip-to-Floor Test

Source:(Merritt et al., 1986)

Sit-and-Reach Test

The sit-and-reach test was conducted on a standardised sit-and-reach box of 33 centimetres in height, equipped with a measuring scale on its top surface (PK & Shaikh, 2022). Participants assumed a seated position with their knees and feet firmly positioned against the front-end panel of a constructed box (Arora et al., 2016; PK & Shaikh, 2022). They then gradually pushed the ruler on top of the standard reach box using both hands, ensuring a smooth motion without any sudden movements (Toriola et al., 2018). Additionally, they extended their trunk and straightened both hands while fully extending their knees to reach as far as possible and maintain the position for around 2 seconds. The maximum distance achieved by the fingertips will be measured and recorded, rounded to the nearest centimetre. This test was carried out three times, and the final score was calculated as the mean (Arora et al., 2016; PK & Shaikh, 2022). The sit-and-reach test is a valuable alternative for assessing hamstring flexibility, especially in school settings or while conducting large-scale studies (Mayorga-Vega, Merino-Marban, & Viciana, 2014).

Statistical Analysis

The statistical analyses were conducted using IBM SPSS statistical software version 26.0 (IBM, Armonk, NY). The demographic characteristics of the participants were analysed and summarised using descriptive statistics. The independent T-test was used to compare the study variables between gender and Spearman's correlation coefficient to examine the relationship between BMI and muscle flexibility. The significance level was set at $p<0.05$ for all statistical tests.

Results

Demographic Information

Participants' demographic information is shown in Table 1. The study included a cohort of 143 adolescents from secondary school, with an average age of 14.55 ± 1.24 and a BMI of 20.23 ± 5.17. The participants comprised 64 boys (44.8%) and 79 girls (55.2%). Table 1 also displays the disparities in body composition between genders. Boys have a statistically significant

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IJMOE
EISSN: 2637-0905
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higher height (1.63 ± 0.12m, $p < 0.001$) and lower BMI (19.00 ± 4.33kg/m^2, $p = 0.01$) as compared to girls.

Table 1: Participants' Demographic Information

Variables	Total (Mean ± SD)	Girls (Mean ± SD)	Boys (Mean ± SD)	*p*-value
Age (years)	14.55 ± 1.24	14.54 ± 1.25	14.56 ± 1.25	.931
Weight (kg)	51.32 ± 14.47	51.18 ± 14.97	51.48 ± 13.95	.903
Height (meter)	1.58 ± 0.11	1.55 ± 0.08	1.63 ± 0.12	<.001*
BMI (kg/m^2)	20.23 ± 5.17	21.22 ± 5.60	19.00 ± 4.33	.01*

*The value is significant at the level of .05.

BMI Classification

Table 2 presents the BMI categorization of the participants, differentiating between boys and girls in this study. Most participants (n = 64, 44.8%) were classified as underweight, with a higher proportion of boys (n = 37, 57.8%). When it comes to being overweight or obese, girls have a higher percentage (n = 4, 5.1%; n = 17, 21.5%) compared to boys.

Table 2: BMI Classification

Category	Total n (%)	Girls n (%)	Boys n (%)
Underweight	64 (44.8)	27 (34.2)	37 (57.8)
Normal	49 (34.3)	31 (39.2)	18 (28.1)
Overweight	6 (4.2)	4 (5.1)	2 (3.1)
Obese	24 (16.8)	17 (21.5)	7 (10.9)

Trunk and Hamstring Muscles Flexibility

Trunk flexibility differed significantly between boys and girls (p = 0.004), but hamstring flexibility did not (p = 0.007). The findings suggest that boys show greater trunk muscle flexibility (3.35 ± 5.7).

Table 3: Muscle Flexibility

Variables	Total (Mean ± SD)	Girls (Mean ± SD)	Boys (Mean ± SD)	*p*-value
Trunk (cm)	5.04 ± 6.31	6.41 ± 6.47	3.35 ± 5.7	.004*
Hamstring (cm)	22.94 ± 7.6	22.08 ± 7.11	23.99 ± 8.08	0.07

*The value is significant at the level of .05.

Relationship between BMI and Muscle Flexibility

The correlation between BMI and muscle flexibility shown in Table 4 indicates that there was no significant relationship between BMI and muscle flexibility (trunk, r = 0.004, p = 0.965; hamstring, r = 0.018, p = 0.442).

Table 4: Correlation between BMI and Muscle Flexibility

	BMI	
Muscle Flexibility	r-value	*p*-value
Trunk	.004	.965
Hamstring	.018	.829

Discussion

Several significant findings concerning gender, BMI, and flexibility arise from the analysis of the study's results, which examined a variety of measurements and body compositions among

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adolescents. These insights substantially contribute to our comprehension of adolescents' growth and physical well-being.

The study demonstrates that boys have a significantly higher height (1.63 ± 0.12 m) and lower BMI (19.00 ± 4.33 kg/m²) in comparison to girls, with statistical significance ($p < 0.001$ for height and $p = 0.01$ for BMI). This finding is consistent with the typical patterns observed during adolescent development, wherein boys frequently undergo a delayed yet more prominent period of rapid growth compared to girls (Mlakar et al., 2023; Pinto et al., 2018). The lower BMI seen in boys (19.00 ± 4.33 kg/m²) compared to girls in the same age group can be explained by the difference in the timing of peak growth velocities, which may also indicate a higher lean body mass typically found in adolescent boys (Pinto et al., 2018). The implication of these findings is that boys may be at a distinct stage of physiological development in comparison to girls of the same age (Bentham et al., 2017). This physiological development could have an impact not only on physical health but also on psychological well-being.

A notable aspect of the study is the significant occurrence of being underweight among the group, especially among boys, with 57.8% of them are categorised as underweight. This finding indicates the potential risk of inadequate nutrition or eating disorders, which are not as frequently acknowledged in male teenagers (Iduoriyekemwen, Abiodun, Sadoh, & Onyiriuka, 2023; Weichselbaum & Buttriss, 2011). In contrast, girls had a greater proportion of being overweight or obese, with 5.1% classified as overweight and 21.5% classified as obese, indicating that girls were more likely than boys to experience weight gain during adolescence due to different metabolic or lifestyle factors (Iduoriyekemwen et al., 2023; McCarthy, 2014; Noonan, 2022). This result indicates the presence of varying health risks that may necessitate specific interventions targeting eating patterns and physical exercise.

The study also reveals a statistically significant difference in trunk flexibility between boys and girls, with boys exhibiting more flexibility, parallel with previous research (Allam et al., 2023; Divyashri, Prathap, & Preetha, 2021). This discovery is fascinating because it contradicts the widely accepted belief that females often display more adaptability due to physiological and hormonal distinctions. The higher degree of trunk flexibility observed in boys could contribute to variances in the sorts of physical activities or sports they engage in, which prioritise core strength and flexibility, which can influence specific muscle group development and flexibility (Iduoriyekemwen et al., 2023; Noonan, 2022). The significance of this element of physical well-being is particularly essential, as there is a correlation between flexibility and a lower incidence of injuries in teenagers (Gleim & McHugh, 1997; Mikkelsson et al., 2006).

This study examined the relationship between BMI and muscular flexibility, explicitly focusing on the trunk and hamstring, in a group of school adolescents aged 13 to 16. Interestingly, there was no significant correlation between BMI and muscle flexibility for the trunk and hamstrings (trunk, $r = 0.004$, $p = 0.965$; hamstring, $r = 0.018$, $p = 0.442$). The study's finding is consistent with other studies that found no relationship between these two variables (Allam et al., 2023; Teju & Sinawang, 2023). Moreover, this result is noteworthy because it contradicts many commonly held beliefs about the influence of body fat on physical ability, such as flexibility. Prior research has indicated that higher levels of adiposity can limit the range of motion and flexibility of joints (Bulbrook et al., 2021; Kasović, Oreški, Vespalec, Gimunová, & Štefan, 2022). Nevertheless, this study proposes that BMI alone may not be a conclusive indicator of

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IJMOE
EISSN: 2637-0905
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flexibility in adolescents. Other variables, such as genetics, muscle composition, or consistent engagement in flexibility-oriented activities, may have a more significant impact.

Based on these findings, health interventions in schools must be customised to address the distinct requirements of different genders and body compositions. Comprehensive nutritional programmes should be designed to tackle the prevalent issues of underweight and overweight conditions, with a focus on promoting well-rounded diets and fostering healthy eating habits that are customised to the individual's body composition and degree of physical activity. In addition, physical education should not solely focus on improving overall fitness but should also emphasise activities that improve flexibility. This is essential for preventing injuries and increasing overall well-being.

Conclusion

This study provides important insights into the physiological disparities and health risks linked to adolescence, emphasising the significance of gender-specific strategies in health interventions. There was no association between BMI and muscle flexibility in this study, but greater level of trunk flexibility found in boys may indicate variations in physical activity patterns that prioritise core strength. This finding suggests that physical education programmes should include exercises that promote flexibility and are adaptable to different body types and fitness levels. In summary, the study recommends a holistic approach to adolescent health that integrates nutritional, physical, and educational measures. This strategy aims to promote optimal development and prevent long-term health problems related to differences in body composition and flexibility during early life.

Acknowledgement

The researchers express gratitude to the school students who participated in this study and UiTM Cawangan Pulau Pinang for the support.

Conflict of Interest

The authors declare that they have no conflict of interest in publishing this article.

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