International Journal of Sport Studies for Health

Journal Homepage

Impact of Age, Gender, and Body Composition on Balance, Coordination, and Agility in Children and Adolescents

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Article Info

Article type:
Original Research

How to cite this article:
Ebrahimi, M., & Changizi, M. (2025). Impact of Age, Gender, and Body Composition on Balance, Coordination, and Agility in Children and Adolescents. *International Journal of Sport Studies for Health*, *8*(2), 27-34.
http://dx.doi.org/10.61838/kman.intjssh.8.2.4

ABSTRACT

Objective: Balance and coordination are crucial for the development of motor skills and are influenced by age and gender. This study aimed to examine the effects of age and gender on balance, coordination, and agility in children and adolescents.
Methods and Materials: A total of 405 participants (211 boys and 194 girls) aged 7 to 13 years were assessed. Static balance (with eyes open and closed) was measured with the Stork Test, coordination was assessed using the Eye-hand coordination test, and agility was measured through the T-test and 4×9 test. Pearson correlation and independent t-test were used for data analysis.
Findings: The results indicated significant differences in BMI (P=0.048) and body fat percentage (P=0.001) in girls compared to boys at age 9, as well as in static balance with eyes closed at ages 7 (P=0.034) and 10 (P=0.003). Coordination was also significantly higher in boys than girls at ages 11 (P=0.000) and 12 (P=0.000). Furthermore, body fat percentage was found to have a stronger effect on balance and motor function in boys than in girls.
Conclusion: Based on these findings, maintaining a healthy body fat percentage is recommended for both genders to support better health and physical performance.
Keywords: *Gender, Age, Body composition, Balance, Coordination, Agility*.

1. Introduction

Children's physical development is measured by changes in body size or composition as well as changes in physical fitness and motor skills (1, 2). Body composition is a crucial factor, and understanding the impact of age and gender on it can help improve both health and athletic performance (3). Body composition includes various parameters such as fat mass, lean mass, and muscle distribution, all of which significantly change with age and may vary between genders (4). "Motor skills, which manifest through movement, are dependent on the type of movement, human abilities, and their development in specific moments and conditions (5). These skills are divided into two main categories: basic motor skills and specific motor skills. Basic motor skills are those that most people acquire throughout their lives, whereas specific skills are more commonly developed in athletes through practice and experience (6, 7). Gender, as a primary determinant,

Article history:
Received 24 January 2025
Revised 28 February 2025
Accepted 09 March 2025
Published online 01 April 2025

significantly influences body composition, balance, coordination, and agility due to morphological and physiological differences, all of which are essential for maintaining functional mobility and preventing injuries in physical activities. Balance is defined as the ability to maintain the body's center of gravity over a base of support (8). The base of support and the distance between the center of gravity and the line of gravity negatively impact balance (8). Proper balance control is a critical aspect of child development and is considered one of the more complex mechanisms. It involves the functioning of multiple systems, including sensory systems (i.e., visual, vestibular, and proprioceptive systems). Therefore, normal development of balance ability in early childhood is an essential part of the development of balance skills in adulthood (9). If the development of balance abilities is compromised during early years, it is likely to hinder a child's ability to master complex motor skills and increase the likelihood of injury. This, in turn, can impact their future ability to participate in sports activities (10, 11). Neuromuscular coordination refers to the connection between the brain and muscles to perform various movements. Coordination and agility are two critical physical fitness factors that play a vital role in sports performance. These two factors are largely influenced by age, training age, gender, anthropometric structure, activity level, muscle tone, muscle strength, and fatigue level (3).

In this regard, Li et al. (2022) showed that there is a gender difference in preschool children, with static and dynamic balance being influenced by age. Balance improves with age during preschool years, and overall, girls outperformed boys in most balance tests (12). Another study by Liu et al. (2024) on age and gender differences in static and dynamic balance in Chinese preschoolers found that balance is affected by both age and gender (13). Generally, balance ability improves with age in children, and girls perform better than boys in balance tests. However, the results of Conner et al. (2019) and Marchesi et al. (2022) indicated that motor performance in dynamic balance changes with age, but static balance is not dependent on age (14, 15).

Several studies have examined the relationship between age and gender on coordination and agility (3, 11, 16). Rusek et al. (2021) demonstrated that body composition, balance, and agility differ between genders and with age in children and adolescents. Higher BMI was associated with better balance in this population. Girls outperformed boys in all balance parameters (17). However, Gonzalez-Devesa et al. (2024) found no significant association between agility, age, and gender in children and adolescents. Additionally, higher BMI was associated with lower agility, and boys performed better than girls (18). Furthermore, a study by Boutios et al. (2021), which assessed the impact of age and gender on motor coordination abilities in Taekwondo practitioners, indicated that coordination skills, including agility and accuracy, improve with age and are positively influenced by practicing a sport (19).

There are inconsistencies in previous research. Therefore, in this study we aimed to asses the relationship between body composition and change in balance, coordination and agility with age in children and adolescents.

2. Methods and Materials

2.1 Study Design and Participants

The present study was a cross-sectional and observational research. The statistical sample included 405 (211 boys and 194 girls) aged 7 to 13 years randomly selected from Semnan province. The eligibility criteria stipulated that participants must be free from injuries and refrain from using any medications prior to or during the testing phase. Comprehensive information regarding the experimental risks was provided to all participants, who subsequently provided their informed consent. Furthermore, written informed consent was obtained from the parents or guardians of each participant to ensure ethical compliance. Before the testing session, participants engaged in a standardized 15-minute warm-up. This warm-up comprised 5 minutes of submaximal running followed by 5 minutes of static and dynamic stretching exercises.

2.2 Measures

2.2.1 Body Composition Measurements

Body fat percentage measured using the bioelectrical impedance method (InBody 230, manufactured in Korea), Participants' height (cm) and body weight (kg) were recorded while they were barefoot and dressed only in shorts and a t-shirt. Body mass was assessed using an electronic scale, while height was measured with a portable stadiometer.

2.2.1.1 Balance, Coordination, and Agility Test Measurements

the Stork Test was used to measure balance, recorded in seconds. This test involved standing on one leg with eyes open and closed. For measuring coordination, The Alternate Hand Wall Toss (AHWT) the Eye-hand coordination test was applied. The participant stood 2 meters away from the wall and tossed the tennis ball with one hand to the wall, aiming to catch it with the opposite hand. The ball was then thrown with the opposite hand and caught by the initial hand. The number of successful throws and catches within 30 seconds was recorded.

To assess agility, the 4×9 meter test and the T-test were employed (in seconds). In the 4×9 meter test, upon the start signal, the participants ran the 9-meter distance at maximum speed, picked up a piece of wood, and brought it to the opposite side, repeating this for the second piece. The participant covered the 9-meter distance 4 times at maximum speed and capacity. The T-test, started at cone A as shown in the Figure 1. Upon the timer signal, the participant ran to cone B, touched its base with the right hand, then turned left to cone C, touching its with the left hand. The participant then moved sideways to cone D, touched its with the right hand, and returned to cone B and touch it with the left hand, finishing by running backward to cone A. The stopwatch stopped when the participant crossed cone A.

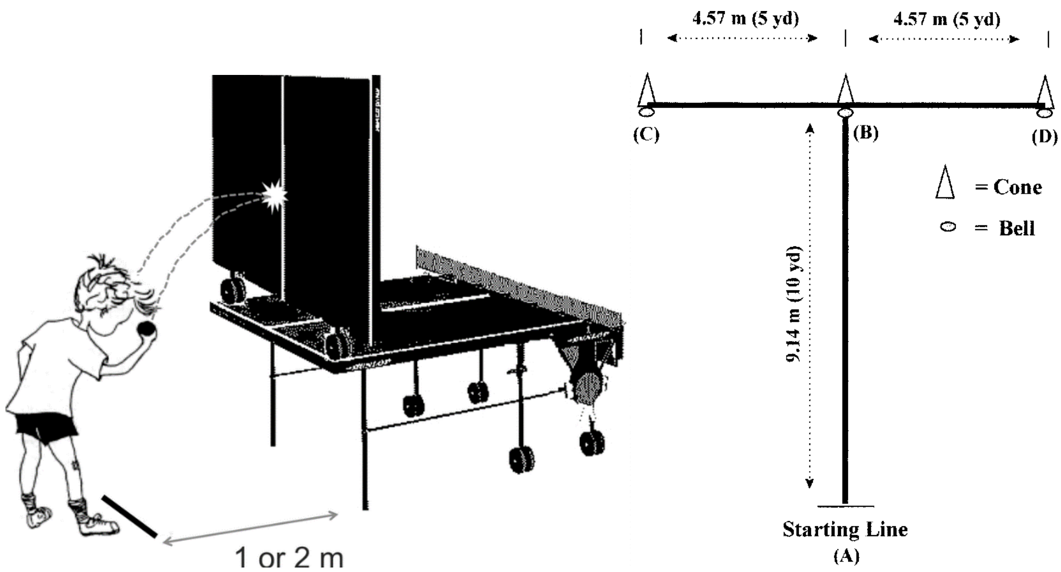

Figure 1. Diagram of T-test and coordination test

2.3 Data Analysis

Data analysis was performed using the Pearson correlation coefficient and independent t-test, with the statistical significance threshold set at 0.05.

3. Results

The characteristics of the participants are presented in Table 1.

Table 1. Mean and Standard Deviation of Individual Characteristics of the Participants

group / variable	Age	weight	height
Boys (n=211)	10/03±1/69	35/91±12/11	136/03±10/72
Girls (n=194)	10/4±1/34	40/06±12/67	151/63±9/39

As shown in Figure 2, the independent t-test indicated that BMI (P=0.048) and body fat percentage (P=0.001) was significantly higher only at age 9 in girls compared to boys. Additionally, in static balance with open (P=0.035) and closed (P=0.034) eyes at age 7, and only closed eyes (P=0.003) at age 10, were significantly higher in girls than in boys. Furthermore, in coordination reveal significant differences in boys compared to girls at ages 11 (P=0.000) and 12 (P=0.000). Agility, as measured by the T-test and the 4×9-meter shuttle run, was also significantly higher in boys compared to girls at ages 9 (p=0.007 and p=0.015, respectively) and 12 (p=0.008 and p=0.000, respectively). No significant differences were observed between the two genders for all other variables at other ages.

Table 2. Changes in Variables Between Gender Groups

Variable 1=boys, 2= girls			BMI	Fat %	Balance (Open eyes)	Balance (closed eyes)	coordination	4×9 Test	T-Test
1	BMI	Correlation	1	0.851**	-0.117	-0.156*	0.022	0.148*	0.053
		Sig		0.000	0.089	0.023	0.753	0.031	0.462
	Fat %	Correlation	0.851**	1	-0.233**	-0.237**	-0.147*	0.414**	0.299**
		Sig	0.000		0.001	0.000	0.032	0.000	0.000
	Balance (Open eyes)	Correlation	-0.117	-0.233**	1	0.368**	0.263**	-0.355**	-0.299**
		Sig	0.089	0.001		0.000	0.000	0.000	0.000
	Balance (closed eyes)	Correlation	-0.156*	-0.237**	0.368**	1	0.228**	-0.277**	-0.268**
		Sig	0.023	0.000	0.000		0.001	0.000	0.000
	coordination	Correlation	0.022	-0.147*	0.263**	0.228**	1	-0.586**	-0.630**
		Sig	0.753	0.032	0.000	0.001		0.000	0.000
	4×9 Test	Correlation	0.148*	0.414**	-0.355**	-0.277**	-0.586**	1	0.872**
		Sig	0.031	0.000	0.000	0.000	0.000		0.000
	T-Test	Correlation	0.053	0.299**	-0.299**	-0.268**	-0.630**	0.872**	1
		Sig	0.462	0.000	0.000	0.000	0.000	0.000	
2	BMI	Correlation	1	0.841**	-0.115	-0.177*	0.121	0.062	-0.061
		Sig		0.000	0.110	0.013	0.092	0.388	0.422
	Fat %	Correlation	0.841**	1	-0.130	-0.225**	-0.045	0.263**	0.211**
		Sig	0.000		0.069	0.002	0.531	0.000	0.005
	Balance (Open eyes)	Correlation	-0.115	-0.130	1	0.359**	0.127	-0.196**	-0.130
		Sig	0.110	0.069		0.000	0.078	0.006	0.084
	Balance (closed eyes)	Correlation	-0.177*	-0.225**	0.359**	1	0.110	-0.063	-0.111
		Sig	0.013	0.002	0.000		0.124	0.379	0.142
	coordination	Correlation	0.121	-0.045	0.127	0.110	1	-0.307**	-0.496**
		Sig	0.092	0.531	0.078	0.124		0.000	0.000
	4×9 Test	Correlation	0.062	0.263**	-0.196**	-0.063	-0.307**	1	0.469**
		Sig	0.388	0.000	0.006	0.379	0.000		0.000
	T-Test	Correlation	-0.061	0.211**	-0.130	-0.111	-0.496**	0.469**	1
		Sig	0.422	0.005	0.084	0.142	0.000	0.000	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

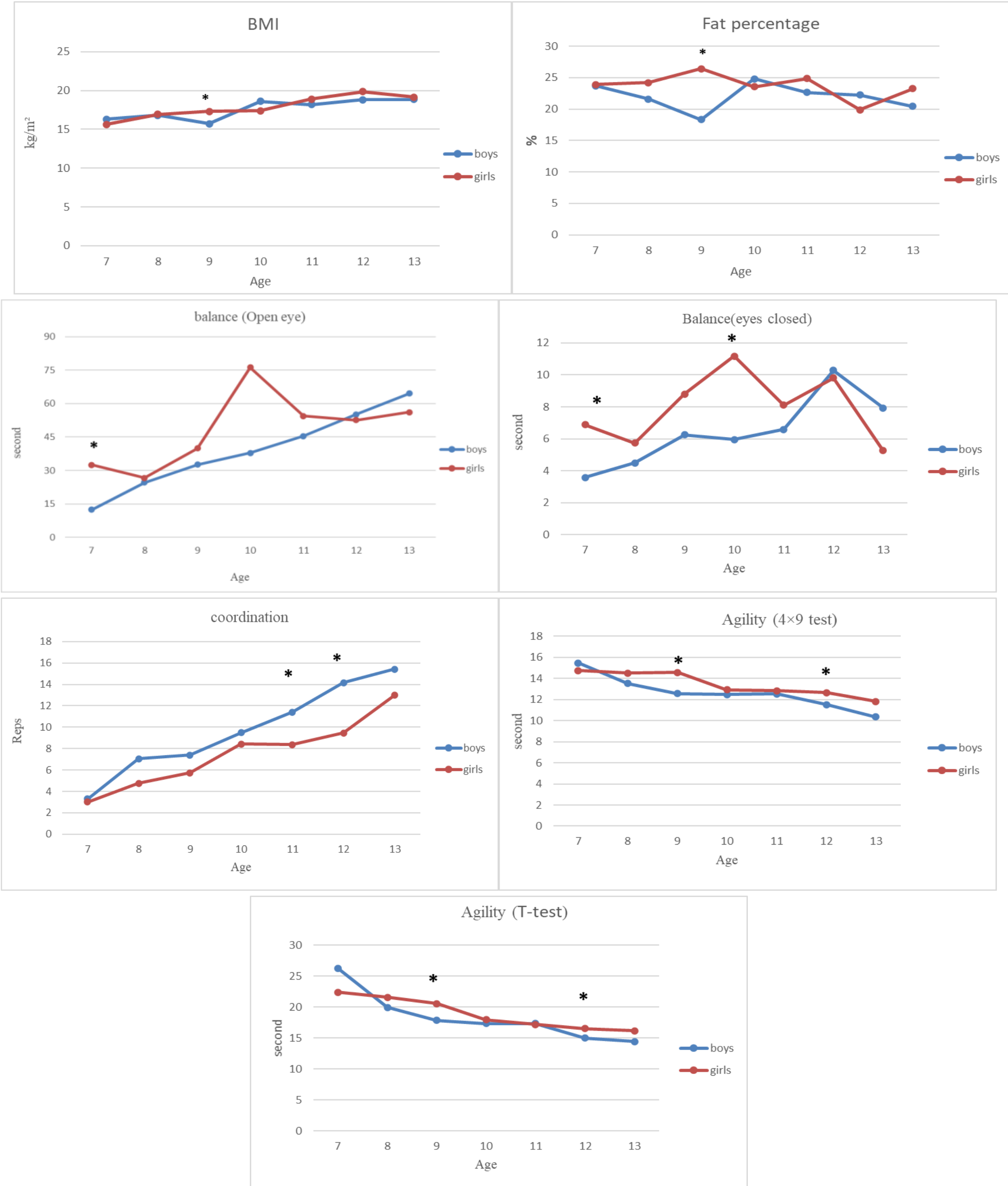

Figure 2. Levels of Variable Changes with Increasing Age

* Indicates significant differences with age increase at a significance level of 0.05.

In both boys and girls, the results indicated a significant correlation between Body Mass Index (BMI) and body fat percentage (r=0.851, p=0.000 - r=0.841, p=0.000). This suggests that an increase in body fat percentage may lead to an increase in BMI. Specifically, in the cohort of boys, the percentage of body fat was found to have significant correlations with various physical performance measures, including balance (eyes open) (r=-0.233, p=0.001), balance (eyes closed) (r=-0.237, p=0.000), coordination (r=-0.147, p=0.032), agility (4×9 test) (r=0.414, p=0.000), and agility

(T-test) (r=0.299, p=0.000). In girls, a significant correlation was observed between body fat percentage and balance (eyes closed) (r=-0.225, p=0.002), as well as agility (4×9 test) (r=0.263, p=0.000) and agility (T-test) (r=0.211, p=0.005)

In boys, balance, coordination, and agility exhibited strong significant correlations. This indicates that improvement in one of these factors can lead to enhancements in the others. However, in girls, only a significant correlation was found between balance (eyes open) and agility in the 4×9 test (r=-0.196, p=0.006), as well as coordination with agility in the 4×9 test (r=-0.307, p=0.000) and coordination with agility in the T-test (r=-0.496, p=0.000). This demonstrates the positive impact of balance on agility.

4. Discussion and Conclusion

In summary, the present study's findings, aimed at examining the effects of age and gender on body composition, balance, coordination, and agility in children and adolescents, reveal significant differences in how these parameters change with growth. The study revealed that at age 9, girls had significantly higher Body Mass Index (BMI) and body fat percentage compared to boys, while demonstrating superior static balance at ages 7 and 10. In contrast, boys excelled in coordination and agility at ages 11 and 12, with significant correlations between body fat percentage and various physical attributes in both genders, indicating interconnectedness among balance, coordination, and agility.

The findings of this study regarding body composition with age in both gender groups align with those of Conner et al. (2019) and Marchesi et al. (2022). During early childhood, rapid growth occurs, and body composition changes significantly. Both fat mass and lean mass increase, with fat mass being relatively high during infancy and decreasing as children grow. Hormonal changes significantly impact body composition with age, particularly through the reduction of anabolic hormones such as testosterone and growth hormone. This decline is associated with notable changes in body composition, including an increase in fat mass and a decrease in lean mass (14, 15).

Significant changes in BMI and body fat percentage in girls at the age of 9 indicate that before puberty, body fat tends to stabilize or decrease slightly, while lean mass (muscle and bone) continues to increase, particularly in boys. During puberty, the interaction between age and gender significantly affects body composition in girls. Therefore, maintaining optimal body composition is essential for improving physical performance, especially in agility and balance. Age impacts body composition in children and adolescents through a combination of biological, environmental, and behavioral factors (20, 21).

According to the study's results, levels of change in static balance in girls show a significant increasing trend before and during puberty, but after puberty, this trend decreases. In contrast, boys show an increasing trend starting before puberty, and this trend continues.

Before puberty, body fat tends to stabilize or slightly decrease, while lean mass (muscle and bone), particularly in boys, continues to increase. The interaction of age and gender significantly affects body composition. Maintaining optimal body composition is essential for improving physical performance, especially agility and balance. Age affects body composition in children and adolescents through a combination of biological, environmental, and behavioral factors (16, 22).

The present study also revealed significant changes in balance with eyes open and closed in boys as they aged. However, in girls, the changes in balance were not significant. Previous studies, such as those by Li et al. (2022) and Liu et al. (2024), have reported inconsistent results (13, 23) These differences are often attributed to variations in body composition, muscle mass, and physical activity levels between genders. Standing balance with eyes open and closed is a critical assessment in evaluating proprioception and overall balance abilities. The effect of age on balance in children, including both boys and girls, is influenced by the development of various physiological and neurological systems (21). The maturation of these systems occurs at different rates. Age influences balance in girls and boys through the maturation of neuromuscular, sensory, cognitive, and biomechanical systems. While girls typically achieve balance earlier due to earlier maturation, boys may develop balance during adolescence due to increased strength and muscle mass. The complex interplay of these factors contributes to improved balance as children grow. Although the main mechanism behind the lack of correlation between functional factors in girls with age is not clearly defined, it may be due to the growth spurt in girls caused by rapid changes in body size and proportions (20, 24). Additionally, this study, which found no significant correlation between body fat percentage and balance or coordination in girls, highlights the importance of maintaining an optimal body fat percentage to enhance balance and coordination in children and adolescents.

The study indicates that gender differences in coordination and agility become clearly evident after puberty. As age increases, boys show a significant improvement in these two traits compared to girls. After puberty, boys consistently progress in coordination and agility. Overall, the findings emphasize the importance of gender-specific training during and after puberty to enhance coordination and agility.

This study showed significant changes in coordination and agility in both gender groups with age, aligning with the study by Boutis et al. (2021), which examined the impact of age and gender on the coordination abilities of taekwondo athletes (19). Their findings revealed that coordination skills, including agility and accuracy, improve with age, reflecting the maturation of motor skills and the nervous system. The results suggest that older athletes perform better in coordination tests, highlighting the benefits of age and experience in sports.

Younger children are often in the stage of learning basic motor skills (e.g., running, jumping), while older children and adolescents refine these skills into more complex motor patterns (e.g., dribbling). As children grow, they also gain more experience with various movements and develop cognitive skills. This experiential learning enhances motor patterns and coordination (25).

As a limitation, in this study we did not examine ages after 13 years. Future studies could address wider age ranges. Also, if the sample size was larger, the data could be more reliable. Further research could be conducted on other factors of children's physical fitness.

The findings of this study, which examined the effects of age and gender on body composition, balance, coordination, and agility in children and adolescents, highlight significant differences in how these parameters change as they grow. Research suggests that boys and girls follow different patterns of change in these indices, particularly after the onset of puberty. that girls had higher BMI and body fat percentage at age 9 and demonstrated better static balance at younger ages, while boys excelled in coordination and agility at ages 11 and 12. Significant correlations were observed between body fat percentage and balance, coordination, and agility, indicating the interconnectedness of these physical attributes in both genders.

Authors' Contributions

M. C. and M. E. contributed equally to the study, with M. E. taking the lead on research design. Both M. C. and M. E. assisted in data collection, which included anthropometric measurements and body composition analysis. They were also responsible for conducting the statistical analysis using SPSS and contributed to the interpretation of the data. Additionally, M. C. was involved in writing and reviewing the manuscript and provided approval for its final version.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

This research is supported by the postdoc grant of the of the Semnan university (number: 32212).

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. This research was approved by the Research Ethics Committee of Semnan University Of Medical Sciences and Health Services (IR.SEMUMS.REC.1404.008).

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