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Original Article

Somatotype and body mass index as predictors of aerobic and anaerobic capacity in young women

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Abstract:
Physical performance served as a key indicator in assessing individual fitness, particularly among adolescent girls. Various factors, including somatotype and body mass index (BMI), played a role in determining anaerobic and aerobic capacity. Previous studies indicated that mesomorphs excelled in anaerobic activities, while ectomorphs demonstrated superiority in aerobic capacity. However, a research gap remained in specifically examining the combined influence of these two factors within the adolescent female population. Additionally, the impact of obesity on decreased physical performance gained attention due to the increasing prevalence of sedentary lifestyles. This study employed a quantitative approach by measuring somatotype and BMI in adolescent girls and analyzing their relationship with physical performance. Anaerobic performance was assessed using a 60-meter sprint test, whereas aerobic capacity was measured through the bleep test. The data were analyzed to identify patterns of relationships between body composition and physical performance test results. This study aimed to understand how somatotype and BMI influenced physical performance in adolescent girls, particularly in sprint speed and aerobic capacity. Furthermore, it sought to provide evidence-based recommendations for developing more effective training programs tailored to individual physiological characteristics. The findings indicated that individuals with an ectomorphic somatotype dominated aerobic performance in the bleep test and also performed relatively well in the 60-meter sprint, which was associated with an optimal strength-to-body-weight ratio. Mesomorphs tended to excel in the sprint test due to their higher muscle mass, which supported explosive power production. Conversely, individuals with an endomorphic somatotype exhibited lower physical performance in both anaerobic and aerobic capacity, attributed to greater body mass and lower cardiorespiratory efficiency. Additionally, individuals with normal BMI displayed better physical performance compared to those who were overweight or obese, who were generally classified in the "Very Poor" category for both performance tests. This study confirmed that somatotype and BMI played significant roles in determining physical performance among adolescent girls. Ectomorphs tended to have advantages in both aerobic and anaerobic capacity, while mesomorphs excelled in sprinting. A normal BMI was associated with optimal performance, whereas obesity negatively impacted physical capacity. These findings could serve as a foundation for coaches and fitness practitioners in designing more effective training programs tailored to individual characteristics. Further research was necessary to explore interventions that could optimize physical performance based on somatotype and BMI categories, as well as to understand the underlying physiological mechanisms behind these differences.
Key Words*:* **Somatotype, Body Mass Index, Physical Performance, Anaerobic Capacity, Aerobic Capacity**

Introduction

Physical performance serves as a crucial indicator in assessing an individual's fitness level, particularly among the young population. Various factors, such as body composition, somatotype, and body mass index (BMI), often become the focus of sports and health research due to their impact on movement efficiency, as well as anaerobic and aerobic capacity (Gültekin et al., 2021; Mainer-Pardos et al., 2021). In a global context, the prevalence of obesity and sedentary lifestyles reaches alarming levels. Data from the World Health Organization (2024) indicate that more than 2.5 billion adults are overweight, with 890 million classified as obese—a condition that significantly affects speed, endurance, and muscle strength. Conversely, individuals with normal BMI tend to exhibit metabolic efficiency that supports optimal physical performance (Mohammed et al., 2016).

Somatotype, as an anthropometric indicator classifying body types into endomorph (adiposity), mesomorph (muscularity), and ectomorph (linearity), plays a critical role in physical activity. Mesomorphic dominance closely relates to anaerobic abilities, such as a 60-meter sprint, due to superior muscle mass and explosive power (Nikbakht, 2011; Cinarli et al., 2022). Studies on female adolescent soccer players demonstrate that balanced mesomorphs achieve faster sprint times compared to other somatotypes (Mainer-Pardos et al., 2021). On the other hand, ectomorphs, with their linear body structure, show advantages in aerobic capacity, such as the beep test, supported by metabolic efficiency during endurance activities (Carter et al., 2022; Ciftci & Kurtoglu, 2023).

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However, endomorphs with high body fat proportions tend to experience physical performance limitations due to increased mechanical load and reduced cardiorespiratory efficiency (Abdioğlu et al., 2024).

BMI further moderates this relationship. High BMI in female adolescents negatively affects sprint performance, as excessive body mass increases mechanical load and reduces acceleration (Mainer-Pardos et al., 2021). Conversely, an optimal BMI range correlates with enhanced aerobic endurance, as observed among university students, where those with normal BMI outperform overweight peers in endurance running. However, excessive thinness (low BMI) may also impair muscle strength, highlighting a complex balance (Guo et al., 2024). Despite these insights, limited studies holistically examine how somatotype and BMI jointly influence anaerobic capacity (e.g., 60-meter sprint) and aerobic capacity (e.g., beep test) in female adolescents.

Existing research primarily focuses on male athletes, mixed populations, or younger children, leaving a gap in targeted recommendations for female adolescents. This study addresses this gap by analyzing the dual impact of somatotype and BMI on physical performance metrics in this demographic. Somatotyping data may also assist coaches in designing training programs tailored to the physiological needs of individual athletes (Gutnik et al., 2015; Kutseryb et al., 2017).

Research by Ciftci & Kurtoglu et al. (2023) on children aged 48–72 months highlights the importance of somatotype profiles in athletic performance indicators, yet further exploration in adolescent groups remains necessary. Meanwhile, Ryan-Stewart et al. (2018) affirm that somatotype influences anaerobic performance, although their study does not specifically focus on female adolescents.

Therefore, this study aims to analyze the relationship between somatotype and body mass index in relation to physical performance, particularly in 60-meter sprint speed as a parameter for assessing anaerobic capacity and the beep test as a parameter for evaluating aerobic capacity among female adolescents. The findings of this study are expected to provide a more comprehensive understanding of the factors influencing female adolescents' physical performance and contribute to the development of more effective and personalized training programs. These findings are also expected to offer evidence-based recommendations for precision training programs while supporting health policies in addressing obesity and malnutrition issues among the young population.

Material & methods

Participants

This study employed an analytical observational design with a cross-sectional approach. It aimed to explore the relationship between somatotype and body mass index (BMI) in relation to physical performance among 129 young female respondents aged 20–32 years. The characteristics of the 129 respondents, with a mean age of 23.22 ± 3.2 years, were documented. The majority of the respondents had an average height of 158.58 ± 4.2 cm and a body weight of 54.96 ± 7.8 kg, with a mean BMI of 21.85 ± 2.9 kg/m².

Instruments

Body Mass Index (BMI) was calculated using the standard formula, which involves dividing body weight (kg) by height (m) squared. The BMI categories were classified according to the WHO classification (Khanna et al., 2022), namely Underweight, Normal weight, Overweight, and Obesity. This study also utilized data related to the bleep test and 60-meter sprint speed, which are standard assessment tools for evaluating aerobic and anaerobic capacity (Flotyńska et al., 2023; Rasteiro et al., 2023).

Anaerobic capacity was assessed using the speed parameter of the 60-meter sprint, which was measured on a standard track with a digital stopwatch in seconds. Aerobic capacity was evaluated using the Multistage Fitness Test (MFT) as a parameter. The MFT was conducted on a 20-meter track, following an increasing pace dictated by an audio signal. The measurement unit consisted of levels or speed stages, which were convertible to VO_2max (mL/kg/min). Subsequently, the numerical data were transformed into categorical data. This study was approved by the institutional ethics committee under approval number 4097/UN36.11/TU/2024. Respondents received comprehensive information regarding the data collection process, provided written informed consent before data collection, and were assured of data confidentiality and anonymity.

Statistical analysis

Statistical analysis was conducted using SPSS version 28. Descriptive statistics were employed to calculate absolute and relative frequencies, means, and standard deviations. Data normality was assessed using the Shapiro-Wilk test. The Mann-Whitney and Kruskal-Wallis tests were used to compare sprint speed and endurance scores with other variables involved in this study. To examine differences between groups, a One-Way ANOVA test was applied (Adiputra et al., 2021).

Results

A total of 129 respondents, with a mean age of 23.22 ± 3.2 years, participated in this study. The majority of respondents had an average height of 158.58 ± 4.2 cm and a body weight of 54.96 ± 7.8 kg, with a mean body mass index (BMI) of 21.85 ± 2.9 kg/m². Most respondents were classified as ectomorphs (67.4%), followed by mesomorphs (19.4%) and endomorphs (13.2%).

Table 1. Relationship between Somatotype, Body Mass Index and Anaerobic Capacity of Respondents

Variabel		Running Speed Category 60 M					p^a
		Very Poor	Poor	Avarage	Good	Very Good	
		n (%)	n (%)	n (%)	n (%)	n (%)	
Somatotype	Ectomorph	9 (10.3%)	35 (40.2%)	36 (41.4%)	6 (6.9%)	1 (1.1%)	
	Mesomorph	2 (8.0%)	11 (44.0%)	9 (36.0%)	3 (12.0%)	0 (0.0%)	0,148
	Endomorph	4 (23.5%)	8 (47.1%)	5 (29.4%)	0 (0.0%)	0 (0.0%)	
BMI category	Underweight	0 (0.0%)	2 (16.7%)	9 (75.0%)	1 (8.3%)	0 (0.0%)	
	Normal Weight	11 (10.9%)	44 (43.6%)	37 (36.6%)	8 (7.9%)	1 (1.0%)	
	Overweight	4 (28.6%)	6 (42.9%)	4 (28.6%)	0 (0.0%)	0 (0.0%)	0,021*
	Obesity	0 (0.0%)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Age category	20 YO	3 (8,5%)	11 (31,4%)	17 (48,6%)	4 (11,4%)	0 (0,0%)	
	21 YO	4 (30,8%)	4 (30,8%)	4 (30,8%)	1 (7,7%)	0 (0,0%)	
	22 YO	1 (7,1%)	7 (50,0%)	5 (35,7%)	1 (7,1%)	0 (0,0%)	
	23 YO	1 (5,0%)	10 (50,0%)	7 (35,0%)	1 (5,0%)	1 (5,0%)	
	24 YO	0 (0,0%)	4 (40,0%)	6 (60,0%)	0 (0,0%)	0 (0,0%)	
	25 YO	0 (0,0%)	7 (77,6%)	2 (22,2%)	0 (0,0%)	0 (0,0%)	
	26 YO	2 (28,6%)	3 (42,9%)	1 (14,3%)	1 (14,3%)	0 (0,0%)	0,553
	27 YO	1 (33,3%)	0 (0,0%)	2 (66,7%)	0 (0,0%)	0 (0,0%)	
	28 YO	1 (14,3%)	2 (28,6%)	4 (57,1%)	0 (0,0%)	0 (0,0%)	
	29 YO	0 (0,0%)	4 (80,0%)	1 (20,0%)	0 (0,0%)	0 (0,0%)	
	30 YO	1 (100,0%)	0 (0,0%)	0 (0,0%)	0 (0,0%)	0 (0,0%)	
	31 YO	1 (25,0%)	2 (50,0%)	0 (0,0%)	1 (25,0%)	0 (0,0%)	
	32 YO	0 (0,0%)	0 (0,0%)	1 (100,0%)	0 (0,0%)	0 (0,0%)	

*Kruskal Wallis Test.

Based on Table 1, it was concluded that for somatotype, no significant relationship was found (p = 0.148). However, respondents categorized as ectomorphs exhibited a higher proportion of the best performance levels ("Fair" and "Good") in anaerobic capacity compared to mesomorphs and endomorphs. When associated with BMI, a significant relationship (p = 0.021) with anaerobic capacity was observed. Respondents with a normal BMI demonstrated the highest proportion of optimal performance in anaerobic capacity, whereas those classified as overweight and obese predominantly fell into the "Poor" category. These findings indicated that an increase in BMI negatively impacted anaerobic speed performance.

Table 2. Relationship between Somatotype, Body Mass Index and Aerobic Capacity of Respondents

Variabel		Bleep Test				p^a
		Very Poor	Poor	Avarage	Good	
		n (%)	n (%)	n (%)	n (%)	
Somatotype	Ectomorph	44 (50,6%)	35 (40,2%)	7 (8,0%)	1 (1,1%)	
	Mesomorph	19 (76,0%)	6 (24,0%)	0 (0,0%)	0 (0,0%)	0,025*
	Endomorph	12 (70,6%)	5 (29,4%)	0 (0,0%)	0 (0,0%)	
BMI category	Underweight	7 (58,3%)	4 (33,3%)	1 (8,3%)	0 (0,0%)	
	Normal Weight	56 (55,4%)	38 (37,6%)	6 (5,9%)	1 (1,0%)	
	Overweight	11 (78,6%)	3 (21,4%)	0 (0,0%)	0 (0,0%)	0,400
	Obesity	1 (50.0%)	1 (35,7%)	0 (0,0%)	0 (0,0%)	
Age category	20 YO	15 (42,9%)	20 (57,1%)	0 (0,0%)	0 (0,0%)	
	21 YO	4 (30,8%)	6 (46,2%)	2 (15,4%)	1 (7,7%)	
	22 YO	10 (71,4%)	4 (28,6%)	0 (0,0%)	0 (0,0%)	
	23 YO	13 (65,0%)	6 (30,0%)	1 (5,0%)	0 (0,0%)	
	24 YO	7 (70,0%)	3 (30,0%)	0 (0,0%)	0 (0,0%)	
	25 YO	7 (77,8%)	1 (11,1%)	1 (11,1%)	0 (0,0%)	
	26 YO	5 (71,4%)	1 (14,3%)	1 (14,3%)	0 (0,0%)	0,161
	27 YO	2 (66,7%)	0 (0,0%)	1 (33,3%)	0 (0,0%)	
	28 YO	4 (57,1%)	3 (42,9%)	0 (0,0%)	0 (0,0%)	
	29 YO	5 (100,0%)	0 (0,0%)	0 (0,0%)	0 (0,0%)	
	30 YO	0 (0,0%)	1 (100,0%)	0 (0,0%)	0 (0,0%)	
	31 YO	3 (75,0%)	0 (0,0%)	1 (25,0%)	0 (0,0%)	
	32 YO	0 (0,0%)	1 (100,0%)	0 (0,0%)	0 (0,0%)	

*Kruskal Wallis Test

Based on Table 2, the statistical hypothesis analysis revealed differences among the somatotype groups in the bleep test, suggesting a relationship between somatotype and aerobic capacity. It was concluded that a significant relationship existed (p = 0.025). Respondents categorized as ectomorphs had the highest proportion in the "Fair" to "Good" categories (50.6%), whereas mesomorphs and endomorphs predominantly fell into the "Very Poor" aerobic capacity category.

Regarding BMI, no significant differences were found (p = 0.400). However, respondents with a normal BMI showed the best distribution in the "Fair" to "Good" categories (43.6%). These findings suggested that a leaner body favored more efficient aerobic movement.

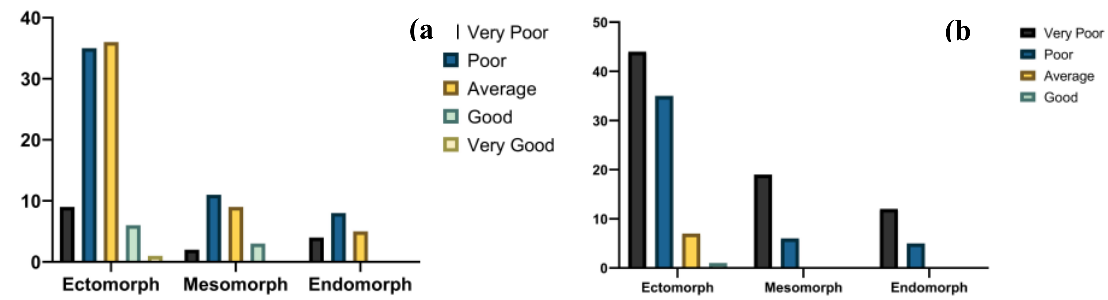

Figure 1. Relationship of 60 Meter Running Speed (a) and Bleep Test (b) Categories with Somatotype

Figure 1a illustrated the relationship between 60-meter sprint speed and somatotype categories. Ectomorphs dominated the "Poor" and "Average" categories, indicating limited anaerobic capacity for sprinting. Mesomorphs excelled in the "Good" and "Very Good" categories, reflecting their muscular advantage in high-intensity, short-distance activities. Endomorphs were primarily classified as "Very Poor" and "Poor," suggesting that their high-fat composition hindered sprint performance.

Figure 1b demonstrated that ectomorphs dominated the "Very Poor" and "Poor" categories, indicating lower aerobic capacity. Mesomorphs exhibited a more balanced distribution, with some representation in the "Good" category, reflecting better adaptability to aerobic activities. Endomorphs were concentrated in the "Very Poor" category, indicating significant limitations in aerobic performance due to their higher body fat proportion.

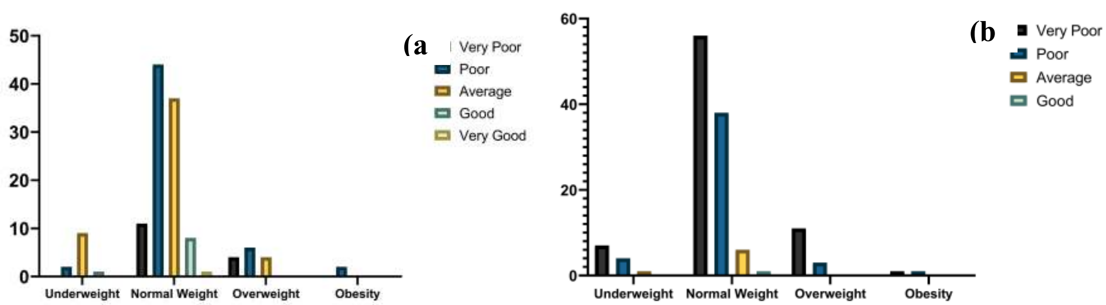

Figure 2. Relationship of 60 Meter Running Speed (a) and Bleep Test (b) Categories with Body Mass Index

Figure 2a showed that participants with a normal BMI dominated the "Average" and "Good" categories, indicating optimal anaerobic performance. Individuals classified as underweight were mostly in the "Poor" category, suggesting limited muscular strength for sprinting. Overweight and obese individuals were concentrated in the "Very Poor" category, highlighting the negative impact of excess weight on anaerobic performance. Figure 2b demonstrated that participants with a normal BMI predominantly fell into the "Poor" and "Very Poor" categories, suggesting moderate aerobic capacity.

Underweight individuals exhibited a similar trend but with lower representation. Overweight and obese participants were concentrated in the "Very Poor" category, indicating significant limitations in aerobic performance due to excessive body weight.

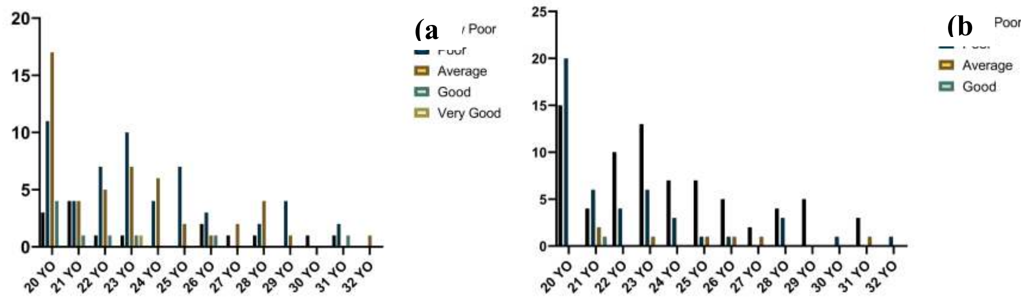

Figure 3. Relationship of 60 Meter Running Speed (a) and Bleep Test (b) Categories with Age

Figure 3a illustrated the relationship between 60-meter sprint performance, representing anaerobic capacity, and age category (20–32 years). Younger participants, particularly those aged 20–24 years, dominated the "Poor" and "Average" categories, with a small proportion achieving "Good" and "Very Good" performance. In contrast, participants aged 25 years and older were predominantly classified as "Very Poor," suggesting a decline in anaerobic capacity with increasing age. Figure 3b showed the relationship between bleep test performance, representing aerobic capacity, and age category (20–32 years). Participants aged 20–24 years dominated the "Very Poor" and "Poor" categories, indicating limited aerobic capacity in younger age groups. As age increased, particularly among those aged 25 years and older, participants were largely concentrated in the "Very Poor" category, suggesting a further decline in aerobic capacity with aging.

Discussion

This study unveils the complex relationship between somatotype, body mass index (BMI), and physical capacity in adolescent females, with significant implications for evidence-based fitness program design. The key findings indicate that the ectomorph somatotype dominates both aerobic (bleep test) and anaerobic (60-meter sprint) performance, despite the contrasting physiological characteristics of these activities. In the 60-meter sprint test, ectomorphs achieved performance ratings ranging from "Fair" to "Good" (Figure 1a), which may be attributed to an optimal strength-to-weight ratio. Their lean body structure minimizes motion inertia, facilitating rapid acceleration despite relatively low muscle mass (Carter et al., 2022). However, the superiority of mesomorphs in the "Good" and "Very Good" categories (Figure 1a) underscores the crucial role of muscle composition in anaerobic activity.

Skeletal muscle comprises two primary fiber types: slow-twitch (Type I) and fast-twitch (Type II), which differ in contractile properties and metabolic characteristics (Head & Arber, 2013; Duan et al., 2017). These muscle fiber types play a crucial role in athletic performance and metabolic health. Slow-twitch (Type I) fibers are predominant in endurance athletes, whereas fast-twitch (Type II) fibers dominate in strength-based athletes (Plotkin et al., 2021). Trappe et al. (2015) found that sprinters exhibit a high proportion of fast-twitch fibers, particularly myosin heavy chain IIx (MHC IIx), in their leg muscles. MHC IIx muscle fibers demonstrate responsiveness to high-intensity training at the transcriptional level for genes involved in muscle growth and remodeling. Understanding the genetic determinants of muscle fiber composition is essential, as they have significant implications for athletic performance, metabolic health, and cardiovascular disease risk (Ahmetov et al., 2012)

Meanwhile, endomorphs encounter biomechanical and metabolic challenges, as individuals with this somatotype are at a higher risk of metabolic syndrome, which can negatively impact overall physical capacity (Kusumaningnastiti et al., 2019; Romanova et al., 2022). In the aerobic test (bleep test), the superiority of ectomorphs (50.6% in the "Fair-Good" category; Figure 1b) aligns with their physiological characteristics. Ectomorphs tend to have lower body weight, fat percentage, and lean mass compared to endomorphs and mesomorphs. In aerobic capacity tests, ectomorphs exhibit lower peak oxygen uptake and higher lactate concentrations during peak exercise (Bolonchuk et al., 2000). However, ectomorphy has been positively correlated with aerobic fitness, sprinting performance, and improved aerobic capacity (Nikbakht, 2011). Marta et al. (2013) also reported that in preadolescent children, ectomorphy positively influences sprinting performance and aerobic fitness development. Conversely, endomorphs performed in the "Very Poor" category in the bleep test. These findings suggest that adolescents with an endomorphic body type, characterized by higher body fat, exhibit lower cardiorespiratory fitness compared to their normal-weight counterparts (Minatto et al., 2016). Other studies by Zhou (2021) and Chaeroni et al. (2024) indicate that an increase in BMI is negatively associated with VO_2 Max, a key indicator of aerobic capacity.

Normal BMI has been shown to be a predictor of optimal physical performance in both tests. Participants with normal BMI dominated the "Good" category for the 60-meter sprint (Figure 2a) and demonstrated the best distribution in the bleep test (43.6% in the "Fair-Good" category; Figure 2b). Normal BMI implies a complex interaction between somatotype and body composition, although ectomorphs exhibited superior performance. For instance, ectomorphs tend to have lower fat mass even within the normal BMI range, maximizing their strength-to-weight ratio. Sedeaud et al. (2014) explained that BMI serves as a significant performance indicator in sports, where lighter and smaller athletes (ectomorphs) excel in endurance sports, whereas heavier and taller athletes (endomorphs) perform better in sprinting events. Studies by La Kamadi et al. (2019) and Tsukru & Rhetso (2023) also demonstrated that normal BMI is positively correlated with better physical capacity in running performance.

On the other hand, participants with overweight/obese BMI were concentrated in the "Very Poor" category in both tests (Figures 2a–2b), reinforcing the findings of Das et al. (2024) that excess adiposity impairs mitochondrial function by increasing oxidative stress and intramuscular lipid accumulation. This condition reduces anaerobic capacity by limiting phosphocreatine ATP synthesis and decreases aerobic capacity by disrupting insulin-glucose signaling. The decline in physical capacity observed at the age of 24 (Figures 3a–3b) indicates a critical transition in late adolescent physiology. Furthermore, after the age of 25, the deterioration in anaerobic performance ("Very Poor" category) may be linked to declining levels of growth hormone (GH) and testosterone, which reduce muscle protein synthesis.

This study highlights the importance of considering somatotype and BMI when designing fitness programs for adolescent females. A tailored approach based on individual characteristics can not only enhance physical performance but also potentially promote long-term participation in physical activities, which is crucial for overall health and well-being. Further research is needed to explore specific interventions that optimize physical performance across different somatotypes and BMI categories, as well as to deepen our understanding of the physiological mechanisms underlying these performance differences.

Conclusions

This study provides valuable insights into the complex relationship between somatotype, body mass index (BMI), and physical performance in adolescent girls. The key findings indicate that the ectomorph somatotype exhibits advantages in both aerobic and anaerobic capacity, while a normal BMI serves as a strong predictor of optimal physical performance. Ectomorphs demonstrate superior performance in the 60-meter sprint and the beep test, outperforming mesomorphs and endomorphs. A normal BMI positively correlates with better physical performance in both anaerobic and aerobic capacity. In contrast, overweight and obesity significantly impair physical performance, particularly in aerobic capacity.

This study also highlights the importance of an individualized approach in designing fitness programs for adolescent girls by considering their somatotype and BMI. A decline in physical performance is observed after the age of 24, suggesting significant physiological changes during late adolescence. Muscle fiber composition and metabolic efficiency play crucial roles in determining physical performance across different somatotypes. These findings may serve as a foundation for developing more effective intervention strategies to enhance adolescent girls' fitness and overall health. Further research will be needed to explore the physiological mechanisms underlying these performance differences and to develop targeted interventions for different somatotypes and BMI categories.

Conflicts of interest - The authors declare no conflict of interest

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