European Journal of Sport Sciences
Vol 4 | Issue 4 | August 2025
ISSN 2796-0048

RESEARCH ARTICLE

Body Mass Index and Sport Type as Predictors of Strength, Power, and Agility in Adolescent Athletes: A Cross-Sectional Study

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ABSTRACT

This Body Mass Index (BMI) is a commonly used anthropometric measure in youth athletic evaluations. However, its utility in predicting physical performance outcomes among trained adolescent athletes remains unclear, especially when considering the influence of sport type. This study aimed to examine the interrelationships between BMI and key physical performance attributes—upper body strength, lower body strength, lower body power, and agility—in adolescent athletes. A secondary objective was to compare performance profiles between contact and non-contact sport athletes and evaluate BMI's predictive utility. A cross-sectional study was conducted with 198 adolescent athletes (mean age 15.19 ± 1.33 years) from contact (boxing, wrestling, soccer) and non-contact (track and field, Chinese martial arts) sports. Anthropometric data and physical performance metrics were collected, including 1RM bench press, 1RM squat, standing long jump, and T-agility test. Correlation and regression analyses evaluated BMI's association with performance outcomes. Independent sample t-tests assessed group differences by sport type. BMI was moderately associated with upper body strength ($r = 0.41$) and weakly with lower body strength ($r = 0.31$) but showed no significant relationship with lower body power or agility ($p > 0.2$). Regression models indicated that BMI accounted for 16.8% of the variance in upper body strength and 9.9% in lower body strength. Contact sport athletes exhibited significantly greater strength and power than non-contact athletes ($p < 0.05$), but no significant group differences in agility or BMI were observed. While BMI may serve as a partial proxy for upper-body strength in adolescent athletes, it lacks sensitivity for evaluating agility and power. Sport type appears to be a stronger determinant of performance profiles than BMI. These findings suggest that BMI should not be used in isolation for athletic talent identification or performance prediction. Sport-specific and functional assessments are recommended to guide training and development in youth sports.

Submitted: June 25, 2025

Published: August 07, 2025

10.24018/ejsport.2025.4.4.244

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Keywords: Adolescent athletes, body composition, BMI, strength.

1. Introduction

Body Mass Index (BMI) is a widely used anthropometric measure in clinical and athletic settings to assess weight status relative to height (Nuttall, 2015). It serves as a general indicator of body morphology and nutritional status, both of which are closely linked to fat composition, long-term health outcomes, and disease risks (Jingya *et al*., 2013). BMI is also widely employed as a screening tool in health evaluations and large-scale epidemiological surveys conducted by health professionals (Chinn, 2006).

Prior research has explored the relationship between BMI and various components of physical fitness, such as strength, power, and agility, in the general pediatric and adolescent populations. Studies have often shown that a higher BMI score is associated with reduced motor skill proficiency and a lower level of overall physical fitness in youth (Graf *et al*., 2004; Okely *et al*., 2004; Raudsepp & Jürimäe, 1997). However, these studies frequently excluded trained adolescent athletes whose performance profiles and body composition differed substantially from their non-athletic peers. Furthermore, few studies have concurrently examined how BMI correlates with multiple key performance attributes, especially upper body strength, lower body strength, lower extremity power, and agility, within sport-specific adolescent populations.

The relationship between BMI and athletic performance remains inconsistent across studies. Several studies have suggested that higher BMI, when attributed to lean muscle mass, is associated with enhanced strength performance (Chen *et al*., 2025; Haugen *et al*., 2019; Sun *et al*., 2025; Wang *et al*., 2023). In contrast, other studies indicate that excessive BMI due to increased fat mass may impair movement efficiency, reduce agility, and limit explosive power in young athletes (Rolland *et al*., 2004; Sung *et al*., 2022; Zoico *et al*., 2004). In addition, studies by Zaccagni and Tiggemann have raised concerns that BMI alone may not capture sport-specific physique ideals or psychological consequences (Tiggemann, 2005; Zaccagni & Gualdi-Russo, 2023). Their study reported that female athletes in leanness-promoting sports, such as track and field, exhibited significantly higher body dissatisfaction despite having similar BMI levels. It highlights the role of sports culture and internalized psychological messaging in shaping body image concerns.

Evidence from elite track and field athletes further illustrates the complexity of BMI as a performance metric. For example, BMI has been shown to correlate positively with sprinting speed, whereas lower BMI values are more common in endurance-based events. These findings suggest that optimal performance is shaped by discipline-specific biometric profiles (Sedeaud *et al*., 2014). Additionally, variations in physical demands across different sport types, such as contact sports (e.g., wrestling, soccer, boxing) vs. non-contact sports (e.g., track and field, martial arts), may contribute to divergent athlete profiles. Contact sports generally prioritize muscular strength and mass, whereas non-contact sports focus on speed, agility, and body control. Research from Sedeaud also found that high-level performance was associated with progressively narrower BMI variability, indicating that each sport may favor a specific physique profile (Sedeaud *et al*., 2014). A study conducted by Lotan *et al*. identified an association between BMI, body weight, and traumatic long-bone fractures in healthy adolescents, especially in the male population (Lotan *et al*., 2023). Another study of 152 football players showed that overweight players who had a previous ankle sprain were 19 times more likely to sustain a noncontact ankle sprain than a normal-weight player with no previous ankle sprain (Tyler *et al*., 2006). However, it remains unclear whether these sport-specific demands influence the relationship between BMI and performance outcomes in adolescents.

It is important to note that a growing need for rapid and cost-effective methods to evaluate and predict the physical performance of adolescent athletes. Within school-based settings, financial and logistical constraints often limit access to advanced testing tools, such as force plates, motion capture systems, or dual-energy X-ray absorptiometry. Many high schools operate under restricted budgets and have to manage large numbers of athletes, which makes comprehensive physiological evaluations impractical (Li, 2015). Therefore, simple, accessible, and reliable anthropometric measures such as BMI may serve as practical proxies for assessing performance-related traits. These cost-effective approaches are essential for supporting talent identification, individualized training design, and injury prevention strategies in youth sports programs.

The primary objective of this study was to investigate the relationship between BMI and upper and lower body strength, lower extremity power, and agility in adolescent athletes from various sports. A secondary aim was to compare performance profiles between contact and non-contact sports athletes to determine whether sport type moderates the association between BMI and performance outcomes. Finally, this study aimed to evaluate the potential utility of BMI as a predictive tool for assessing physical performance in adolescent athletes.

2. Methods

2.1. *Participants*

Our study examined a sample of adolescent athletes from a local high school in the Shan Dong Province, China. A total of 220 adolescent athletes (mean age 15.19 ± 1.33 years) were initially recruited. All participants were members of their school's varsity team and had at least one year of consistent training in their respective sports. At the time of the study, all the athletes were actively training or competing. Informed consent was obtained from all participants and their guardians, in accordance with institutional ethics.

2.2. *Screening Protocol*

A licensed medical professional conducted a pre-participation physical evaluation to ensure participant safety and apply consistent selection criteria. Physical screening included a review of medical history and a comprehensive examination to identify any pre-existing conditions or injuries that could interfere with test performance or pose a risk during testing. Muscular strength, reflexes, and sensory abilities were evaluated, and orthopedic examinations were conducted with a primary focus on the cervical, thoracic, and lumbar spines. The participants with a history of significant injury or surgery underwent further evaluation. Only athletes who received full medical clearance were included in this study. Following screening, 198 participants met all eligibility criteria and were included in the final analysis.

2.3. Testing Protocol

Each participant began the test day with a standardized early morning anthropometric evaluation. Height was measured by the athletes standing against the wall. A stadiometer was used to measure the distance from the foot bottom to the head top. Body weight and composition were measured using Inbody 770 (Beverly Hills, California, USA) according to the manufacturer's instructions (Zhang *et al*., 2024). The athletes were instructed to perform these measurements without consuming food or liquids. Participants were permitted to have a light meal or snack after the anthropometric evaluation. However, 30 minutes before the physical performance test, no food was permitted.

All physical tests were conducted under standardized conditions on an indoor hardwood surface. Before testing, each participant completed a dynamic warm-up led by a professional strength conditioning coach. The warm-up program included mobility exercises, mild squats, and jogging for five–seven minutes. Testing followed a predetermined sequence, and a rest period of three–five minutes was provided between each test to minimize fatigue and ensure maximum effort.

T- Agility Test

The T-agility test was performed following a modified version of the protocol described by Semenick (Maffiuletti *et al*., 2007). Four cones were arranged in a T-shape on the testing field, and white tape was used to mark the route between each cone. On the T-shaped straight line, three bells were positioned on top of the cone. Following a 9-meter sprint, the competitors shuffled 4.5 meters to the left and right before returning to the center and backpedaling to the starting line. The timer began when the subject crossed the starting line and stopped when the subject crossed the finish line. If a participant did not ring the bell atop each cone, or if they crossed their feet while shuffling and did not face forward, the test was repeated.

Standing Long Jump Test

The standing long jump was used to gauge the horizontal force (Akbar *et al*., 2022; Black *et al*., 2010; Hasan *et al*., 2016). Every athlete underwent testing on an indoor stadium track. The rope ruler is located along the side of the leaping area. White tape was used to mark the starting position, and the subjects began behind it. A marker was positioned behind the athlete's heel, and the athletes were told to execute a front leap as best as possible. To the closest 0.1 m, the best of three trials was recorded.

One-Repetition Maximum (1RM) Squat Test

The 1RM back squat was used to determine the maximum lower-body strength. Prior to attempting larger lifts, the athletes completed a warm-up session consisting of 5–10 repetitions at approximately 60% of their anticipated maximum. Three spotters were used for safety purposes. The feet were spaced shoulder-width apart and rotated externally from 15° to 30°. The squat was considered legitimate only when the top of the thigh fell below the parallel. Up to three attempts per weight were made by each athlete until failure with increasing weight. The largest successful lift was also noted.

One-Repetition Maximum (1RM) Bench Press Test

Upper body strength was measured using a 1RM bench press (kg) (Black *et al*., 2010; Sung *et al*., 2022). The athletes were permitted to perform two heavier sets of three to five repetitions using heavier weights, and one warm-up set of five to ten repetitions with various loads. The starting point for the athletes' bench press exercise was 85% of the most recent maximum load. Until they failed, they were permitted to add weight to their favor. Failure results from any inability to finish the test or from using the wrong method. One RM bench press (kg) divided by body mass (kg), multiplied by 100, and expressed as a percentage was used to determine the athlete's relative upper body strength.

Fig. 1 illustrates the participant flow diagram, outlining recruitment, physical screening, testing procedures, and inclusion in the final analysis.

2.4. Statistical Analysis

All statistical analyses were performed using the IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (means and standard deviations) were calculated for the primary variables: BMI**,** upper body strength (1RM bench press in kg), lower body strength (1RM squat in kg), lower body power (standing long jump distance in m), and agility (measured in seconds).

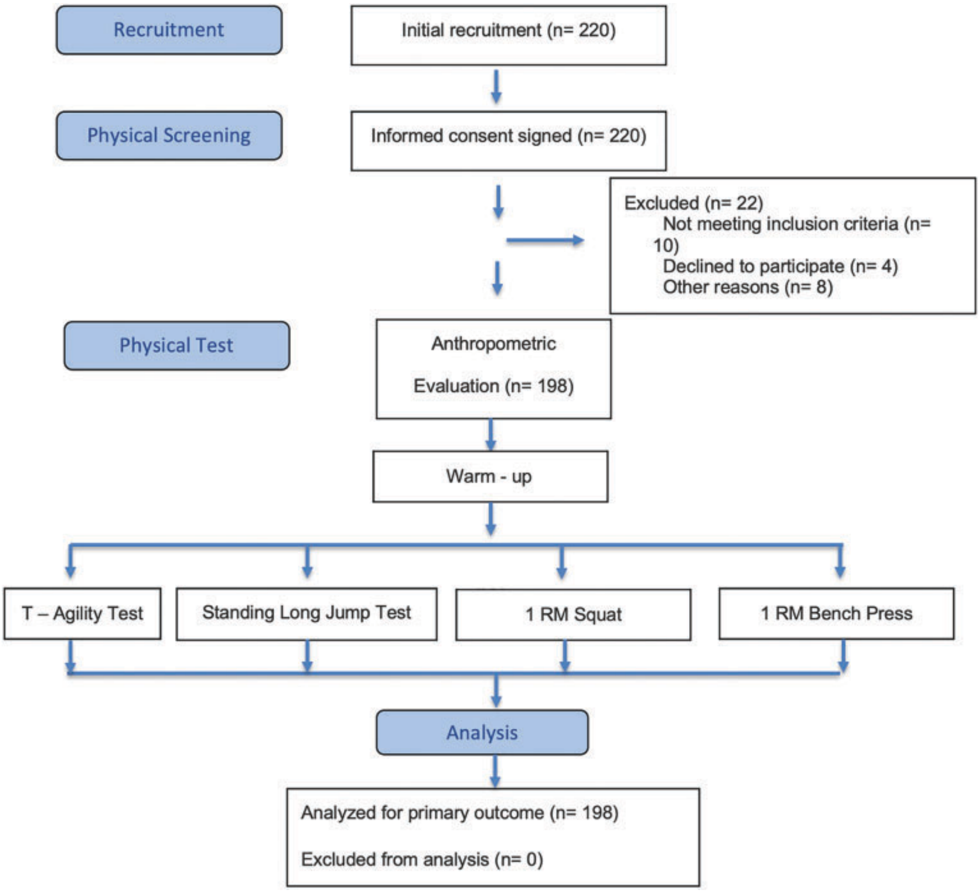

Fig. 1. Flow diagram of subject recruitment, testing, and analysis.

Pearson's correlation coefficients were used to evaluate the relationship between BMI and each performance variable. Correlation strength was interpreted as weak ($r < 0.3$), moderate ($0.3 \leq r < 0.5$), or strong ($r \geq 0.5$).

To evaluate the predictive value of BMI, a series of simple linear regression analyses was conducted, with BMI as the independent variable and upper body strength, lower body strength, lower body power, agility, and age as dependent variables. For each model, the unstandardized regression coefficient (B), intercept, coefficient of determination (R^2), and p-values are reported. The R^2 value was used to assess the proportion of variance in the dependent variable explained by the BMI.

Group differences between contact and non-contact sports athletes were evaluated using independent sample t-tests, comparing means for BMI, upper and lower body strength, lower extremity power, and agility. Cohen's d effect sizes were calculated to estimate the magnitude of group differences, which were interpreted as small ($d = 0.20$), medium ($d = 0.50$), or large ($d \geq 0.80$). All statistical tests were two-tailed and interpreted using a significance threshold of $p < 0.05$.

3. Results

In total, 198 adolescent athletes were included in the final analysis. The descriptive statistics for all variables are presented in Table I. The \ mean BMI was 21.06 ± 4.25, and the mean age was 15.19 ± 1.33 years. The mean upper body strength (1RM bench press) was 52.85 ± 18.46 kg, and the mean lower body strength (1RM squat) was 102.45 ± 30.07 kg. Lower extremity power, assessed via standing long jump, averaged 2.29 ± 0.32 m, and agility performance averaged 6.05 ± 0.78 seconds.

As shown in Table II, the majority of adolescent athletes in both sports fell within the normal BMI range. A slightly higher proportion of non-contact sport athletes had normal BMI values than their contact sport counterparts (93.6% vs. 84.5%). Among contact sport athletes, 9.5% were classified as overweight and 6.0% as obese, whereas only 1.2% and 2.4% of non-contact athletes were categorized as overweight and obese, respectively. The BMI classifications were defined as normal (<25), overweight (25–29.9), or obese (≥30). Values are presented as frequencies (percentages of the total group).

Pearson's correlation analysis revealed a moderate positive correlation between BMI and upper body strength ($r = 0.41$) and a weak positive correlation with lower body strength ($r = 0.31$). BMI showed no significant correlation with lower body power ($r = -0.07$), agility ($r = 0.09$), or age ($r = 0.08$).

TABLE I: Descriptive Statistics for Study Variables (N = 198)

Variable	Mean ± SD
Age (years)	15.19 ± 1.33
BMI	21.06 ± 4.25
Upper body strength (kg)	52.85 ± 18.46
Lower body strength (kg)	102.45 ± 30.07
Lower body power (m)	2.29 ± 0.32
Agility (s)	6.05 ± 0.78

TABLE II: Distribution of BMI Categories by Sport Type

BMI category	Contact sport (n = 116)	Non-contact sport (n = 82)
Normal	98 (84.5%)	79 (96.3%)
Overweight	11 (9.5%)	1 (1.2%)
Obese	7 (6.0%)	2 (2.4%)

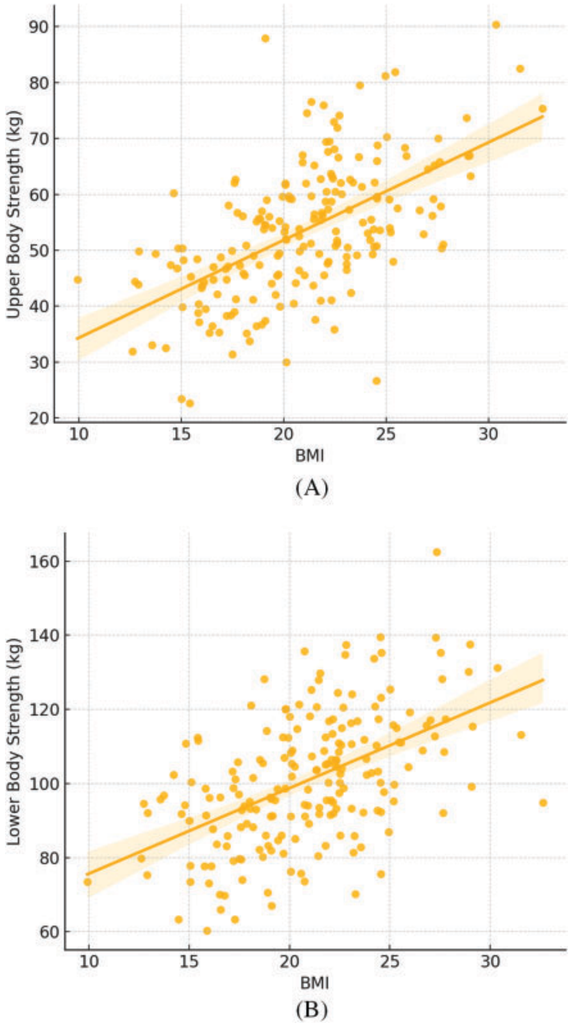

Fig. 2. (A) BMI vs Upper body strength. (B) BMI vs. Lower body strength.

Simple linear regression models were used to assess the predictive capacity of BMI for each performance outcome. The model predicting upper-body strength was statistically significant and explained 16.8% of the variance.

Upper Body Strength (kg) = 1.78 × BMI + 15.42 ($R^2 = 0.168$, $p < 0.001$)

BMI was also a modest predictor of lower body strength:

Lower Body Strength (kg) = 2.22 × BMI + 55.61 ($R^2 = 0.099$, $p = 0.004$)

In contrast, the models for lower body power and agility were not statistically significant ($R^2 < 0.01$, all $p > 0.2$), suggesting that BMI does not predict these outcomes in this population. Fig. 2 illustrates the correlation between BMI and both upper and lower body strength.

TABLE III: Group Comparison of Contact and Non-Contact Sport Athletes on Physical Performance

Variable	Contact mean (SD)	Non-contact mean (SD)	p-value	Cohen's *d*
BMI	21.23 (± 4.45)	20.81 (± 3.96)	0.479	0.10
Upper body strength (kg)	57.84 (± 18.80)	45.79 (± 15.51)	<0.001	0.69
Lower body strength (kg)	106.34 (± 27.72)	96.95 (± 32.49)	0.035	0.32
Lower body power (m)	2.17 (± 0.19)	2.26 (± 0.31)	0.030	−0.34
Agility (s)	6.38 (± 0.77)	6.35 (± 0.67)	0.804	0.04

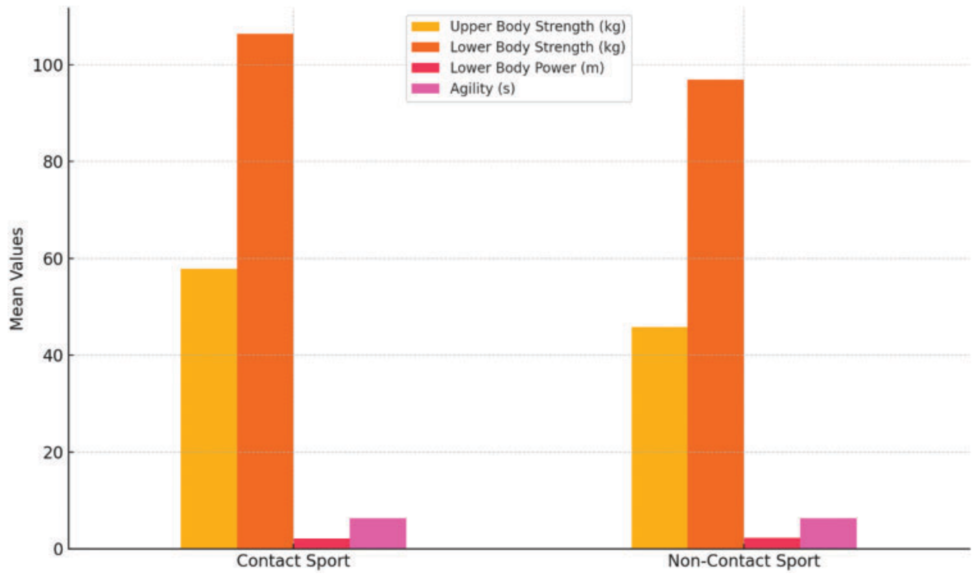

Fig. 3. Performance metrics contact sport vs Non-contact sport.

Group comparisons between contact and non-contact sports athletes are summarized in Table III. Athletes in contact sports demonstrated significantly greater upper body strength ($p < 0.001$, Cohen's $d = 0.69$), lower body strength ($p = 0.035$, $d = 0.32$), and lower body power ($p = 0.030$, $d = -0.34$). No significant differences were found for BMI ($p = 0.479$) or agility ($p = 0.804$). To further illustrate the differences in performance between contact and non-contact sports athletes, Fig. 3 presents a visual comparison across the four key metrics.

4. Discussion

The results of our study showed that participants demonstrated a normal BMI range in both the contact and non-contact sports groups. This result aligns with previous findings that sports participation is associated with a decreased likelihood of obesity (Baleilevuka-Hart *et al.*, 2024). However, our results contrast with prior research, which stated that the trend of physical fitness among Chinese students is declining (Tian *et al.*, 2016). Additionally, our findings revealed a higher proportion of overweight and obese individuals in contact sports than in non-contact sports. This discrepancy may reflect the sport-specific morphological demands of disciplines in wrestling, boxing, and soccer, where increased lean muscle mass can confer a mechanical advantage to physical confrontations, resistance-based movements, and postural control. Importantly, BMI does not differentiate between fat and muscle mass, and elevated values in this context likely reflect muscular hypertrophy, rather than adiposity. This limitation highlights the need for sport-specific body composition analysis, such as the muscle-to-fat ratio, to accurately assess athletic conditioning. In contrast, the lower BMI observed in non-contact athletes aligns with the physiological demands of Track and Field and Chinese Martial Arts, which emphasize agility and speed over size and strength (Chen *et al.*, 2025; Haugen *et al.*, 2019; Sun *et al.*, 2025). These athletes likely benefit from a leaner physique, which can optimize the relative strength-to-weight ratios and minimize inertia during rapid directional changes.

The moderate correlation between BMI and upper-body strength ($r = 0.41$) suggests that increased body mass, presumably reflecting greater muscle mass in trained adolescents, may enhance upper-body force production. This interpretation aligns with prior findings that lean mass, rather than total body weight, is the primary driver of muscular strength (Rolland *et al.*, 2004; Sung *et al.*, 2022; Wang *et al.*, 2023; Zoico *et al.*, 2004). The regression model in this study showed that BMI accounted for approximately 17% of the variance in upper-body strength, which, while modest, underscores its potential value as a preliminary screening measure in youth populations lacking access to advanced tools. However, BMI does not capture regional hypertrophy or distinguish between muscle and fat compartments, limiting its precision in the evaluation process. A study conducted by Wang *et al*. reported that body composition impacted three aspects of upper-limb physical fitness, especially grip strength and anaerobic power (Wang *et al*., 2023). Interestingly, other studies in adult populations have shown that obese individuals may exhibit greater absolute muscle strength, but reduced relative strength and functional efficiency, especially in tasks requiring bodyweight support (Rolland *et al*., 2004). These findings highlight the complex interplay between absolute mass, strength capacity, and sport-specific demands, highlighting the need for future studies using tools such as DEXA, ultrasound, or segmental BIA to isolate lean mass contributions to strength performance in young athletes.

The weaker correlation between BMI and lower body strength ($r = 0.31$, $R^2 = 0.099$) indicates that BMI has only limited predictive value for lower extremity force production. While greater body mass may lead to mechanical loading adaptations over time, particularly in weight-bearing joints such as the hips and knees, strength development in the lower body is highly dependent on neuromuscular factors, including motor unit recruitment patterns, intermuscular coordination, and muscle-tendon stiffness. These elements were not captured by BMI. Furthermore, although excess body mass may stimulate muscle hypertrophy via chronic loading, it can also introduce metabolic inefficiencies, particularly if a large proportion of the mass is composed of adipose tissue. Studies in obese youth have found increased quadriceps strength, likely due to load adaptation, while others have reported reduced power output when normalized to body weight (Hasan *et al*., 2016; Maffiuletti *et al*., 2007). Lafortuna *et al*. observed lower muscle quality and power output in obese subjects, likely because of higher intramuscular fat infiltration, which can impair contractile efficiency (Maffiuletti *et al*., 2007). Similarly, Maffiuletti and colleagues reported that elevated intramuscular fat might inflate the cross-sectional area without enhancing actual force production (Maffiuletti *et al*., 2007). These discrepancies highlight the importance of distinguishing between functional and non-functional masses. In adolescent athletes, variations in growth, maturity status, and hormonal milieus, such as estrogen and progesterone levels, may further modulate muscle development (Reis *et al*., 1995; Sung *et al*., 2014). Thus, BMI alone may be insufficient to explain lower-body strength differences, particularly in dynamic sports contexts.

Unlike strength measures, BMI was not significantly associated with lower-extremity power or agility in this study. This result illustrates the limitations of BMI as a non-specific anthropometric index that fails to capture critical components of performance, such as neuromuscular efficiency, rate of force development, and motor coordination. Dynamic performance traits, such as jump distance and agility, are influenced not only by muscular strength but also by velocity-specific neural activation patterns, segmental limb proportions, and proprioceptive control. For example, athletes with similar BMI values may differ significantly in tendon elasticity, ground contact time, or intersegmental coordination, all of which directly affect jump and agility performance. Our results contrast with those of previous studies that reported a negative correlation between BMI and explosive power or jump performance in overweight adolescents (Lopes *et al*., 2019). However, these studies often lacked control for the training background and maturity levels. Performance outcomes, such as jumping ability and agility, are more sensitive to neuromuscular efficiency, limb length ratios, and motor control than simply body size or mass (Akbar *et al*., 2022; Black *et al*., 2010; Bosco *et al*., 1982; Lamas *et al*., 2012). This suggests that while BMI may reflect generalized mass-related adaptations, it does not adequately capture the functional and biomechanical qualities underpinning high-speed movement, especially in sports that require quick acceleration, deceleration, and directional change.

Comparative analyses between contact and non-contact sports athletes revealed greater upper and lower body strength in contact sports and greater lower body power in non-contact sports. These findings likely reflect sport-specific adaptations, as contact sports generally involve frequent resistance-based movements, physical collisions, and a greater emphasis on muscular development. Interestingly, despite these differences, no group disparities were found in terms of agility performance or BMI. The lack of difference in agility suggests that, regardless of sport type, agility may be influenced more by individual motor skills training than by sport classification. Likewise, the similarity in BMI across groups highlights its limited utility in capturing training-specific physiological adaptations.

However, prior studies have reported that a higher BMI is associated with reduced levels of physical performance in adults and walking speed (Visser *et al*., 1998; Woo *et al*., 2007). In our results, the contact sports group has higher BMI compared to the non-contact sports group, and they tend to have better upper body strength (57.84 ± 18.80 vs 45.79 ± 15.51) and lower body strength (106.34 ± 27.72 vs 96.95 ± 32.49). Notably, the non-contact sports group with lower BMI had better performance in terms of lower body power (2.26 ± 0.31 vs 2.17 ± 0.19). This observation can be interpreted through Newton's law (Power = Force × velocity), where jumping performance reflects both speed and strength. Recent frameworks on ballistic performance emphasize the importance of the force-velocity (f-v) profile, with optimal performance occurring when the force and velocity are appropriately balanced (Morin & Samozino, 2016; Samozino *et al*., 2008, 2012, 2013). These findings suggest that sport type and the specific neuromuscular demands it imposes may play a more critical role than BMI in determining the strength and power outcomes in adolescent athletes.

Collectively, these findings highlight the need for more precise assessment tools for evaluating the physical performance of adolescent athletes. Although BMI may offer some predictive utility for upper-body strength owing to its partial reflection of muscle mass, it is inadequate for capturing dynamic performance attributes such as power and agility. Future studies should consider including measures such as fat-free mass, segmental muscle volume, or sport-specific training history to better capture the determinants of athletic performance.

Limitations:

Several limitations of this study should be considered when interpreting these findings. First, sport-specific training history, nutritional status, and pubertal maturation were not assessed, which may have influenced physical performance and confounded relationships with BMI. These variables need to be assessed in future analyses so that individual variability can be better illustrated. Second, the cross-sectional design precludes causal inferences between BMI and performance outcomes. Longitudinal studies would be better to evaluate how changes in body composition over time influence strength, power, and agility development in young athletes. Finally, our sample included adolescent athletes from five sports, which may limit the generalizability of the findings to other sports. Future studies should include a wider variety of sports to enhance the external validity.

Practical Applications:

This study provides important insights for coaches, athletic trainers, and sports scientists working with adolescent athletes. While BMI can offer a rough estimate of body size, it should not be used as a standalone measure to evaluate athletic potential or physical fitness. Clinical practitioners should prioritize functional assessments and body composition analysis over BMI to identify performance capabilities and tailor strength and conditioning programs more effectively. In particular, contact sports athletes may benefit from targeted strength and hypertrophy programming, and non-contact athletes might focus more on speed, agility, and power development, which aligns with their sport-related demands. Moreover, the findings highlight that sport type is a stronger predictor of performance traits than BMI is. Therefore, individualized training strategies should account for the specific neuromuscular and metabolic demands of each sport rather than rely on generalized anthropometric metrics.

5. Conclusion

Our study found that BMI was moderately associated with upper-body strength and weakly associated with lower-body strength among adolescent athletes. However, there was no significant association between BMI and lower-body power or agility. Additionally, athletes in contact sports demonstrate greater strength and power than those in non-contact sports. Therefore, we can conclude that BMI may offer some predictive value for upper body strength; however, it appears insufficient for evaluating overall athletic performance. Based on the present findings, future studies should utilize a longitudinal method and focus on sport-specific demands when assessing adolescent athletic performance.

Funding

Authors declare that they do not receive any funding.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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