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BODY MASS INDEX AS A PREDICTOR OF VERTICAL POWER, AGILITY AND LOCAL MUSCULAR ENDURANCE IN SCHOOL -AGED GIRLS

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Abstract: Excess body mass in pediatric populations acts as a significant biomechanical constraint, potentially compromising the acquisition of fundamental motor skills and neuromuscular performance. Objective: This study aimed to examine the relationship between Body Mass Index (BMI) and specific motor performance indicators in school-aged girls, with a particular focus on the dissociated effect of body mass on core musculature. Methods: A cross-sectional study was conducted on 60 female students aged 8 to 10 years (9.2 ± 0.6 years). Somatic characteristics were assessed, and motor performance was evaluated using four standardized tests: 20m Coordination Test (agility), Counter Movement Jump (vertical power), 30s Sit-ups (abdominal endurance), and 30s Trunk Extensions (posterior chain endurance). Data normality was confirmed, and Pearson's correlation coefficient (r) was used for analysis. Results: BMI acted as a significant negative predictor for all weight-bearing tasks. Strong correlations were observed for agility ($r = 0.582$, $p < .001$) and vertical power ($r = -0.495$, $p < .001$). The most severe penalty was found in abdominal endurance ($r = -0.612$, $p < .001$), where BMI explained 37.5% of the performance variance. Conversely, no statistically significant correlation was found for the trunk extension test ($p > .05$). Conclusion: Excess body mass imposes a significant mechanical constraint ("dead weight" effect) on vertical power and agility. Furthermore, BMI differentially affects local muscular endurance; while anterior chain performance is severely compromised, posterior chain function appears preserved, potentially due to the chronic functional loading of the erector spinae muscles required for postural stabilization in heavier children.

Key words: Body Mass Index, Motor Competence, Vertical Power, Biomechanical Constraints, Posterior Chain.

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INTRODUCTION

Childhood obesity has become one of the most pressing public health challenges of the 21st century, with global prevalence rates rising alarmingly among school-aged children (NCD Risk Factor Collaboration, 2017; World Health Organization, 2021). Beyond the well-documented metabolic and cardiovascular risks, excess adipose tissue has profound implications for the development of motor competence and physical fitness (Cattuzzo et al., 2016). The pre-pubertal period (8–10 years) is considered a critical window for the acquisition of fundamental movement skills, yet an increasing number of children are entering this phase with suboptimal body composition, potentially hindering their athletic development (Stodden et al., 2008).

The relationship between Body Mass Index (BMI) and motor performance is generally inverse, particularly in tasks requiring the displacement of the body's center of mass (D'Hondt et al., 2009). Biomechanically, excess body mass acts as a non-functional load - often described as a "dead weight"- which increases the inertial resistance during locomotion and jumping (Castro-Piñero et al., 2010; Malina et al., 2004). Previous research has extensively documented that children with higher BMI perform significantly worse in weight-bearing activities such as running and jumping compared to their normoweight peers (Lubans et al., 2010; Tokmakidis et al., 2006). This phenomenon is explained by Newton's second law of motion (F=m x a), implying that to achieve the same acceleration, a heavier child must generate significantly higher ground reaction forces (Dragoș et al., 2025; Zatsiorsky & Kraemer, 2006).

While the negative correlation between BMI and general aerobic fitness is well established (Tomkinson et al., 2018), the literature presents more nuanced findings regarding specific neuromuscular components such as explosive power and local muscular endurance. For instance, while absolute muscle strength may be higher in overweight children due to the chronic stimulus of carrying extra weight, their relative power (power-to-weight ratio) is often compromised (Artero et al., 2011; Mookerjee et al., 2016). Furthermore, standardized field test batteries, such as Eurofit, include items like sit-ups and agility shuttles, which heavily penalize body mass (Fjørtoft et al., 2011). However, fewer studies have simultaneously analyzed the contrast between anterior chain endurance (e.g., abdominal sit-ups) and posterior chain function (e.g., back extensions) in relation to somatic constraints.

Therefore, the aim of this study was to examine the influence of Body Mass Index on specific components of the speed-power profile and local muscular endurance in pre-pubertal girls. Specifically, we analyzed the correlations between BMI and performance in vertical power (Counter Movement Jump), complex agility (20m coordination), and core endurance, hypothesizing that BMI acts as a significant negative predictor for tasks involving vertical and horizontal body displacement (Markovic et al., 2004; Ortega et al., 2008).

METHODOLOGY

Participants

The study was conducted on a sample of 60 female school-aged children (N=60), aged between 8 and 10 years old (Mean age = 9.2 ± 0.6 years). The participants were recruited from the local school system and were assessed during the academic year. The study design was cross-sectional, treating the entire cohort as a single group to analyze the correlations between body composition and motor performance.Inclusion criteria were: (1) valid enrollment in the educational system, (2) active participation in regular physical education classes, and (3) absence of any musculoskeletal injuries or medical conditions that could impair motor performance in the six months preceding the study. All participants and their legal guardians provided written informed consent prior to the commencement of the study. The research procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki.

Anthropometric measurements were performed to determine Body Mass (kg) and Stature (m). Based on these values, the Body Mass Index (BMI) was calculated using the standard formula (kg/m2).The descriptive statistics for the entire sample are presented in (table 1). The data indicates a wide range of somatic characteristics, providing sufficient variability to examine the influence of BMI on physical

Table 1. Descriptive Statistics of the Participants (N=60)

Variable	*Mean ± SD*	*Minimum*	**Maximum**
Age (years)	9.2 ± 0.6	8.0	10.0
Body Mass (kg)	28.57 ± 7.55	18.0	57.0
Stature (m)	1.30 ± 0.09	1.15	1.64

Motor Performance Assessment

The assessment protocol included four specific tests designed to evaluate coordination, explosive power, and trunk muscular endurance. All tests were administered in a gymnasium setting, under the supervision of the research team.

20m Complex Coordination Test

This test was designed to evaluate the participants' agility and hand-eye coordination under conditions of dynamic displacement.

Setup: A 10-meter linear track was marked. Two pairs of cones were placed at the 5-meter mark and the 10-meter mark (turnaround point). The cones in each pair were spaced 2 meters apart. A tennis ball was placed on one cone of each pair.

Protocol: Upon the auditory signal (whistle), the participant sprinted from the start line to the 5-meter mark, transferred the tennis ball from the first cone to the second cone, and continued to the 10-meter mark. At 10 meters, the participant transferred the second tennis ball, circled the right-side cone, and sprinted back. On the return leg, the participant stopped again at the 5-meter mark to transfer the ball once more before sprinting to the finish line.

Measurement: The time was recorded from the start signal until the participant's torso crossed the finish line. A single attempt was allowed, and the time was recorded in seconds.

Vertical Power: Counter Movement Jump (CMJ) Free Arms

Vertical explosive power was assessed using the OptoJump optical measurement system.

Protocol: The participant stood between the transmitting and receiving bars of the OptoJump system. The test involved a rapid downward movement (eccentric phase) followed immediately by a maximal vertical extension (concentric phase). Unlike the standard "hands-on-hips" protocol, participants were instructed to use a free arm swing to maximize the vertical impulse.

Measurement: The flight time was measured with a precision of 0.001 seconds and converted into jump height (cm). A single maximal attempt was recorded.

Local Muscular Endurance: Trunk Flexion (30s)

Abdominal strength and endurance were assessed using the 30-second sit-up test.

Setup: Participants started in a supine position (lying on the back) with knees bent at 90 degrees and feet secured flat on the floor by a partner. Hands were interlocked behind the neck.

Protocol: On the command "Ready... Start," the particip ant raised their trunk until it reached a vertical position and then returned to the starting position.

Measurement: The total number of correct repetitions completed in 30 seconds was recorded. The test was performed once.

Local Muscular Endurance: Trunk Extension (30s)

The strength and endurance of the back extensor muscles were evaluated using a timed hyperextension test.

Setup: Participants lay in a prone position (lying on the stomach) with arms extended overhead . A partner secured the participant's ankles to the ground

.Protocol: On the command "Ready... Start," the participant lifted their chest and upper trunk off the floor as high as possible and returned to the prone position.

Measurement: The total number of correct repetitions completed in 30 seconds was recorded. The test was performed once

Statistical Analysis

Statistical processing was performed using IBM SPSS Statistics (Version 28.0). Descriptive statistics (Mean ± Standard Deviation) were calculated for all variables. Data normality was verified using the Shapiro-Wilk test. Results indicated that all variables followed a normal distribution ($p > .05$), thereby justifying the use of parametric statistical methods for further analysis. To determine the association between body composition and physical fitness, the Pearson Product-Moment Correlation Coefficient (r) was calculated. Additionally, the Coefficient of Determination (R2) was computed to assess the proportion of variance in motor performance explained by BMI.

The magnitude of the correlation coefficients was interpreted according to standard thresholds: small ($r = 0.10 - 0.29$), moderate ($r = 0.30 - 0.49$), and large ($r \geq 0.50$). The level of statistical significance was set at $p \leq .05$.

RESULTS

The descriptive results for the four motor tests assessed (Mean ± Standard Deviation) are displayed in (table 2) . The data reveals a heterogeneous distribution of performance levels within the study sample, typical for this age group (8-10 years).).

Table 2. Descriptive Statistics of Motor Performance Variables (N=60)

Variable	*Mean ± SD*	*Minimum*	*Maximum*
20m Coordination (sec)	16.50 ± 2.66	11.23	23.30
Counter Movement Jump (cm)	19.92 ± 5.57	10.34	30.90
Abdominal Endurance (reps/30s)	13.62 ± 3.69	8.00	20.00
Trunk Extension (reps/30s)	26.47 ± 5.52	16.00	37.00

Note: Values represent the baseline performance levels of the entire cohort.

Relationships between BMI and Motor Performance

To determine the influence of somatic characteristics on motor potential, Pearson correlation coefficients (r) and coefficients of determination (R^2) were calculated. The analysis revealed statistically significant correlations in three out of the four tested variables, identifying Body Mass Index as a strong negative predictor for tasks involving vertical and horizontal body displacement. Detailed statistical outcomes, including 95% Confidence Intervals (95% CI), are displayed in (table 3).

Table 3. Correlations between BMI and Motor Performance Indicators (N=60)

Variable Pair	*Pearson r*	*95% CI*	R^2 *(%)*	*p-value*
BMI – 20m Coordination	0.582	[0.38, 0.73]	33.9	<.001
BMI – CMJ (Vertical Power)	-0.495	[-0.66, -0.27]	24.5	<.001
BMI – Sit-ups	-0.612	[-0.75, -0.42]	37.5	<.001
BMI – Trunk Extensions	-0.185	[-0.42, 0.07]	3.4	.156

Impact on Muscular Endurance

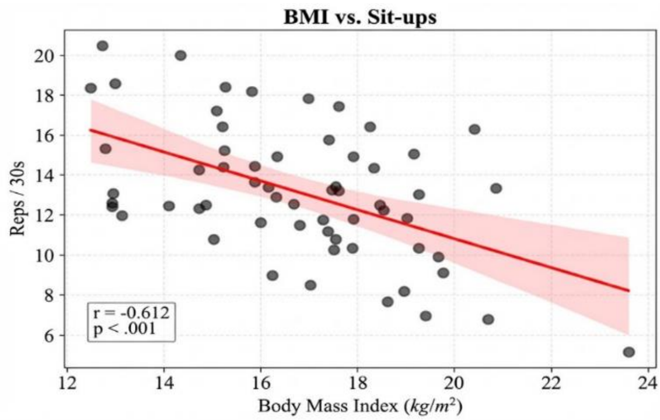

Figure 1. Correlation between BMI and Anterior Chain Muscular Endurance (Sit-ups).

The strongest correlation in the study (r = -0.612, p < .001) indicates a severe mechanical penalty for heavier participants during trunk flexion. The steep negative slope highlights that lifting the upper body against gravity becomes progressively more difficult as BMI increases, with body mass explaining 37.5% of the performance variance.

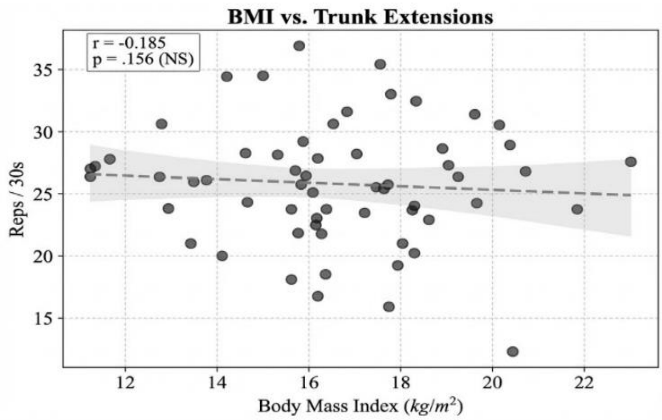

Figure 2. Scatter plot of BMI versus Posterior Chain Endurance (Trunk Extensions)

Unlike the anterior chain, the relationship between BMI and trunk extension performance was not statistically significant (r = -0.185, p = .156). The dashed regression line is nearly horizontal, visually confirming that posterior chain endurance is relatively preserved in children with higher BMI compared to abdominal function

Impact on Agility and Power

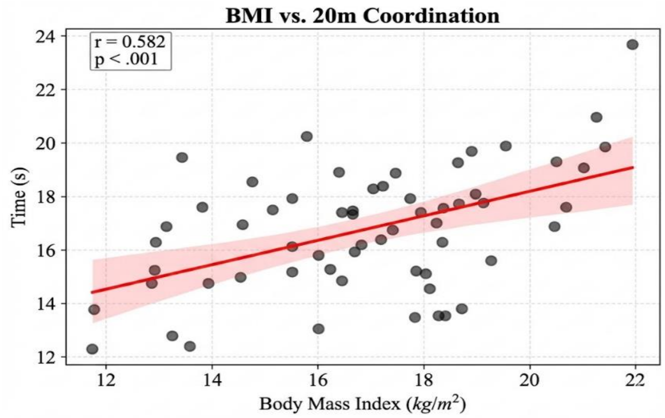

Figure 3. Scatter plot illustrating the relationship between Body Mass Index (BMI) and agility performance (20m Coordination Test).

The analysis revealed a significant positive correlation ($r = 0.582$, $p < .001$) between BMI and the time required to complete the 20m Coordination test. As illustrated, higher BMI values are associated with increased time scores, indicating slower multidirectional movement. The coefficient of determination ($R^2 = 33.9\%$) suggests that somatic constraints account for approximately one-third of the variance in agility performance.

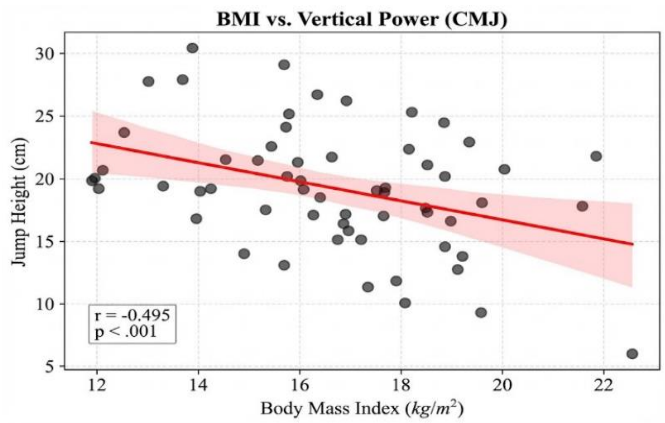

Figure 4. Linear regression analysis of BMI and Vertical Power (Counter Movement Jump).

A significant inverse relationship ($r = -0.495$, $p < .001$) was observed between BMI and vertical jump height. The downward trendline demonstrates the "dead weight" phenomenon, where excess body mass negatively impacts the power-to-weight ratio required for vertical propulsion during the concentric phase of the jump ($R^2 = 24.5\%$).

DISCUSSIONS

The present study aimed to examine the relationship between body composition (BMI) and functional motor performance in school-aged girls. The findings strongly support the hypothesis that excess body mass acts as a significant limiting factor for activities requiring vertical power, agility, and local muscular endurance against gravity. However, a key finding of our research is the dissociated impact of BMI on core musculature, revealing a specific mechanical constraint for the anterior chain that does not equally affect the posterior chain.

The "Dead Weight" Effect on Power and Agility

Our results revealed a significant inverse relationship between BMI and vertical jump performance (r = -0.495). This aligns with fundamental biomechanical principles described by Newton's Second Law (F = m × a). To achieve the same vertical acceleration as a normoweight peer, a child with a higher BMI must generate significantly higher ground reaction forces. Since the excess mass in this population is largely adipose (non-contractile tissue), it acts as a "dead weight," reducing the relative power-to-weight ratio.

Similarly, the strong positive correlation found in the 20m Coordination test (r = 0.582) suggests that body mass significantly impairs agility. Complex motor tasks requiring rapid changes of direction involve repeated cycles of braking (deceleration) and propulsive (acceleration) forces. Increased inertia in overweight children demands greater mechanical work to stop and restart the body's movement, resulting in slower execution times.

The Anterior vs. Posterior Chain Contrast: A Biomechanical Perspective

A novel and critical finding of this study is the sharp discrepancy between abdominal endurance and back extension performance.

Abdominal Endurance: The strongest negative correlation in the entire study was observed here (r = -0.612). During a sit-up, the trunk acts as a load arm, and the axis of rotation is the hip joint. A heavier torso significantly increases the resistance torque that the abdominal muscles must overcome to lift the body against gravity. This creates a "mechanical penalty" for children with higher BMI, regardless of their actual muscle contractility.

Posterior Chain Resilience: In contrast, the lack of significant correlation for trunk extensions ($p > .05$) is a noteworthy finding. We hypothesize two mechanisms for this phenomenon:

Postural Adaptation: The erector spinae muscles are tonic (postural) muscles responsible for maintaining upright stance. In overweight children, these muscles are under chronic tension to stabilize the heavier trunk during daily locomotion, potentially leading to a "training effect" that preserves posterior chain strength relative to body mass.

Biomechanical Leverage: The range of motion and the lever arm in the prone extension test may be less mechanically disadvantageous for a heavier body compared to the full flexion required in sit-ups.

Study Limitations

While the findings provide valuable insights, certain limitations must be acknowledged. First, the cross-sectional design precludes causal inferences. Second, the Counter Movement Jump (CMJ) protocol used in this study involved a free arm swing. While this approach increases ecological validity by mimicking natural movement patterns used in school settings, it may introduce variability related to coordination rather than pure lower-limb power. The contribution of the arm swing can increase jump height by 10-20% compared to the standard "hands-on-hips" protocol, potentially masking some deficits in leg power among children with better coordination.

CONCLUSIONS

Determinant Role of BMI: This study confirms that Body Mass Index is a strong negative predictor for motor tasks requiring body mass displacement in pre-pubertal girls. Specifically, higher BMI significantly impairs performance in agility (r = 0.582) and vertical power (r = -0.495), confirming the mechanical disadvantage of excess weight in dynamic activities.

Anterior vs. Posterior Chain Discrepancy: A critical finding is the dissociated effect of BMI on core musculature. While anterior chain endurance (sit-ups) is the most severely penalized by increased body mass (r = -0.612), posterior chain function (trunk extensions) remains statistically independent of somatic constraints (p > .05). This indicates that heavier children may possess adequate back strength despite poor performance in standard abdominal tests.

Assessment Implications: The strong correlation between BMI and test results suggests that traditional school-based assessments (such as sit-ups and vertical jumps) evaluate somatic status as much as, or more than, actual muscular fitness. Consequently, physical education grading should prioritize ipsative assessment (individual progress) over normative standards to avoid unfairly penalizing students with higher BMI.

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