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The Relationship Between Nutritional Status and Muscular Endurance in Early School-Aged Children

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Abstract

Background/Objectives: Early school age is a critical period for monitoring nutritional status and physical fitness to promote health and prevent obesity. This study aimed to determine nutritional status and muscular endurance in children aged 7–10 years and to examine differences by age and sex. Additionally, associations between anthropometric characteristics and muscular endurance were assessed, emphasizing comparisons between raw anthropometric measures and derived indices (BMI, WHR, WHtR). **Methods:** A cross-sectional study was conducted on 375 healthy children (184 boys, 191 girls) aged 7–10 years from Primorje, Gorski Kotar County, Croatia. Anthropometric measures included height, weight, waist circumference, and hip circumference, and muscular endurance was assessed via pull-up hold, 30-second sit-up, plank-to-failure, and squat-to-failure tests. Age and sex differences were analysed using MANOVA/ANOVA, and associations between anthropometric measures and endurance outcomes were examined using ANCOVA. **Results:** Age was the strongest predictor of performance across all endurance tests (p<.001), explaining 5.4–12.7% of variance, with the largest effect in the pull-up hold test. Sex differences were significant only at age 7, with boys performing better in sit-up, pull-up hold, and plank tests (p≤.039). Raw anthropometric measures were weak predictors after adjusting for age, whereas derived indices were more informative. WHtR was negatively associated with performance in the pull-up hold test at age 9 (p=.031) and the 30-second sit-up test at age 10 (p=.040). **Conclusions:** Age is a key determinant of muscular endurance, whereas a higher WHtR is associated with poorer performance in body-weight endurance tasks.:

Keywords: early school-age children; anthropometry; body composition indices; muscular endurance; waist-to-height ratio (WHtR)

Introduction

Early school age is a critical developmental window for monitoring nutritional status and health-related physical fitness because exposures and habits established at this time can persist into adolescence and adulthood. In the WHO European Childhood Obesity Surveillance Initiative (COSI), which includes large-scale surveillance across the region, a substantial proportion of children aged 7–9 years live with overweight (including obesity) and obesity, underscoring the ongoing public health relevance of early prevention approaches.[1] In parallel, health-related physical fitness in youth, especially muscular fitness, has been recognized as a meaningful marker of current and future health, with links to adiposity and cardiometabolic risk factors.[2–4]

From a prevention standpoint, children should be supported to accumulate sufficient physical activity that includes not only aerobic activities but also muscle- and bone-strengthening stimuli. Current global guidance emphasizes that school-aged children and adolescents should engage in regular moderate-to-vigorous physical activity, and that strengthening activities are part of health-promoting movement patterns.[5,6] In practice, however, opportunities for structured and unstructured activity may vary by context and participation. Croatian sources have emphasized that

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developmental opportunities missed in childhood may be difficult to fully compensate later, and that participation in organized or additional kinesiological activities can support broader motor development.[7–9] Consistent with this, early sex- and age-related differences in morphological and motor characteristics have been reported in regional samples, suggesting that growth-related changes and participation patterns may shape observed fitness profiles.[10,11]

Health monitoring in school settings commonly relies on anthropometric indicators because they are practical, inexpensive, and scalable. Traditional descriptors include body height and mass, alongside circumferences (e.g., waist and hip), which can be used to compute indices such as body mass index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR).[7] BMI remains the most widely used screening index and is often interpreted using international age- and sex-specific thresholds for overweight and obesity.[12] At the same time, BMI is a proxy that cannot distinguish fat mass from fat-free mass; therefore, it may be an imperfect reflection of body composition in growing children, particularly in the presence of inter-individual differences in muscularity.[13] Measures of central adiposity may provide complementary, functionally and clinically relevant information. WHtR, in particular, has been proposed as a simple screening tool for central fat distribution, often communicated via the practical boundary concept that the waist should remain below half of the height.[14] Recent multinational evidence suggests that WHtR cut-offs around 0.50 may be reasonable for predicting cardiometabolic risk in European and U.S. pediatric populations, while lower values may be optimal in some other regions, highlighting both the usefulness and the need for contextual interpretation.[15] Longitudinal work also supports WHtR as a robust anthropometric correlate of DXA-derived fat mass over time in youth.[16]

In parallel with health screening, field-based fitness testing is frequently used in school-age populations. Classic European approaches include the Eurofit test framework, which incorporates tests reflecting strength and muscular endurance (e.g., bent arm hang, sit-ups) alongside other components.[17] More recent health-related batteries (e.g., ALPHA) have aimed to standardize feasible, school-applicable tests aligned with health outcomes.[18] Alongside these batteries, national or regional initiatives have developed pragmatic field norms to support educational practice and interpretation of children's fitness results.[19]

A key rationale for integrating anthropometric indices with muscular endurance tests is that excess body mass, especially central adiposity, may pose a mechanical and metabolic disadvantage for tasks requiring repeated lifting or stabilization of one's own body weight. International studies show that higher BMI and/or waist circumference are generally associated with poorer performance across several fitness components, and that these negative associations can strengthen with age.[20] Systematic reviews further suggest that youth with obesity may appear stronger in absolute terms in some laboratory contexts, while body-weight-dependent field tests often reveal impaired relative performance due to the greater load that must be moved or stabilized.[21] At the population level, muscular fitness is also inversely associated with total and central adiposity, and with clustered cardiometabolic risk, supporting its role as a health-related outcome and potential intervention target in childhood.[3,4]

Therefore, the present study aimed to (i) determine nutritional status and muscular endurance in clinically healthy children aged 7–10 years; (ii) examine age- and sex-related differences in morphological and endurance characteristics; and (iii) test associations between anthropometric measures and muscular endurance, with emphasis on comparing raw measures with derived body composition indices (BMI, WHR, WHtR).[7–11,14,16]

Materials and Methods

Participants

The study sample consisted of 375 children (184 boys and 191 girls) aged 7 to 10 years from Primorje, Gorski Kotar County in the Republic of Croatia. The age distribution included 99 children aged 7 years (39 boys and 59 girls), 97 children aged 8 years (43 boys and 54 girls), 79 children aged

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9 years (41 boys and 38 girls), and 101 children aged 10 years (61 boys and 40 girls). All participants were clinically healthy and without diagnosed medical conditions that could affect anthropometric or motor performance.

Measures

A total of eleven variables were included in the analysis, comprising seven morphological characteristics and four motor variables related to muscular endurance. Morphological characteristics included body height, body mass, waist circumference, and hip circumference. Based on these measures, three derived body composition indices were calculated: body mass index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR).

Muscular endurance was assessed using four motor tests. Repetitive strength was evaluated using the pull-up hold test and the 30-second sit-up test, while static strength was assessed using the plank-to-failure and squat-to-failure tests.

Statistical Analysis

Age- and sex-related differences were analysed using multivariate and univariate analyses of variance (MANOVA and ANOVA). Multivariate testing of the null hypothesis that group centroids were equal to the common centroid was performed using Wilks' Lambda and Rao's R coefficient. Statistical significance at the univariate level was calculated using the F-test (p>.05). All statistical analyses were conducted using IBM SPSS Statistics 20.

Results

Table 1 presents the descriptive statistics for the anthropometric measures (height, weight, waist and hip circumference, and derived indices) and muscular endurance test performances, organized by age group and sex.

Table 1. Descriptive Statistics of Anthropometric Measures and Muscular Endurance by Age and Sex (Mean ± SD).

Variable	7 y Boys (n=39)	7 y Girls (n=59)	8 y Boys (n=43)	8 y Girls (n=54)	9 y Boys (n=41)	9 y Girls (n=38)	10 y Boys (n=61)	10 y Girls (n=40)
Height (cm)	129.5±6.5	129.0±5.4	136.0±5.7	132.4±5.9	141.1±6.3	139.5±7.3	147.5±7.6	144.7±8.7
Body mass (kg)	26.1±6.2	25.9±5.8	31.9±6.3	29.3±5.6	36.7±10.5	32.8±6.3	40.9±10.7	37.1±8.4
Waist circumference (cm)	61.8±7.0	59.7±9.7	63.5±8.0	60.6±6.7	64.9±9.3	61.7±8.4	71.0±10.7	64.6±7.9
Hip circumference (cm)	68.1±6.3	67.3±6.5	72.0±6.2	69.0±5.7	72.8±6.8	72.2±8.4	78.5±9.2	75.4±7.7
BMI (kg/m²)	15.3±2.5	15.5±2.9	17.2±2.6	16.6±2.4	18.3±4.4	16.8±2.5	18.6±4.1	17.5±2.9
WHtR	.48±.04	.46±.07	.47±.05	.46±.05	.46±.07	.44±.05	.48±.07	.45±.05
WHR	.91±.05	.90±.12	.89±.05	.88±.05	.87±.06	.85±.05	.90±.05	.86±.05
Sit-ups (30 s)	16.5±2.9	14.7±2.8	16.0±3.9	16.8±4.3	18.3±6.7	19.0±3.7	20.8±3.6	19.9±4.2
Pull-up hold (s)	13.6±9.6	10.4±7.2	16.4±15.0	18.2±21.4	21.8±21.4	21.4±16.5	22.3±19.8	25.4±24.2
Squat to failure (s)	84.5±71.3	74.0±64.6	99.4±79.9	104.0±78.3	79.1±74.2	101.5±95.8	111.9±107.0	164.6±123.9
Plank to failure (s)	101.1±68.3	61.9±36.2	77.5±50.9	91.4±65.6	110.3±55.0	87.5±46.2	94.3±54.9	117.4±54.2

Note. Values are presented as mean ± standard deviation. BMI = body mass index; WHR = waist-to-hip ratio; WHtR = waist-to-height ratio.

The descriptive results indicate that anthropometric measures (height, weight, circumferences, and associated indices) steadily increase with age across all groups, with only small, non-systematic differences between boys and girls. On average, boys have slightly higher waist-to-height ratio

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(WHtR) and waist-to-hip ratio (WHR) values than girls, whereas body mass index (BMI) values are similar between the sexes. In the muscular endurance tests, a clear improvement with age is evident: older children perform better on all measures of muscular endurance. The greatest within-group variability in performance is observed in the pull-up hold and squat-to-failure tests. Sex differences in performance are generally minimal, except in the youngest group (7-year-olds), where boys outperform girls in the 30-second sit-up and plank-to-failure tests (these differences are examined in detail below).

An initial one-way analysis of covariance (ANCOVA) on the full sample (N=324) confirmed that age is a statistically significant predictor of performance in all muscular endurance tests. In every model, the effect of age was significant (all $F>18.23$, $p<.001$), with age accounting for approximately 5.4% to 12.7% of the variance in test outcomes ($\eta p^2=.054–.127$). The largest age effect was observed in the pull-up hold test ($F=46.14$, $p<.001$). In contrast, the direct effects of the raw anthropometric measures (height, weight, waist circumference, and hip circumference) on performance were diminished when age was considered. Based on this finding, further analyses were conducted separately for each age group (7, 8, 9, and 10 years) to control for age effects.

Analyses conducted within each age group revealed that sex was a significant predictor of performance only among the 7-year-olds. At age 7, boys performed significantly better than girls in the 30-second sit-up test ($F(1,83)=8.88$, $p=.004$, $\eta p^2=.097$), the pull-up hold test ($F(1,83)=4.39$, $p=.039$, $\eta p^2=.050$), and the plank-to-failure test ($F(1,83)=15.35$, $p<.001$, $\eta p^2=.156$). In the 8-, 9-, and 10-year-old groups, sex had no significant effect on any of the endurance tests (all $p>.10$). We also evaluated the predictive value of raw anthropometric measures within each age group using multivariate ANCOVA. These models indicated low predictive power for the raw measures, with generally small effect sizes (partial ηp^2 values) and few significant effects. The only statistically significant predictor among the raw measures was waist circumference in the 8-year-old group, which was negatively associated with pull-up hold performance ($F=4.757$, $p=.033$, $\eta p^2=.071$; $B=–1.963$). In addition, a few non-significant trends emerged in the 8-year-old group: hip circumference showed a positive trend with pull-up hold time ($p=.096$, $B=+2.070$), and body height showed a negative trend ($p=.055$, $B=–1.247$) for the same test. Hip circumference also exhibited a positive trend with sit-up performance in 8-year-olds ($p=.084$, $B=+0.459$). In the 10-year-old group, body weight demonstrated a weak positive trend with sit-up performance ($p=.100$, $B=+0.183$). These trends did not reach statistical significance but suggested that larger body size or dimensions might relate to performance outcomes in certain age groups.

Table 2 presents the results of the ANCOVA models using the standardized body composition indices (BMI, WHtR, and WHR) as predictors of muscular endurance test performance in each age group.

Table 2. ANCOVA Results for the Association Between Anthropometric Indices and Muscular Endurance Performance.

Predictor	Outcome	7 years	8 years	9 years	10 years
Sit-ups (30 s)	**BMI**	B=+0.325, p=.077, ηp²=.037	B=−0.503, p=.092, ηp²=.045	B=−0.237, p=.425, ηp²=.010	*B=+0.517, **p=.031**, **ηp²=.058***
	WHtR	B=−5,29, p=0,710, ηp²=0,002	B=+33.944, p=.155, ηp²=.032	B=−24.294, p=.223, ηp²=.022	*B=−39.515, **p=.040**, **ηp²=.052***
	WHR	B=+4.583, p=.599, ηp²=.003	B=−36.853, p=.074, ηp²=.050	B=+15.774, p=.376, ηp²=.012	B=+7.102, p=.600, ηp²=.004
Pull-up hold (s)	**BMI**	B=−0.939, p=.079, ηp²=.037	B=−2.562, p=.081, ηp²=.047	B=−1.057, p=.305, ηp²=.016	B=−0.023, p=.986, ηp²=.000

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Predictor	Outcome	7 years	8 years	9 years	10 years
	WHtR	B=−11.696, p=.777, ηp²=.001	B=+109.406, p=.349, ηp²=.014	*B=−150.251, **p=.031**, **ηp²=.067******	B=−151.216, p=.144, ηp²=.027
	WHR	B=+2.182, p=.931, ηp²=.000	B=−145.137, p=.151, ηp²=.033	B=+41.682, p=.499, ηp²=.007	B=+21.081, p=.774, ηp²=.001
Squat to failure (s)	BMI	B=−6.221, p=.161, ηp²=.024	B=−0.721, p=.906, ηp²=.000	B=+0.894, p=.855, ηp²=.001	B=−0,332, p=.963, ηp²=.000
	WHtR	B=−68.502, p=.842, ηp²=.000	B=−292.162, p=.552, ηp²=.006	B=−313.383, p=.339, ηp²=.014	B=−395.308, p=.497, ηp²=.006
	WHR	B=+23.715, p=.910, ηp²=.000	B=−69.913, p=.868, ηp²=.000	B=+98.308, p=.737, ηp²=.002	B=−164.645, p=.691, ηp²=.002
Plank to failure (s)	BMI	B=+0.179, p=.958, ηp²=.000	B=−4.155, p=.315, ηp²=.016	B=+0.977, p=.753, ηp²=.001	B=−1.743, p=.596, ηp²=.004
	WHtR	B=−408.681, p=.124, ηp²=.028	B=−279.985, p=.398, ηp²=.011	B=−289.927, p=.166, ηp²=.028	B=−238.676, p=.367, ηp²=.010
	WHR	B=+190.218, p=.241, ηp²=.017	B=−2.043, p=.994, ηp²=.000	B=+108.033, p=.562, ηp²=.005	B=+47.547, p=.801, ηp²=.001

Note. B = unstandardized regression coefficient; p = level of statistical significance; ηp² = partial eta squared; BMI = body mass index; WHR = waist-to-hip ratio; WHtR = waist-to-height ratio; s = seconds; *p<.05.

In these index-based models, BMI, WHtR, and WHR emerged as more reliable predictors of muscular endurance performance than the raw anthropometric measures. Notably, when using the indices as predictors, sex was no longer a significant factor in the 8-, 9-, and 10-year-old groups, whereas in the 7-year-old group the effect of sex remained significant for the plank and sit-up tests (as observed in the earlier analysis for that age). This indicates that the body composition indices account for much of the variance in performance, especially in the older children, rendering sex differences negligible in those groups.

The waist-to-height ratio (WHtR) showed the strongest and most consistent relationships with performance outcomes. In the 9-year-old group, a higher WHtR was significantly associated with lower performance on the pull-up hold test (p=.031, B=–150.251, ηp²=.067), meaning children with higher central adiposity tended to hang for shorter durations. Similarly, in the 10-year-old group, a higher WHtR predicted a significantly lower number of sit-up repetitions in 30 seconds (p=.040, B=–39.515, ηp²=.052). In addition to WHtR, BMI also demonstrated a notable effect in the oldest group: among 10-year-olds, higher BMI was significantly associated with better sit-up performance (p=.031, B=+0.517, ηp²=.058). This finding suggests that in this age group, a higher body mass (potentially reflecting greater muscle mass) contributed positively to repetitive trunk strength (sit-ups).

Several additional trends were observed in the index-based analysis, although these did not reach statistical significance. At age 7, BMI showed a positive trend with sit-up performance (p=.077, B=+0.325) and a negative trend with pull-up hold time (p=.079, B=–0.939). At age 8, BMI demonstrated negative trends for both sit-up (p=.092, B=–0.503) and pull-up hold (p=.081, B=–2.562) performances, and WHR exhibited a negative trend for sit-up performance (p=.074, B=–36.853).

Discussion

The present findings indicate that chronological age is the dominant determinant of muscular endurance performance across early school age, while sex-related differences are limited and appear

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primarily in the youngest group. In addition, derived anthropometric indices, particularly WHtR, provided more consistent associations with muscular endurance outcomes than raw anthropometric measures after age adjustment, suggesting that indices capturing body size relative to height and/or fat distribution may be more functionally informative in this age range.

A strong age gradient in both anthropometric indicators and performance is expected in children aged 7–10 years, reflecting normal growth, neuromuscular maturation, and increasing movement competency across primary school years.[28] As children grow taller and heavier, changes in limb length, lever arms, and muscle mass contribute to improved absolute force generation and endurance capacity; concurrently, motor learning and coordination typically improve with repeated exposure to age-appropriate physical tasks.[21,22] In the present results, age explained a meaningful proportion of variance across all endurance tests, consistent with the premise that early school age represents a period of rapid development in multiple fitness domains.[23–27]

Sex differences were statistically evident only in 7-year-olds (boys performing better in sit-ups, pull-up hold, and plank). This pattern aligns with evidence that sex differences in muscular strength exist even before puberty but are generally small-to-moderate in magnitude in younger age groups, with larger divergence emerging as maturation progresses (particularly for upper-limb strength).[29,30] In early school age, observed sex differences may reflect not only biological factors but also differences in play behaviours, activity preferences, and early exposure to strength-demanding tasks.[6] The limited persistence of sex effects beyond the youngest group in this sample may indicate that age-related development and within-age variability (including participation in organised activities) overshadow sex-based differences in these specific endurance tasks.[8–11]

A central interpretive point is that raw anthropometric measures showed limited predictive value once age was accounted for, whereas indices derived from these measures were more informative in selected age groups. This distinction may reflect the fact that raw height, mass, and circumferences are all strongly age-dependent in 7–10-year-olds; when age is controlled statistically, the remaining inter-individual variance in raw measures may be relatively small or heterogeneous. In contrast, indices such as WHtR are scaled to height and can therefore better reflect central adiposity relative to body size, which may be more directly relevant to functional tasks requiring trunk stabilization or repeated lifting of body mass.[16–18]

WHtR emerged as the most consistent negative predictor of muscular endurance, particularly for tasks with high body-weight dependency (pull-up hold and sit-ups). This observation is coherent with broader evidence that central adiposity is associated with less favourable health profiles and may be more strongly linked to functional limitation than BMI alone.[16–18] Mechanistically, a higher WHtR likely reflects a greater proportion of abdominal mass relative to stature, which increases the mechanical load during body-weight tasks, potentially alters trunk mechanics, and may reduce relative force-to-mass ratio. International findings similarly indicate that higher BMI and waist circumference are negatively correlated with multiple fitness components in school-aged children and that the magnitude of these associations may increase with age.[20] In obese youth, systematic-review evidence suggests that disadvantages in field-based muscular fitness are often most apparent when performance depends on moving or holding one's own body weight (i.e., relative rather than absolute strength/endurance).[19] From a practical screening perspective, WHtR is attractive because it is easy to compute, interpretable, and supported by an accessible health message ("keep your waist to less than half your height"), though context-specific cut-offs should be considered in paediatric populations.[16,17]

An apparently counterintuitive result was the positive association between BMI and sit-up performance in 10-year-olds. This does not necessarily indicate a beneficial role of higher adiposity for muscular endurance; rather, it likely illustrates the limitation of BMI as a composite index of mass relative to height that does not distinguish fat mass from fat-free mass. Children with higher BMI may, in some cases, have higher lean mass that supports absolute performance in certain tasks, especially those less constrained by upper-limb relative strength and more influenced by trunk strength, pacing, and familiarity with repeated movement.[15,19] This interpretation reinforces the value of including central adiposity indicators (e.g., WHtR) and, where possible, more direct assessments of body composition when examining functional outcomes in children.[15,17,18]

From an applied standpoint, these findings support a dual monitoring approach in early school age: (i) routine anthropometric screening that includes BMI and a central adiposity indicator (preferably WHtR), and (ii) simple school-feasible muscular endurance tests that reflect functionally relevant, body-weight-dependent performance.[12,13,16] Such monitoring aligns with public health emphasis on early identification of children at risk for unhealthy trajectories and on supporting physical activity patterns that include muscle-strengthening components.[5,6] For physical education and school-based health promotion, a practical implication is that children with higher WHtR may require targeted support to improve trunk and upper-body endurance in a progressive, developmentally appropriate manner, reducing the performance barrier posed by excess central mass.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference and does not capture individual growth trajectories. Second, maturity status, habitual physical activity, diet, and socioeconomic variables were not incorporated and could mediate associations between anthropometry and endurance. Third, while field tests are valuable for ecological validity, performance can be influenced by motivation, familiarization, and instruction quality. Despite these limitations, the use of multiple endurance tests and the comparison of raw anthropometrics versus indices provide a more nuanced view of how body size and central adiposity relate to functional performance in early school age.

Conclusions

Chronological age represents a primary determinant of muscular endurance development in early school-aged children, reflecting ongoing growth-related changes in neuromuscular function and movement competence. Body composition indices, particularly waist-to-height ratio (WHtR), appear to be more sensitive predictors of muscular endurance performance than raw morphological measures in this population. Increased abdominal adiposity may negatively influence the ability to sustain muscular effort, especially in tasks requiring the stabilization or repeated lifting of one's own body mass, likely due to an unfavourable force-to-mass ratio and altered trunk mechanics.

These findings suggest that anthropometric screening in school-aged children may benefit from incorporating indicators of central adiposity alongside traditional indices such as BMI. From a practical perspective, WHtR represents a simple, cost-effective measure that may help identify children at risk of reduced functional fitness in body-weight-dependent tasks. Early identification of such risk profiles may support targeted interventions aimed at improving muscular endurance and promoting healthier physical development trajectories.

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