



The Mediating Role of Anthropometric Improvements in The Effects of Resistance Training on Speed, Strength, and Power in U20 Futsal Athletes

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Abstract

Background. Adolescence is characterized by heightened trainability, yet approximately 18 % of young people are overweight or obese. It has been noted that in five Yogyakarta futsal clubs, 37–51 % of U17 players show BMI ≥ 25 kg·m⁻², potentially hampering performance.

Objectives. This study aimed to examine whether implementing an eight-week resistance-training programme enhances 20-m sprint speed, lower-body strength, and explosive power in U17 futsal athletes, and whether body fat change mediates these effects.

Materials and methods. Thirty 18-19-year-old male players completed periodised resistance sessions that were conducted on a thrice-weekly basis. Body mass, BMI, body fat percentage (BF %), sprint time, one-repetition-maximum leg press, and standing long-jump distance were measured in the pre-/post-intervention phase. Paired-sample t-tests were used to assess within-group changes. Mediation models (PROCESS; 5,000 bootstraps) examined whether Δ BF % transmitted the influence of Δ BMI on performance.

Results. A substantial decrease was observed in body mass (–1.21 kg), BMI (–0.43 kg·m⁻²), and BF % (–1.48 %), while sprint time (–0.95 s), leg-press strength (+11.9 kg), and jump distance (+11.8 cm) improved (all $p < .001$). Δ BMI predicted Δ BF % ($B = 5.38$, $p < .001$). BF % partially mediated the BMI–sprint link (indirect effect = 3.52, 95 % CI [2.70, 4.47]), although a significant direct path persisted. Mediation was non-significant for strength and power; BMI reduction showed no relation to strength change, yet retained a strong direct association with power gains independent of BF %.

Conclusions. The findings of this study indicate that resistance training markedly improves neuromuscular performance and body composition in youth futsal athletes. A lower BMI enhances sprint speed both directly and through concurrent reductions in BF %, whereas adaptations in strength and power arise through mechanisms other than adiposity. Training programmes should therefore combine neuromuscular loading with strategies for healthy weight management to optimise youth futsal performance.

Keywords: anthropometric, resistance training, speed, strength, power, futsal.

Introduction

In contemporary youth-athlete development, enhancing key physical capacities — strength, speed, and explosive power — has become a central objective across many

sports, including futsal. Futsal is a high intensity discipline that demands explosiveness, agility, and rapid acceleration within a confined playing area. Meeting these demands requires an optimal physical profile that supports dynamic and efficient play (Barbero-Alvarez, Soto, Barbero-Alvarez, & Granda-Vera, 2008; Yulvia Miftachurochmah, Tomoliyus, & ER, 2023; Milanović et al., 2011). Resistance training is widely recommended to build such capacity and has been shown to improve muscular strength, explosive power, and

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sprint speed (Behringer, Vom Heede, Yue, & Mester, 2010; Faigenbaum et al., 2009).

Physiologically, adolescence is considered a golden age of trainability, marked by heightened adaptability to exercise stimuli. Hormonal and neuromuscular changes during this period accelerate training responses, making it strategically advantageous for optimizing physical development (Lloyd & Oliver, 2012; Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015). Recent evidence confirms that structured, progressive resistance training programmes significantly enhance adolescent performance indicators such as muscular strength, sprint velocity, and jump height (Behm et al., 2017; Dias et al., 2023; Vesci, Webster, Sich, & Marinko, 2017). While biological maturation contributes to these gains, sport specific neuromuscular adaptations elicited by targeted training also play a decisive role. A parallel challenge has emerged with the global rise in adolescent overweight and obesity. Zhang et al. (2024) reported that approximately 18 % of individuals aged 5–19 years are overweight or obese, with faster growth rates in developing nations, including Indonesia. Preliminary observations in five futsal clubs within the Special Region of Yogyakarta indicated that 37–51 % of U20 players recorded a body mass index (BMI) $\geq 25 \text{ kg}\cdot\text{m}^{-2}$, suggesting excess body mass that may hinder optimal on court performance.

Body composition variables — particularly fat mass and fat free mass — are closely linked to athletic performance. In adult cohorts, excess body mass, especially elevated fat mass, increases mechanical load, reduces sprint efficiency, slows change of direction ability, and impairs acceleration (Bishop et al., 2007). Conversely, recent intervention studies demonstrate that reducing fat percentage can promote muscle mass accretion even within short training periods (Liu, Li, Lu, & Zhu, 2024). Relative increases in muscle mass further support improvements in strength and explosive power. Hence, programmes that favourably modify body composition are crucial for youth-performance enhancement.

Growing evidence underscores resistance training as a dual purpose intervention that simultaneously amplifies neuromuscular function (increasing strength, power, and speed) and remodels body composition (Behm et al., 2017; Lesinski, Prieske, & Granacher, 2016; Y Miftachurochmah, Sukanti, Arjuna, & Pamungkas, 2023). Yet few studies have examined whether anthropometric improvements actually mediate the link between resistance training and performance gains in late adolescent futsal athletes. Resolving this mechanism has immediate practical value for coaches designing evidence based programmes and tailoring workloads to players with sub optimal BMI or fat mass profiles. Accordingly, the present study investigated the effects of a 8 week resistance training programme on sprint speed, lower body strength, and explosive power in U20 futsal athletes. Crucially, it tested whether reductions in BMI and body fat percentage mediate the training performance relationship, thereby clarifying the pathways through which resistance training enhances on court readiness in this age group.

Materials and Methods

This study employed a quasi-experimental design with a pre-test and post-test approach conducted over an

eight-week period. The primary objective was to examine the mediating role of anthropometric improvements in the effects of resistance training on speed, strength, and explosive power among U20 futsal athletes. The intervention consisted of a structured resistance training program. Pre- and post-intervention assessments were conducted to evaluate changes in anthropometric parameters and physical performance outcomes. This research was approved by the Research Ethics Committee of Universitas Negeri Yogyakarta, registration number: T/36.1/UN34.9/KP.06.07/2024.

Study Participants

A total of 30 male futsal athletes aged 18-19 years participated in this study. Participants were recruited from five futsal clubs located in the Special Region of Yogyakarta, Indonesia. The inclusion criteria were as follows: (1) active participation in futsal training for at least one year, (2) no history of musculoskeletal injury within the past six months, and (3) a body mass index (BMI) between 25.1 and 29.9 at baseline assessment. The exclusion criteria included: (1) any medical condition contraindicating participation in resistance training, and (2) noncompliance with at least 80% of the scheduled training sessions. Written informed consent was obtained from all participants and their legal guardians prior to enrollment in the study.

Experimental Design

Prior to the intervention, participants underwent baseline assessments that included anthropometric measurements and physical performance tests. Anthropometric measurements were conducted first, followed by performance testing, with sufficient rest intervals between tests to minimize fatigue. All assessments were standardized and administered by the same team of evaluators to ensure consistency and reliability of the results. Following the initial assessment, participants engaged in a structured resistance training program for eight weeks while continuing their regular futsal training schedules. The resistance training sessions were conducted three times per week, with a minimum of 48 hours between sessions. Each session lasted approximately 60 minutes, consisting of 5-10 minutes of dynamic warm-up, 40-50 minutes of resistance training, and 5-10 minutes of cool-down. The program followed the principle of progressive overload, starting at moderate intensity (60% of one-repetition maximum, 1RM) and gradually progressing to high intensity (up to 80% of 1RM) in the final weeks. The resistance training exercises included both upper- and lower-body dominant movements, as detailed below outlining the training program. Participant attendance was recorded, and inclusion in the final analysis required participation in at least 80% of the training sessions. At the end of the intervention period, post-test assessments identical to the baseline evaluations were conducted to determine changes in anthropometric and physical performance variables.

Testing Procedure

Anthropometric measurements included assessments of body mass and height. Height was measured using a stadiometer with participants barefoot. Body mass index (BMI) and body fat percentage (BF) were estimated using a

bioelectrical impedance analyzer (Omron HBF 375, Tokyo, Japan), following standard pre-test conditions such as fasting and hydration control.

Physical performance testing was conducted to assess sprint speed, lower-body strength, and lower-body explosive power. Sprint speed was evaluated using a 20-meter sprint test, with timing recorded by three stopwatch operators. Each participant performed two sprint trials, and the fastest time was recorded as the final result. Lower-body strength was assessed using a one-repetition maximum (1RM) test on a leg press machine (Technogym), in accordance with standard maximal strength testing guidelines (Baechle & Earle, 2008). Following a warm-up, participants performed incremental lifts until they reached the maximum load they could lift once with proper technique. Lower-body explosive power was measured using the long broad jump test to assess horizontal jumping ability. Each participant completed three maximal-effort jumps, and the best distance achieved was recorded as the final result.

Statistical Analysis

Descriptive statistics were calculated for all variables and are presented as means and standard deviations. The normality of data distribution was assessed using the Shapiro–Wilk test. Paired-sample t-tests were conducted to analyze changes in anthropometric and physical performance variables between pre- and post-intervention measurements.

Furthermore, to examine the mediating role of anthropometric improvements (i.e., changes in BMI and body fat percentage) in the relationship between resistance training and improvements in sprint speed, muscular strength, and explosive power, a mediation analysis was performed using the PROCESS macro for SPSS (Model 4) developed by Hayes (2013). The significance of indirect effects was evaluated using a bootstrapping procedure with 5,000 resamples, and 95% bias-corrected confidence intervals (CIs) were reported. Indirect effects were considered significant if the confidence interval did not include zero. The level of statistical significance for all analyses was set at $p < .05$. All statistical analyses were performed using

IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

Results

Table 1 presents the descriptive statistics—including minimum, maximum, mean, and standard deviation—for each measured variable at both pre-test and post-test phases. The results show consistent trends reflecting the effectiveness of the resistance training intervention.

In terms of sprint performance, the average time for the 20-meter sprint decreased from 5.57 seconds (SD = 0.78) at pre-test to 4.62 seconds (SD = 0.89) at post-test, indicating improved speed. Leg strength, as measured by the leg dynamometer, increased from a pre-test mean of 110.08 kg (SD = 3.91) to 122.00 kg (SD = 5.31) at post-test. Similarly, explosive power — assessed via the long broad jump — increased from 180.27 cm (SD = 13.89) to 192.10 cm (SD = 13.65). Anthropometric measures also showed favorable changes. Body weight decreased from a mean of 73.07 kg (SD = 3.10) at pre-test to 71.86 kg (SD = 3.10) at post-test. Body mass index (BMI) decreased from 25.95 (SD = 0.65) to 25.52 (SD = 0.63), and body fat percentage declined from 26.97% (SD = 0.81) to 25.49% (SD = 0.86), indicating improvements in body composition following the intervention. Overall, these descriptive results reflect consistent improvements across both anthropometric and performance variables from pre- to post-intervention, supporting the effectiveness of the resistance training program. However, to statistically verify the effects of resistance training on these variables, further analysis using paired sample t-tests is required.

To fulfill the assumptions of the paired t-test, a normality test was conducted. The Shapiro–Wilk test was selected due to the sample size being fewer than 50 participants. The test was applied to all dependent variables at both pre-test and post-test stages. The results indicated that all p-values exceeded the significance threshold of .05, suggesting that none of the variables violated the assumption of normality. Detailed results of the normality test are presented in Table 2.

The results show that for the 20-meter sprint, the Shapiro–Wilk test indicated no significant deviation from

Table 1. Summary of Pre- and Post-Test Descriptive Statistics for All Study Variables

Variable			MIN	Max	Mean	SD
	20 m Sprint	Pre-Test	4.40	7.00	5.57	0.78
		Post-Test	3.13	6.13	4.62	0.89
Performance Ability	Leg Dynamometer	Pre-Test	102.50	117.50	110.08	3.91
		Post-Test	115.00	135.00	122.00	5.31
	Long Broad Jump	Pre-Test	159.00	210.00	180.26	13.89
		Post-Test	170.00	220.00	192.10	13.65
Antropometric	Body Weight	Pre-Test	65.00	78.00	73.07	3.095
		Post-Test	64.00	76.80	71.86	3.104
	BMI	Pre-Test	25.04	27.51	25.95	0.65
		Post-Test	24.53	26.92	25.52	0.63
	Body Fat	Pre-Test	25.50	28.90	26.97	0.81
		Post-Test	23.60	26.90	25.49	0.86

normality at either the pre-test ($W = 0.950, p = .165$) or post-test ($W = 0.979, p = .810$). Similarly, leg strength, as measured by the leg press machine, was normally distributed ($p = .108$ at pre-test and $p = .072$ at post-test). Long broad jump scores

Table 2. Results of the Shapiro–Wilk Normality Test for All Measured Variables

Variable	X	W	df	p	
Performance Ability	20m Sprint	Pre-Test	0.950	30	0.165
		Post-Test	0.979	30	0.810
	Leg Dynamometer	Pre-Test	0.943	30	0.108
		Post-Test	0.936	30	0.072
	Long Broad Jump	Pre-Test	0.961	30	0.330
		Post-Test	0.959	30	0.284
Anthropometric	BMI	Pre-Test	0.956	30	0.242
		Post-Test	0.970	30	0.531
	Body Fat	Pre-Test	0.987	30	0.972
		Post-Test	0.977	30	0.744

also conformed to a normal distribution ($p = .330$ for pre-test and $p = .284$ for post-test). For the anthropometric measures, BMI values showed no significant deviation from normality ($p = .242$ for pre-test and $p = .531$ for post-test), and body fat percentage demonstrated strong normality at both time points ($p = .972$ for pre-test and $p = .744$ for post-test). These results support the use of parametric statistical procedures, such as paired sample t-tests, in subsequent analyses.

To evaluate the effectiveness of the resistance training intervention on anthropometric and performance outcomes, a series of paired sample t-tests were conducted to compare pre-test and post-test values across six key variables: body weight (BW), body mass index (BMI), body fat percentage (BF), 20-meter sprint time, leg press strength (LP), and long broad jump distance (LBJ). All difference scores were calculated as the mean difference between pre-test and post-test values (i.e., pre-test minus post-test), where positive values reflect a reduction (e.g., in body weight, BMI, and body fat percentage), and negative values indicate improvement in variables where higher post-test scores are desirable (e.g., strength and power). An exception applies to sprint time, where a positive value still represents improvement, as it

Table 3. Results of Paired t-Tests on Pre- and Post-Intervention Outcomes

Variable Pair	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Difference	t	df	p	95% CI of Difference	Cohen's d
BW (kg)	73.07 (3.10)	71.86 (3.10)	1.21	25.32	29	< 0.001	[1.11, 1.31]	4.62
BMI	25.95 (0.65)	25.52 (0.63)	0.43	24.27	29	< 0.001	[0.39, 0.47]	4.56
BF (%)	26.97 (0.82)	25.49 (0.86)	1.48	14.72	29	< 0.001	[1.27, 1.68]	2.69
Sprint (sec)	5.57 (0.78)	4.62 (0.82)	0.95	10.81	29	< 0.001	[0.77, 1.13]	1.97
Leg Press (kg)	110.08 (3.91)	122.00 (5.31)	-11.92	-18.25	29	< 0.001	[-13.25, -10.58]	-3.33
LBJ (cm)	180.27 (13.89)	192.10 (13.65)	-11.83	-19.57	29	< 0.001	[-13.07, -10.60]	-3.57

Table 4. Mediating Role of Body Fat in the Relationship Between BMI and Physical Performance Outcomes

Outcome	Mediation Path	B (Raw)	β (Std.)	SE	p	95% CI (LLCI, ULCI)
Speed	Δ BMI \rightarrow Δ BF (a path)	5.3776	0.9513	0.3292	<0.001	[4.7033, 6.0520]
	Δ Body Fat \rightarrow Δ Sprint (b path)	0.6537	0.7474	0.0490	<0.001	[0.5532, 0.7541]
	Δ BMI \rightarrow Δ Sprint (Direct effect c')	1.2754	0.2580	0.2767	<0.001	[0.7076, 1.8433]
	Indirect Effect (a \times b)	3.5152	0.7110	0.4491*	–	[2.7043, 4.4704]†
	Total Effect of Δ BMI on Δ Sprint	4.7907	0.9690	0.2309	<0.001	[4.3176, 5.2637]
Strength	Δ BMI \rightarrow Δ BF (a path)	5.38	0.951	0.33	<0.001	[4.70, 6.05]
	Δ BF \rightarrow Δ Strength (b path)	3.79	0.582	3.94	0.344	[-4.28, 11.87]
	Δ BMI \rightarrow Δ Strength (Direct effect)	-13.94	-0.379	22.25	0.536	[-59.59, 31.71]
	Indirect effect (a \times b)	20.39	0.554	20.20*	–	[-19.31, 60.94]†
	Total Effect of Δ BMI on Δ Strength	6.4528	0.1753	6.8472	0.354	[-7.5734, 20.4791]
Power	Δ BMI \rightarrow Δ BF (a path)	5.38	0.951	0.33	<0.001	[4.70, 6.05]
	Δ BF \rightarrow Δ Power (b path)	-0.06	-0.011	0.84	0.940	[-1.80, 1.60]
	Δ BMI \rightarrow Δ Power (Direct effect)	-32.87	-0.964	4.77	<0.001	[-42.65, -23.08]
	Indirect Effect (a \times b)	-0.35	-0.010	4.72*	–	[-9.42, 8.87]†
	Total Effect (Δ BMI \rightarrow Δ Power)	-33.21	-0.975	1.44	<0.001	[-36.17, -30.26]

Note. B = unstandardized coefficient, β = standardized coefficient, SE = standard error, CI = confidence interval.

*Bootstrapped SE; † Bootstrapped 95% confidence interval with 5000 samples. Δ indicates post-test minus pre-test values; higher Δ Sprint, Δ Strength, and Δ Power reflect performance improvement. BMI = Body Mass Index; BF = Body Fat Percentage.”

indicates a reduction in the time required to complete the 20-meter sprint, denoting enhanced performance. The detailed results of the paired sample t-tests are presented in Table 3 below.

Results showed a significant reduction in body weight, $t(29) = 25.32$, $p < .001$, with an average loss of 1.21 kg (95% CI [1.11, 1.31]). Body mass index (BMI) also significantly declined, $t(29) = 24.27$, $p < .001$, by an average of 0.43 units (95% CI [0.39, 0.47]). Likewise, body fat percentage decreased significantly, $t(29) = 14.72$, $p < .001$, with a mean reduction of 1.48% (95% CI [1.27, 1.68]). Sprint performance improved, as evidenced by a significant decrease in 20-meter sprint time, $t(29) = 10.81$, $p < .001$, with an average reduction of 0.95 seconds (95% CI [0.77, 1.13]). For performance variables where increased values indicate improvement, significant gains were observed. Leg press strength increased by an average of 11.92 kg, $t(29) = -18.25$, $p < .001$ (95% CI [-13.25, -10.58]). Similarly, long broad jump distance improved significantly, $t(29) = -19.57$, $p < .001$, with an average increase of 11.83 cm (95% CI [-13.07, -10.60]). These findings indicate that the resistance training program was effective in producing statistically and practically significant improvements in body composition, muscular strength, and power, as well as in sprint performance.

Since all participants received the same treatment (resistance training), the independent variable does not vary. In this context, anthropometric changes — specifically body mass index (BMI) and body fat percentage (BF) — are regarded as reflections of the intervention effect and are therefore treated as proxies to model their downstream impact on physical performance outcomes. A series of mediation analyses were conducted using PROCESS Model 4 (Hayes, 2022) to examine whether changes in body fat percentage (ΔBF) mediated the effect of changes in body mass index (ΔBMI) on improvements in sprint performance ($\Delta Sprint$), muscular strength ($\Delta Strength$), and explosive power ($\Delta Power$). All change scores were computed as post-test minus pre-test values. The detailed results of the PROCESS Model 4 analyses are presented in Table 4 below.

The results showed that ΔBMI significantly predicted ΔBF ($B = 5.38$, $SE = 0.33$, $p < .001$), and ΔBF significantly predicted $\Delta Sprint$ performance ($B = 0.65$, $SE = 0.05$, $p < .001$), indicating a positive relationship between reductions in body composition and improvements in sprinting ability. The direct effect of ΔBMI on $\Delta Sprint$ also remained significant ($B = 1.28$, $SE = 0.28$, $p = .0001$), suggesting partial mediation. The indirect effect via ΔBF was significant ($B = 3.52$, Boot $SE = 0.45$, 95% CI [2.70, 4.47]), indicating that reductions in BMI enhanced sprint performance both directly and indirectly through decreases in body fat percentage.

For muscular strength, although ΔBMI significantly predicted ΔBF ($B = 5.38$, $SE = 0.33$, $p < .001$), the path from ΔBF to $\Delta Strength$ was not significant ($B = 3.79$, $SE = 3.94$, $p = .344$). The direct effect of ΔBMI on strength was also non-significant ($B = -13.94$, $SE = 22.25$, $p = .536$), as was the total effect ($B = 6.45$, $SE = 6.85$, $p = .354$). Similarly, the indirect effect through ΔBF was non-significant ($B = 20.39$, Boot $SE = 20.20$, 95% CI [-19.31, 60.94]), indicating no evidence for either a direct or mediated effect of ΔBMI on lower-body strength in this sample.

In the model assessing power, ΔBMI again significantly predicted ΔBF ($B = 5.38$, $SE = 0.33$, $p < .001$). However, ΔBF

did not significantly predict $\Delta Power$ ($B = -0.06$, $SE = 0.84$, $p = .940$), and the indirect effect was non-significant ($B = -0.35$, Boot $SE = 4.72$, 95% CI [-9.42, 8.87]). Despite this, the direct effect of ΔBMI on $\Delta Power$ remained highly significant ($B = -32.87$, $SE = 4.77$, $p < .001$), and the total effect was also significant ($B = -33.21$, $SE = 1.44$, $p < .001$), indicating a strong direct association between reductions in BMI and improvements in explosive power, independent of body fat percentage.

These findings suggest that body fat percentage mediates the relationship between BMI reduction and sprint performance, but not between BMI and either muscular strength or explosive power. Although changes in BMI were associated with improvements in power, body fat percentage did not serve as a significant mediator, suggesting that other physiological or biomechanical mechanisms may be involved.

Discussion

This study aimed to examine the effects of an eight week resistance training programme on speed, strength, and power in youth futsal athletes and to evaluate whether anthropometric changes — specifically body mass index (BMI) and body fat percentage (BF%) — mediated those effects. The programme produced marked improvements in 20 m sprint speed ($t_{(29)}=10.81$, $p < .001$, 95 % CI [-1.13, -0.77]), lower body strength ($t_{(29)}=-18.25$, $p < .001$, 95 % CI [+10.58, +13.25]), and explosive power ($t_{(29)}=-19.57$, $p < .001$, 95 % CI [+10.60, +13.07]). Concurrently, body weight decreased by 1.21 kg ($t_{(29)}=25.32$, $p < .001$, 95 % CI [-1.31, -1.11]), BMI by 0.43 units ($t_{(29)}=24.27$, $p < .001$, 95 % CI [-0.47, -0.39]), and BF% by 1.48 percentage points ($t_{(29)}=14.72$, $p < .001$, 95 % CI [-1.68, -1.27]). Mediation analyses further revealed that these anthropometric improvements explained a substantial portion of the gains in sprint performance but not those in strength or power. These findings confirm the dual pathway by which resistance training enhances athletic performance—through direct neuromuscular adaptations and, for speed, through favourable shifts in body composition—while also highlighting that additional mechanisms are likely responsible for strength and power related outcomes.

The findings indicate that every decrement in body mass index (BMI) is accompanied by a proportional reduction in body fat percentage (BF%) and that these concurrent changes are associated with shorter 20 m sprint times. This pattern matches evidence from adolescent footballers, in whom BF% shows the strongest negative correlations with 5–35 m sprint performance ($r = 0.25-0.52$; França et al., 2024). Mechanically, adipose tissue acts as non propulsive mass: unloading 5–10 % of body weight with body weight–support devices shortens ground contact time and braking impulse per step, thereby enhancing initial acceleration (Kratky & Müller, 2013). A lighter body also reduces phosphocreatine cost per metre travelled, enabling athletes to sustain high power output over short distances (di Prampero, Botter, & Osgnach, 2015).

Speed, however, is not determined solely by adiposity. The resistance training programme that lowered BMI elicited rapid neuromuscular adaptations—greater motor

unit recruitment, higher discharge rates, and improved synchronisation (Sterczala et al., 2020) — which are typically detectable within 6–8 weeks in adolescents (Del Vecchio et al., 2019; Herda et al., 2024). These neural changes elevate the rate of force development (Maffiuletti et al., 2016) and, together with post training increases in tendon stiffness (Waugh, Korff, Fath, & Blazevich, 2014), allow maximal propulsive force to be generated earlier during each ground contact (Tumkur Anil Kumar, Oliver, Lloyd, Pedley, & Radnor, 2021). In essence, a lighter body minimises mechanical drag, whereas neuromuscularly “primed” muscle–tendon units augment explosive capacity; the interaction of these pathways explains why BMI reductions enhance sprint performance both directly and through adiposity loss in overweight adolescent futsal players.

The observation that changes in BMI and body fat percentage did not correlate with improvements in leg press strength is consistent with the known time course of strength adaptation. During the first 6–8 weeks of training, increases in maximal leg press load are driven almost entirely by neuromuscular mechanisms: the central nervous system recruits more motor units, fires them at higher frequencies, and better synchronises agonist–antagonist activity. Time course reviews confirm that more than 80 % of the strength gained within 2–8 weeks derives from motor unit recruitment, synchronisation, and neural drive, irrespective of adiposity status (Bontemps et al., 2022). Likewise, body fat has been shown to be unrelated to — and a poor predictor of — muscle strength (Choi, Kim, Hur, & Lee, 2016).

In the present study, the decline in BMI chiefly reflected a loss of adipose tissue rather than an enlargement of the thigh or gluteal cross sectional area that actually produces force in the leg press. Schranz et al (2013) similarly reported large strength gains after resistance training without substantial changes in body composition. Overall, such interventions tend to produce only small changes in body composition yet moderate to large improvements in strength among overweight and obese children and adolescents (Schranz, Tomkinson, & Olds, 2013). Myers et al (2017) reached the same conclusion in overweight adolescents. The absence of a body fat–mediated pathway for strength gains may also reflect the programme’s emphasis on moderate loads executed rapidly and repeatedly, a stimulus that provides insufficient mechanical tension to induce hypertrophy or appreciable fibre accretion. In overweight youths, therefore, fat loss reduces inertial ballast and benefits explosive tasks such as sprinting, but it does not enhance the contractile capacity that determines leg press performance.

Interestingly, the present data show that a reduction in body mass index (BMI) is directly associated with greater explosive power, although the concomitant decline in body fat percentage (BF%) does not mediate this effect. Excess body weight generally impairs explosive performance: Nikolaidis et al. (2015) reported that overweight adolescent basketball players — characterised by higher BMI and BF% — exhibited poorer sprint and jump outcomes (vertical and broad jump) than their normal weight counterparts, indicating that surplus mass, particularly fat, adds non propulsive load and worsens the force to mass ratio. In contrast, other observational studies suggest that BF% is usually the stronger negative predictor of jump performance, whereas BMI is often non significant (Esco et al., 2018). For

example, among adolescent soccer players, BMI showed no meaningful correlation with vertical jump height, whereas BF% was strongly and negatively related to jump performance (Stojanović et al., 2020). Similar results have been reported in combat sport athletes, where BF% correlated negatively with jump height while body mass and BMI did not (Abidin & Adam, 2013). Nevertheless, the influence of BMI and BF% on power warrants further investigation, as power is understood to be driven primarily by strength and speed (Yulvia Miftachurochmah, Tomoliyus, Sukanti, Pamungkas, & Pavlović, 2023).

Multiple studies emphasise that neuromuscular adaptations — particularly increases in the rate of force development (RFD) — and mechanical factors are critical to improvements in explosive power. Strength or plyometric training elevates RFD and inter muscle coordination, enabling higher jump performance without necessarily altering body composition. Lamas et al. (2012) showed that eight weeks of either heavy strength or high velocity power training increased squat jump height by 4–8 cm, driven by a significantly faster concentric phase and a 24–42 % rise in peak rate of force development, underscoring that rapid force production is a stronger determinant of jump performance than body mass alone. Given the complex interplay among body composition (BMI and BF%), strength, and speed in determining power, the current data are insufficient to claim that BMI reduction alone predicts explosive performance. The observed gains in power are most likely influenced by concurrent improvements in strength and sprint speed — variables not analysed separately in this study. Follow up research that measures strength, speed, and detailed body composition changes is required to map the relative contributions of each factor to explosive ability.

In summary, resistance training elicits two partially independent physiological cascades that together explain the pattern observed in the present study. Although the current investigation cannot directly delineate the physiological mechanisms underlying the measured outcomes, plausible explanations can be inferred from the extant literature. The first cascade in resistance training adaptation is neuromuscular–mechanical. Within weeks, heavy load work lowers motor unit recruitment thresholds, elevates firing frequency, and enhances inter unit synchronisation while reducing antagonist co activation (Del Vecchio et al., 2019; Häkkinen, Alen, Kallinen, Newton, & Kraemer, 2000; Hughes, Ellefsen, & Baar, 2018). Concurrent increases in musculotendinous stiffness shorten the electromechanical delay and improve the stretch–shortening cycle (Waugh et al., 2014). These neural adaptations raise maximal force, accelerate the rate of force development, and reduce ground contact time, thereby driving the notable gains in lower body strength, explosive power, and 20 m sprint speed recorded in the present cohort — even before appreciable hypertrophy occurs (Blazevich, Wilson, Alcaraz, & Rubio-Arias, 2020; Del Vecchio et al., 2019; Hughes et al., 2018). With continued training, modest increases in fascicle cross sectional area further augment the “engine” for force production and reinforce the direct association between the observed body composition improvements and power gains (Monti et al., 2020; Zemková et al., 2017).

The second cascade is metabolic–endocrine and operates largely in parallel with, rather than through, the neuromuscu-

lar pathway. Resistance training has been shown to aid weight loss across diverse populations, depending on the methods employed (Lopez et al., 2022; Pamungkas, Rismayanthi, Nasrulloh, & Arjuna, 2024). Appropriately prescribed resistance training elevates excess post exercise oxygen consumption (Greer, O'Brien, Hornbuckle, & Panton, 2021; Kirk et al., 2009), increases sympathetic catecholamines and growth hormone (Athanasίου, Bogdanis, & Mastorakos, 2023; Manini et al., 2012), and adds energetically costly lean tissue, together raising 24-hour energy expenditure and promoting net fat oxidation (Aristizabal et al., 2015). These shifts explain the significant reductions in BMI and body fat percentage observed in the present study. Because lighter limbs incur lower inertial and braking forces, the decline in body fat partially mediated the sprint improvement yet had minimal influence on strength and power, for which force production capacity — rather than body mass — remained the primary limiter. In summary, resistance training enhances speed, strength, and power through rapid neuromuscular and subsequent morphological adaptations while simultaneously lowering BMI and body fat via metabolic mechanisms; the divergent contributions of these cascades are mirrored in the variable specific mediation pattern identified by the PROCESS analysis.

Practically, these results show that a structured resistance training programme performed three times per week under qualified supervision is an effective strategy for improving speed, strength, explosive power, and body composition in youth futsal athletes. Managing key anthropometric variables — particularly BMI and body fat percentage — can enhance movement efficiency and on court explosiveness while reducing injury risk associated with unfavourable body composition. Theoretically, this study extends current knowledge by demonstrating that anthropometric improvements partially mediate the training–performance relationship, underscoring the need to integrate body composition monitoring into athletic development models for adolescents.

This study employed a one group pre test–post test design without a control group, thereby limiting causal inference. The small sample ($n = 30$), consisting exclusively of male athletes from five club in one geographic region, restricts generalisability to other athletic populations, particularly female or recreational players. The eight week intervention may have been insufficient to capture slower morphological adaptations such as muscle hypertrophy and tendon remodelling. Body composition assessment was limited to BMI and body fat percentage—indices that do not distinguish lean from fat mass — and was performed with bioelectrical impedance analysis, which has an estimated error of $\pm 3.5\%$. Test reliability for the performance measures (leg press, broad jump, 20 m sprint) may have been affected by learning effects despite the inclusion of a familiarisation session. Nutritional intake and physical activity outside the training sessions were not rigorously monitored.

Future research should employ a randomised controlled design with larger sample sizes, longer intervention periods, and more precise body composition techniques such as dual energy X ray absorptiometry or segmental bioelectrical impedance analysis. Investigating a range of resistance training modalities (e.g., plyometric or high velocity protocols) and stratifying analyses by biological maturation status would further clarify the adaptive responses of youth athletes to training stimuli.

Conclusions

This study demonstrated that a structured resistance training program significantly improved sprint speed, muscular strength, and explosive power in U20 futsal athletes, accompanied by reductions in body mass index (BMI) and body fat percentage. Anthropometric improvements, particularly the reduction in body fat, were shown to mediate the relationship between BMI and sprint performance. However, no such mediating effect was observed in relation to strength or power. While BMI reductions were associated with improvements in power, this relationship appeared to be independent of changes in body fat, suggesting that other physiological mechanisms may be involved. Similarly, the link between BMI and strength gains was not statistically supported either directly or through body fat, indicating a weaker or more complex relationship in that domain. These findings highlight the complex but meaningful role of body composition — particularly body fat percentage — in mediating the effects of resistance training on specific performance outcomes such as sprint speed. Despite these promising results, the study has several limitations, including the absence of a control group, a relatively small sample size, and reliance on basic anthropometric measures, namely body fat percentage. Therefore, future research is recommended to adopt an experimental design with a control group, a larger sample size, and more advanced techniques for assessing body composition to enhance the generalizability and validity of the findings.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Медіативна роль антропометричних поліпшень у впливі силових тренувань на швидкість, силу та потужність футзалістів вікової категорії U20

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 4 табл., 48 джерел.

Історія питання. Період підліткового віку характеризується здатністю організму до підвищених тренувальних навантажень, проте приблизно 18 % молодих осіб мають надлишкову вагу або страждають на ожиріння. Відзначено, що в п'яти футзальних клубах Джок'якарти 37–51 % гравців віком до 17 років мають ІМТ ≥ 25 кг·м⁻², що потенційно негативно впливає на результативність.

Мета дослідження. Мета цього дослідження полягала у вивченні питання, чи сприяє впровадження восьмитижневої програми силових тренувань підвищенню показників швидкості спринту на 20 метрів, сили нижньої частини тіла та вибухової сили у футзалістів віком до 17 років, а також чи є зміна вмісту жирової маси в організмі чинником, що впливає на зазначені ефекти.

Матеріали та методи. Тридцять 18-19-річних гравців чоловічої статі виконували періодичні силові тренування, які проводилися тричі на тиждень. У перед- та постінтревенційній фазі дослідження вимірювалися показники маси тіла, ІМТ, відсоток жирової маси тіла (ВЖМТ), час спринту, максимальне навантаження під час виконання жиму ногами при одному повторенні та відстань стрибка в довжину з місця. З метою оцінки змін у групі застосовано парні t-критерії. Медіативні моделі (PROCESS; 5000 бутстрепів) досліджували, чи є зміни показників ВЖМТ опосередкованим фактором впливу змін ІМТ на результативність.

Результати. Спостерігалось суттєве зниження показників маси тіла (-1.21 кг), ІМТ (-0.43 кг·м⁻²), а також відсоткового вмісту жиру в організмі (-1.48 %), тоді як показники часу спринту (-0.95 с), сили ніг під час виконання жиму ($+11.9$ кг) та відстань стрибка ($+11.8$ см) покращилися (усі показники $p < 0.001$). Зміни показників ІМТ передбачали варіації ВЖМТ ($B = 5.38$, $p < 0.001$). Рівень ВЖМТ частково опосередковував зв'язок між ІМТ та спринтом (непрямий ефект = 3.52 , 95 % ДІ [2.70 , 4.47]), однак із збереженням значної прямої траєкторії. Медіація не мала істотного значення для показників сили та потужності; зниження ІМТ не виявило жодного зв'язку зі зміною сили, продемонструвавши при цьому сильний прямий зв'язок із підвищенням потужності незалежно від відсотка жирової маси тіла.

Висновки. Результати цього дослідження показують, що силові тренування суттєво покращують нервово-м'язову працездатність та композицію тіла у юних футзалістів. Нижчий рівень ІМТ сприяє підвищенню швидкості спринту як безпосередньо, так і через паралельне зниження відсотка жирової маси тіла, тоді як адаптація показників сили та потужності відбувається за допомогою механізмів, відмінних від ожиріння. Тому тренувальні програми повинні поєднувати нервово-м'язове навантаження зі стратегіями здорового контролю ваги з метою оптимізації результативності юних футзалістів.

Ключові слова: антропометрія, силові тренування, швидкість, сила, потужність, футзал.

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