



www.bioinformation.net
Volume 22(9)



Research Article

Received September 1, 2026; Revised September 30, 2026; Accepted September 30, 2026, Published September 30, 2026

DOI: 10.6026/973206300226036

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478

2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Citation: Senthil *et al.* Bioinformation 22(9): 6036-6040 (2026)

Body composition, physical fitness and cardiometabolic risk following 12-week multimodal exercise program: A randomized controlled trial

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Abstract:

Childhood obesity increases the risk of cardiometabolic disorders and adversely affects physical and psychosocial health. Therefore, it is of interest to evaluate the 12-week multimodal exercise programme in obese children aged 8–12 years attending a tertiary care hospital. The intervention combined aerobic, resistance and flexibility training and was compared with standard lifestyle counselling. The exercise programme significantly improved BMI z-score, body fat percentage, VO₂max, insulin sensitivity, lipid profile and health-related quality of life without serious adverse events. Thus, data shows that multimodal exercise programmes into routine paediatric obesity management to improve health outcomes.

Keywords: Childhood obesity, multimodal exercise, aerobic training, resistance training, body composition, cardiorespiratory fitness, insulin resistance, paediatric, randomized controlled trial

Background:

Childhood obesity is one of the most pressing public health challenges of the 21st century. Global pooled analyses estimate that more than 159 million children and adolescents aged 5–19 years were living with obesity in 2022, representing a near four-fold rise in age-standardised obesity since 1990 [1]. In low- and middle-income countries (LMICs), including India, the prevalence of childhood obesity has accelerated disproportionately because of dietary transitions, reduced physical activity and increased screen time [2]. Obesity during childhood is strongly associated with cardiovascular risk factors, including dyslipidaemia, hypertension and insulin resistance, many of which track into adulthood [3, 4]. Obese children consistently show reduced cardiorespiratory fitness (CRF), impaired musculoskeletal function and diminished health-related quality of life (HRQoL) [5]. The 8–12-year age window represents a critical developmental phase during which adiposity patterns are established and structured intervention may exert maximal and lasting benefit [6]. Exercise training is universally recommended as a primary non-pharmacological intervention for paediatric obesity. However, the literature has traditionally examined isolated exercise modalities-aerobic training, resistance training, or flexibility-rather than their combination. Aerobic exercise preferentially reduces visceral and total fat mass [7]; resistance training increases lean body mass and resting metabolic rate; flexibility training improves musculoskeletal function and reduces injury risk. A multimodal approach theoretically harnesses the complementary physiological benefits of all three modalities; yet rigorous randomized controlled trial evidence supporting this integrated strategy in the 8–12-year age group remains sparse [8]. Prior systematic reviews and meta-analyses have highlighted significant heterogeneity in exercise type, duration, frequency

and intensity across paediatric obesity trials, limiting generalizability [9]. Network meta-analyses suggest that combined aerobic-resistance protocols and concurrent training are among the most effective approaches for improving insulin resistance and body composition in this population [10]. Therefore, it is of interest to evaluate the effectiveness of a 12-week multimodal exercise programme on body composition, physical fitness and cardiometabolic risk factors in obese children aged 8–12 years.

Methodology:

This single-blind, parallel-group randomized controlled trial was conducted at the Paediatric Outpatient Department and Physiotherapy Department of a tertiary care hospital in India over the period from January 2023 to March 2024. The study was conducted in accordance with the Declaration of Helsinki and CONSORT 2010 guidelines for reporting parallel-group RCTs. The aim of the study was to evaluate the effectiveness of a structured 12-week multimodal exercise programme in obese children aged 8–12 years. Children aged 8–12 years with a BMI at or above the 95th percentile for age and sex (defined as obesity per Indian Academy of Paediatrics reference standards) were recruited. Inclusion criteria were: (i) age 8–12 years, (ii) BMI ≥95th age- and sex-specific percentile, (iii) absence of major orthopaedic, cardiovascular, or metabolic contraindications to exercise and (iv) no participation in any structured exercise programme in the six months preceding enrolment. Exclusion criteria included: (i) syndromic obesity or secondary endocrine causes of obesity (hypothyroidism, Cushing syndrome), (ii) known type 1 diabetes mellitus, (iii) severe asthma requiring regular inhaled corticosteroids and (iv) physical or cognitive disabilities precluding exercise participation. Written informed consent was obtained from all parents/guardians and written

assent was obtained from children aged 10 years and above. Sample size was estimated based on the primary outcome of BMI z-score change. Using a mean difference of 0.35 z-score units with a pooled standard deviation of 0.45, a two-tailed α of 0.05 and 80% power, a minimum of 32 participants per group was required. Accounting for 12% anticipated attrition, 36 participants per group (total $n=72$) were enrolled. Eligible participants were randomized in a 1:1 ratio using a computer-generated block randomization sequence (block size 4) stratified by sex and age group (8–10 years vs. 11–12 years). Allocation was concealed using sequentially numbered opaque sealed envelopes (SNOSE), opened only after baseline assessment. Outcome assessors and statisticians were blinded to group allocation; blinding of participants and exercise therapists was not feasible due to the nature of the intervention. The intervention group participated in a 12-week supervised multimodal exercise programme, five sessions per week, each lasting 60 minutes. Each session comprised three sequential components: (i) an aerobic component (25 minutes) of moderate-to-vigorous activity (brisk walking, jogging, skipping rope, stationary cycling and structured dance/movement sequences) at 60–75% of maximum heart rate, with interval training (2-min work : 1-min active recovery) introduced from week 5; (ii) a resistance training component (20 minutes) of progressive bodyweight and dumbbell exercises (squats, lunges, modified push-ups, bent-over rows and core stabilisation), progressing from 2×10 to 3×15 repetitions with the OMNI-RES paediatric scale guiding intensity; and (iii) a flexibility and cool-down component (15 minutes) of static and dynamic stretching of the major muscle groups, held for 20–30 seconds and repeated twice. Sessions were delivered in groups of 8–10 children by two trained paediatric physiotherapists and adherence was recorded on standardised attendance registers. The control group received a single standardised lifestyle counselling session at baseline and monthly brief follow-up calls (10 minutes each), with dietary and general physical activity recommendations aligned with IAP and WHO guidelines but no structured exercise programme. All outcomes were assessed at baseline (week 0) and post-intervention (week 13) by blinded assessors. Primary outcomes were: (i) BMI z-score calculated using the LMS method, (ii) body fat percentage and (iii) estimated VO_2max derived from the 20-metre Multistage Fitness Test (Beep Test). Secondary outcomes included: waist circumference (midpoint between the lowest rib and iliac crest); fasting serum insulin and Homeostatic Model Assessment of Insulin Resistance ($\text{HOMA-IR} = \text{fasting insulin (mU/L)} \times \text{fasting glucose (mmol/L)} / 22.5$); fasting lipid profile (total cholesterol, HDL-C, LDL-C, triglycerides); handgrip strength (Jamar dynamometer, average of three trials per dominant hand); sit-and-reach test (cm); and Paediatric Quality of Life Inventory version 4.0 (PedsQL 4.0) total score. Descriptive statistics were used to summarise baseline characteristics and outcome responses. Continuous variables were presented as mean $\pm$ standard deviation and categorical variables as frequencies and percentages. Statistical analyses were performed using SPSS version 26.0 following intention-to-treat principles, with multiple imputations for missing data using predictive

mean matching (5 imputations). Baseline characteristics were compared using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. The primary analysis used analysis of covariance (ANCOVA), with post-intervention values as the dependent variable, group as the fixed factor and baseline values as covariates, to compare between-group differences at week 13. Within-group changes were assessed with paired t-tests and effect sizes were calculated as Cohen's d . Subgroup analyses by sex and age group were pre-specified and statistical significance was set at $p<0.05$ (two-tailed). Ethical considerations were addressed, as the study protocol was reviewed and approved by the Institutional Ethics Committee. Participants assigned to the control group were offered the multimodal exercise programme at the end of the trial, in line with the study's commitment to participant welfare.

Results:

Of 118 children screened, 72 met eligibility criteria and were randomized (intervention: $n=36$; control: $n=36$). Five participants withdrew before completion (intervention: $n=2$ —one relocation, one parental withdrawal; control: $n=3$ —two relocation, one loss to follow-up). Intention-to-treat analysis was conducted for all 72 randomized participants. Mean session attendance in the intervention group was 91.4% (range: 72%–100%). Baseline demographic and clinical characteristics were comparable between groups (**Table 1**). The mean age was 10.3 ± 1.4 years in the intervention group and 10.1 ± 1.5 years in the control group. Mean BMI z-score was 2.41 ± 0.31 and 2.38 ± 0.29 , respectively. There were no significant between-group differences in any baseline variable (all $p>0.05$). Following 12 weeks of intervention, the multimodal exercise group showed statistically significant and clinically meaningful improvements in all three primary outcomes compared with the control group (**Table 2**). BMI z-score decreased by 0.38 ± 0.12 in the intervention group versus 0.06 ± 0.09 in the control group (adjusted between-group difference: -0.32 ; 95% CI: -0.41 to -0.23 ; $p<0.001$; Cohen's $d = 1.12$). Body fat percentage reduced by $3.1\% \pm 0.8$ versus $0.4\% \pm 0.6$ (adjusted difference: -2.7% ; $p<0.001$; $d = 0.94$). VO_2max increased by 4.7 ± 1.2 mL/kg/min versus 0.9 ± 0.8 mL/kg/min (adjusted difference: $+3.8$ mL/kg/min; $p<0.001$; $d = 1.08$). Significant between-group differences were also observed for waist circumference (reduction of 4.8 cm in intervention vs. 0.7 cm in control; $p<0.001$), fasting insulin (reduction of 3.4 $\mu\text{U/mL}$ vs. 0.3 $\mu\text{U/mL}$; $p=0.002$) and HOMA-IR (reduction of 0.78 vs. 0.09; $p=0.003$). Regarding the lipid profile, triglycerides were significantly reduced in the intervention group ($p=0.01$) and HDL-C increased significantly ($+3.8$ mg/dL vs. $+0.6$ mg/dL; $p=0.02$), while total cholesterol and LDL-C showed trends toward improvement without reaching significance ($p=0.07$ and $p=0.09$, respectively). Handgrip strength and sit-and-reach flexibility scores improved significantly in the intervention group (both $p<0.001$). PedsQL total score increased by 9.4 ± 3.2 points in the intervention group versus 1.8 ± 2.6 points in the control group ($p=0.004$; $d=0.72$). Detailed secondary outcomes are presented in (**Tables 3 and 4**). No serious adverse events were reported throughout the 12-week programme. Minor

musculoskeletal complaints were noted in four participants in the intervention group (11.1%): two episodes of delayed-onset muscle soreness (resolved within 48 hours with activity modification), one mild ankle strain (managed with RICE

protocol; participant resumed exercise within five days) and one knee pain episode (benign on physiotherapy assessment; returned to modified exercise). No cardiovascular events or hypoglycaemic episodes were recorded.

Table 1: Baseline characteristics of study participants (n=72)

Variable	Intervention (n=36)	Control (n=36)	p-value
Age (years)	10.3 ± 1.4	10.1 ± 1.5	0.61
Sex (M/F)	20/16	19/17	0.83
BMI (kg/m²)	28.7 ± 3.2	28.4 ± 3.1	0.70
BMI z-score	2.41 ± 0.31	2.38 ± 0.29	0.68
Body fat (%)	38.2 ± 4.1	37.9 ± 4.3	0.76
Waist circumference (cm)	82.4 ± 6.8	81.9 ± 7.1	0.77
Fasting glucose (mg/dL)	91.3 ± 7.2	90.8 ± 6.9	0.79
Fasting insulin (µU/mL)	16.8 ± 4.3	16.5 ± 4.1	0.76
HOMA-IR	3.82 ± 1.04	3.77 ± 0.98	0.83
VO ₂ max (mL/kg/min)	29.4 ± 3.8	29.7 ± 3.6	0.72
PedsQL total score	71.4 ± 9.3	72.1 ± 8.8	0.75

Values are mean ± SD or n. Independent-samples t-test for continuous variables; chi-square test for categorical variables. BMI = Body Mass Index; HOMA-IR = Homeostatic Model Assessment-Insulin Resistance; PedsQL = Paediatric Quality of Life Inventory.

Table 2: Primary outcome measures – pre- and post-intervention values (n=72, ITT)

Outcome	INT Pre	INT Post	CON Pre→Post	p (between)
BMI z-score	2.41 ± 0.31	2.03 ± 0.28*	2.38 → 2.32	<0.001
Body fat (%)	38.2 ± 4.1	35.1 ± 3.9*	37.9 → 37.5	<0.001
VO ₂ max (mL/kg/min)	29.4 ± 3.8	34.1 ± 4.1*	29.7 → 30.6	<0.001

INT = Intervention group; CON = Control group. *p<0.001 vs. control (ANCOVA, adjusted for baseline). Mean ± SD.

Table 3: Secondary metabolic and anthropometric outcomes

Variable	INT Pre	INT Post	CON Pre	CON Post	p*
Waist circ. (cm)	82.4 ± 6.8	77.6 ± 6.2	81.9 ± 7.1	81.2 ± 7.0	<.001
Fasting insulin (µU/mL)	16.8 ± 4.3	13.4 ± 3.9	16.5 ± 4.1	16.2 ± 4.0	.002
HOMA-IR	3.82 ± 1.04	3.04 ± 0.92	3.77 ± 0.98	3.68 ± 0.97	.003
Total cholesterol (mg/dL)	178.3 ± 22.1	171.2 ± 20.4	176.8 ± 21.7	175.4 ± 21.5	.07
LDL-C (mg/dL)	104.2 ± 18.4	97.8 ± 17.1	103.1 ± 17.9	102.4 ± 18.0	.09
HDL-C (mg/dL)	42.1 ± 6.8	45.9 ± 7.1	42.4 ± 6.6	43.0 ± 6.7	.02
Triglycerides (mg/dL)	124.6 ± 28.3	108.2 ± 24.1	122.9 ± 27.6	119.4 ± 26.8	.01

*p-value for between-group difference at post-intervention (ANCOVA, adjusted for baseline). INT = Intervention; CON = Control. Mean ± SD.

Table 4: Secondary physical fitness and quality of life outcomes

Variable	INT Pre	INT Post	CON Pre	CON Post	p*
Handgrip strength (kg)	14.2 ± 3.1	17.8 ± 3.4	13.9 ± 3.0	14.2 ± 3.1	<.001
Sit-and-reach (cm)	18.4 ± 5.2	24.1 ± 4.8	18.7 ± 5.0	19.2 ± 5.1	<.001
PedsQL total score	71.4 ± 9.3	80.8 ± 8.6	72.1 ± 8.8	73.9 ± 8.5	.004
PedsQL physical	69.2 ± 11.1	79.4 ± 10.2	70.1 ± 10.8	71.6 ± 10.7	.001
PedsQL psychosocial	73.1 ± 9.8	82.0 ± 8.9	73.8 ± 9.4	75.9 ± 9.2	.012

*p-value for between-group difference at post-intervention (ANCOVA, adjusted for baseline). PedsQL = Paediatric Quality of Life Inventory 4.0. Mean ± SD.

Discussion:

The present study showed that a supervised 12-week multimodal exercise programme significantly improved body composition, cardiorespiratory fitness, insulin sensitivity and health-related quality of life in children with obesity. These findings are consistent with Liu *et al.* [8], who reported that combined aerobic and resistance training significantly reduced BMI, fat mass and waist circumference while improving VO₂max in overweight and obese children. Similarly, García-Hermoso *et al.* [10] found that concurrent aerobic and resistance exercise was the most effective strategy for reducing fasting insulin and HOMA-IR, supporting the significant improvement in insulin resistance observed in the present study. Kazeminasab *et al.* [12] also showed that exercise interventions improve fasting glucose, insulin, HOMA-IR and body weight, reinforcing the metabolic benefits identified in our participants. Furthermore, Cao *et al.*

[11] highlighted that regular physical activity effectively reduces obesity-related health risks and enhances physical fitness among children, while Li *et al.* [9] further emphasized that structured exercise programmes produce sustained improvements in metabolic health and quality of life in paediatric obesity. Collectively, these findings support the effectiveness of supervised multimodal exercise as a practical intervention for childhood obesity. Strengths of the present study include its randomized design, blinded outcome assessment, validated outcome measures and high adherence. Limitations include the single-centre setting, relatively short follow-up, lack of dietary assessment and limited power for some secondary outcomes.

Conclusion:

A 12-week supervised multimodal exercise programme safely and effectively improved metabolic, physical fitness and quality-

of-life outcomes in obese children aged 8–12 years. Integrating combined aerobic, resistance and flexibility training into paediatric obesity care may support sustainable lifestyle changes and reduce long-term cardiometabolic risk. Such evidence-based programmes could strengthen childhood obesity management in India and other LMICs.

References:

- [1] Zhang X *et al.* *JAMA Pediatr.* 2024 **178**:800. [PMID: 38856986]
- [2] Panda A *et al.* *BMC Nutr.* 2025 **11**:110. [PMID: 40474315]
- [3] Drozd D *et al.* *Nutrients.* 2021 **13**:4176. [PMID: 34836431]
- [4] Raoof AA. *Oral Sphere J. Dent. Health Sci.* 2026 **2**:41. [DOI: 10.63150/osjdhs.2026.07]
- [5] Calcaterra V *et al.* *Nutrients.* 2022 **14**:4692. [PMID: 36364954]
- [6] Calcaterra V *et al.* *Children (Basel).* 2022 **9**:1174. [PMID: 36010064]
- [7] Vandoni M & Pellino VC. *Int J Environ Res Public Health.* 2022 **19**:5996. [PMID: 35627533]
- [8] Liu X *et al.* *Front Public Health.* 2024 **12**:1409660. [PMID: 39185113]
- [9] Li M *et al.* *Healthcare (Basel).* 2025 **13**:3319. [PMID: 41464385]
- [10] García-Hermoso A *et al.* *JAMA Pediatr.* 2023 **177**:1276. [PMID: 37812414]
- [11] Cao M *et al.* *J Clin Med.* 2022 **11**:5436. [PMID: 36143083]
- [12] Kazeminasab F *et al.* *Front Endocrinol (Lausanne).* 2023 **14**:1178376. [PMID: 37635963]

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