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Effects of a 12-Week School-BasedPhysical Education and Nutrition Education Intervention on Obesity Indices and Cardiorespiratory Fitness in Upper Elementary School Boys: A Quasi-Experimental Study

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ABSTRACT

Childhood overweight, obesity, and declining physical activity are major public-health concerns, and schools provide a practical setting for preventive interventions. This quasi- experimental study examined the effects of a 12-week integrated school-based physical education, nutrition education, and energy-intake management program on body- composition indices and cardiorespiratory fitness in upper elementary school boys in District 5 of Tehran, Iran. One hundred eligible boys were selected by multistage cluster sampling and allocated to an intervention group ($n = 50$) or a control group ($n = 50$). The intervention group participated in a structured physical education program twice weekly for 12 weeks (45 min/session) and received six nutrition-education sessions with guidance designed to reduce habitual energy intake by approximately 200-300 kcal/day without severe dietary restriction. The control group continued usual school activities. Body mass, body mass index (BMI), body-fat percentage, waist circumference, hip circumference, waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), three-site skinfold thickness, 20-m shuttle-run performance, and estimated maximal oxygen uptake (VO_2max) were assessed before and after the intervention. Data were analyzed using paired-samples t tests, independent-samples t tests, and analysis of covariance controlling for pretest values. After 12 weeks, the intervention group showed meaningful reductions in body mass (-6.0%), BMI (-6.8%), body-fat percentage (-15.7%), waist circumference (-7.4%), WHR (-5.6%), WHtR (-7.4%), and total skinfold thickness (-19.8%). Cardiorespiratory-fitness outcomes also improved, with increases in 20-m shuttle-run stages (+40.3%), shuttle-run laps (+45.1%), and estimated VO_2max (+18.7%). ANCOVA confirmed significant between-group differences for all outcomes, with the largest effects for VO_2max (partial $\eta^2 = .41$), 20-m shuttle-run performance (partial $\eta^2 = .39$), total skinfold thickness (partial $\eta^2 = .34$), and body-fat percentage (partial $\eta^2 = .31$). The findings indicate that combining school-based physical education with nutrition education and moderate energy-intake management can improve obesity-related indices and cardiorespiratory fitness in upper elementary school boys. Such integrated programs may represent a feasible and low-cost strategy for child- obesity prevention and health promotion in school settings.

Keywords: *nutrition education; energy-intake management; body composition; cardiorespiratory fitness; childhood obesity; elementary school boys*

1. Introduction

Childhood health is shaped by the interaction of physical activity, diet, growth, and the social environments in opportunities for active play, greater exposure to screen-based sedentary behavior, and increased availability of energy-dense foods have contributed to higher rates of childhood overweight and obesity. The World Health Organization recommends that children and adolescents accumulate an average of at least 60 minutes per day of moderate-to-vigorous physical activity, mostly aerobic, while limiting sedentary behavior (1, 2).

Childhood obesity is clinically important because it is associated with adverse cardiometabolic, functional, and psychosocial outcomes. Reviews of school-aged populations show that physical activity and physical fitness are related to adiposity, cardiometabolic risk, bone health, and psychological indicators (3, 4). Physical fitness in childhood and adolescence has also been described as a strong marker of current and future health status (5). Therefore, interventions that improve body composition and cardiorespiratory fitness during school age may have preventive value beyond the immediate school period.

Schools are a particularly relevant environment for health promotion because they reach children repeatedly, provide structured opportunities for movement, and can integrate physical education with nutrition education. Physical education has long been framed as a public-health resource rather than only a curricular subject (6). Systematic reviews indicate that school-based physical activity programs can improve physical activity and selected fitness outcomes in children and adolescents (7), and quality-based physical education interventions are associated with improvements in health-related physical fitness and fundamental motor skills (8).

Nevertheless, exercise-only school interventions do not always produce substantial changes in BMI. For example, a meta-analysis by Harris et al. (2009) reported limited effects of school-based physical activity interventions on BMI, although other health benefits were evident (9). This suggests that body-composition outcomes may be more responsive when physical activity is paired with nutrition education and energy-intake management. From an energy-balance perspective, combining increased energy expenditure with modest reductions in energy intake is more likely to reduce adiposity than either strategy alone.

In addition to BMI, central-adiposity indicators such as waist circumference and WHtR are important because abdominal fat is strongly linked with cardiometabolic risk. Ashwell and Hsieh (2005) argued that WHtR is a simple screening indicator for obesity-related health risk, and the inclusion of waist-based measures can therefore provide information beyond body mass alone (10). Similarly, cardiorespiratory fitness is a key functional marker in children and can be estimated in school settings using the 20-m shuttle-run test developed by Léger et al. (1988) (11).

Evidence from Iran on integrated school-based interventions that combine structured physical education, nutrition education, and energy-intake management remains limited. The present study therefore investigated the effects of a 12-week school-based intervention on body-composition indices and cardiorespiratory fitness among upper elementary school boys in District 5 of Tehran. The primary hypothesis was that the integrated program would improve obesity-related indicators and cardiorespiratory fitness compared with the usual school program.

2. Methods and Materials

2.1. Study Design and Setting

This quasi-experimental study used a pretest-posttest design with a control group. The intervention was implemented over 12 weeks in elementary schools in District 5 of Tehran, Iran. The intervention group received structured school-based physical education combined with nutrition education and energy-intake management, whereas the control group continued usual school activities.

2.2. Participants and Sampling

The statistical population consisted of upper elementary school boys in grades 4 to 6 in public schools in District 5 of Tehran during the 2026-2027 school year. A total of 100 eligible students were selected by multistage cluster sampling. Four boys' schools were selected from the district, and eligible students were screened and enrolled. Participants were then allocated to an intervention group (n = 50) and a control group (n = 50). The mean age of participants was 11.2 ± 0.8 years.

Inclusion criteria were age 10-12 years, enrollment in upper elementary school, absence of cardiac, respiratory, metabolic, or musculoskeletal conditions that could limit physical activity, no use of medication affecting body metabolism, and written parental consent. Exclusion criteria were absence from more than 20% of sessions, illness or injury during the study, lack of cooperation with testing procedures, or voluntary withdrawal.

2.3. Intervention Protocol

The intervention lasted 12 weeks. Students in the intervention group participated in two structured physical education sessions per week, with each session lasting 45 minutes. Each session included 10 minutes of warm-up, 30 minutes of main activity, and 5 minutes of cool-down. Warm-up activities included light running, dynamic stretching, and low-intensity movement games. The main section included aerobic and skill-based activities such as shuttle runs, short sprints, rope skipping, team games including football, handball, and dodgeball, agility drills, coordination exercises, and group competitions. Activity intensity was maintained at approximately 60%-75% of target maximal heart rate, corresponding to moderate-to-vigorous activity for children. Cool-down included walking, static stretching, and breathing exercises.

2.4. Nutrition Education and Energy-Intake Management

The physical activity program was accompanied by nutrition education and energy-intake management. The intervention group received six 30-minute nutrition-education sessions, delivered every two weeks by the researcher in cooperation with a nutrition specialist. Educational brochures were distributed to parents, and students' dietary patterns were monitored weekly. The educational content covered healthy nutrition principles, breakfast consumption, increased fruit and vegetable intake, reduced intake of sugar-sweetened beverages, restriction of high-fat and high-sugar snacks, portion control, and selection of healthier snacks. The program aimed to produce a mild daily energy deficit of approximately 200-300 kcal relative to the students' habitual intake, without severe restriction or interference with normal growth.

2.5. Measurements

Anthropometric and body-composition measurements were obtained at pretest and posttest. Height was measured with a Seca wall-mounted stadiometer to the nearest 0.1 cm, and body mass was measured with a Seca digital scale to the nearest 0.1 kg. Measurements were performed in the morning with participants wearing light clothing. BMI was calculated as body mass divided by height squared (kg/m²).

Body-fat percentage was measured using a bioelectrical impedance analyzer (Omron BF-511). To improve measurement consistency, students refrained from food and drink intake for at least two hours before testing. Waist circumference was measured at the narrowest part of the torso between the lowest rib and the iliac crest, and hip circumference was measured at the widest part of the buttocks using a nonelastic tape. WHR and WHtR were calculated using standard formulas. Three-site skinfold thickness was measured at the triceps, subscapular, and medial calf sites using a Harpenden caliper with 0.2 mm precision. Each measurement was taken twice, and the mean value was used for analysis.

Cardiorespiratory fitness was assessed using the 20-m shuttle-run test. The number of completed stages and laps was recorded, and VO_2max was estimated using the standard equation of Léger and colleagues (11).

2.6. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics included means, standard deviations, and percentage changes. Normality was evaluated with the Shapiro-Wilk test, and homogeneity of variance was assessed with Levene's test. Baseline group homogeneity was examined using independent-samples t tests. Within-group changes were analyzed using paired-samples t tests. Between-group posttest differences were examined using one-way analysis of covariance (ANCOVA), with pretest values entered as covariates. Partial η^2 was reported as the effect-size index, with .01, .06, and .14 interpreted as small, medium, and large effects, respectively (Cohen, 1988). The significance level was set at $p \leq .05$.

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3. Findings and Results

A total of 100 boys participated in the study, with 50 students in the intervention group and 50 students in the control group. The mean age of the sample was 11.2 ± 0.8 years. Shapiro-Wilk tests indicated acceptable normality for the study variables ($p > .05$), and Levene's tests supported homogeneity of variance ($p > .05$). Independent-samples t tests at baseline showed no statistically significant differences between the groups demographic characteristics or dependent variables ($p > .05$), indicating that the groups were comparable before the intervention.

3.1. Body-Composition Outcomes

Table 1 summarizes the body-composition outcomes at pretest and posttest. After 12 weeks, the intervention group showed reductions in all obesity-related indicators. The largest descriptive reductions were observed for total skinfold thickness (-19.8%), body-fat percentage (-15.7%), WHtR (-7.4%), and waist circumference (-7.4%). In contrast, the control group showed minimal changes.

Table 1
Body-composition outcomes at pretest and posttest

Variable	Group	Pretest M ± SD	Posttest M ± SD	Change
Body mass (kg)	Intervention	46.7 ± 8.2	43.9 ± 7.5	-6.0%
Body mass (kg)	Control	46.1 ± 8.5	46.3 ± 8.4	+0.4%
BMI (kg/m²)	Intervention	22.1 ± 2.7	20.6 ± 2.3	-6.8%
BMI (kg/m²)	Control	22.0 ± 2.5	22.1 ± 2.6	+0.5%
Body fat (%)	Intervention	24.8 ± 4.1	20.9 ± 3.3	-15.7%
Body fat (%)	Control	24.4 ± 4.0	24.2 ± 3.9	-0.8%
Waist circumference (cm)	Intervention	78.6 ± 6.9	72.8 ± 5.7	-7.4%
Waist circumference (cm)	Control	78.2 ± 7.1	78.3 ± 7.0	+0.1%
Hip circumference (cm)	Intervention	88.7 ± 5.8	86.4 ± 5.2	-2.6%
Hip circumference (cm)	Control	88.3 ± 5.9	88.4 ± 6.0	+0.1%
WHR	Intervention	0.89 ± 0.04	0.84 ± 0.03	-5.6%
WHR	Control	0.89 ± 0.05	0.89 ± 0.05	0%
WHtR	Intervention	0.54 ± 0.04	0.50 ± 0.03	-7.4%
WHtR	Control	0.54 ± 0.04	0.54 ± 0.04	0%
Total skinfold thickness (mm)	Intervention	39.8 ± 6.8	31.9 ± 5.4	-19.8%
Total skinfold thickness (mm)	Control	39.5 ± 7.0	39.0 ± 6.9	-1.3%

Note. BMI = body mass index; WHR = waist-to-hip ratio; WHtR = waist-to-height ratio.

Figure 1 illustrates the percentage changes in the main body-composition outcomes. The intervention group showed clearly larger reductions than the control group, particularly for total skinfold thickness, body-fat percentage, WHtR, and waist circumference.

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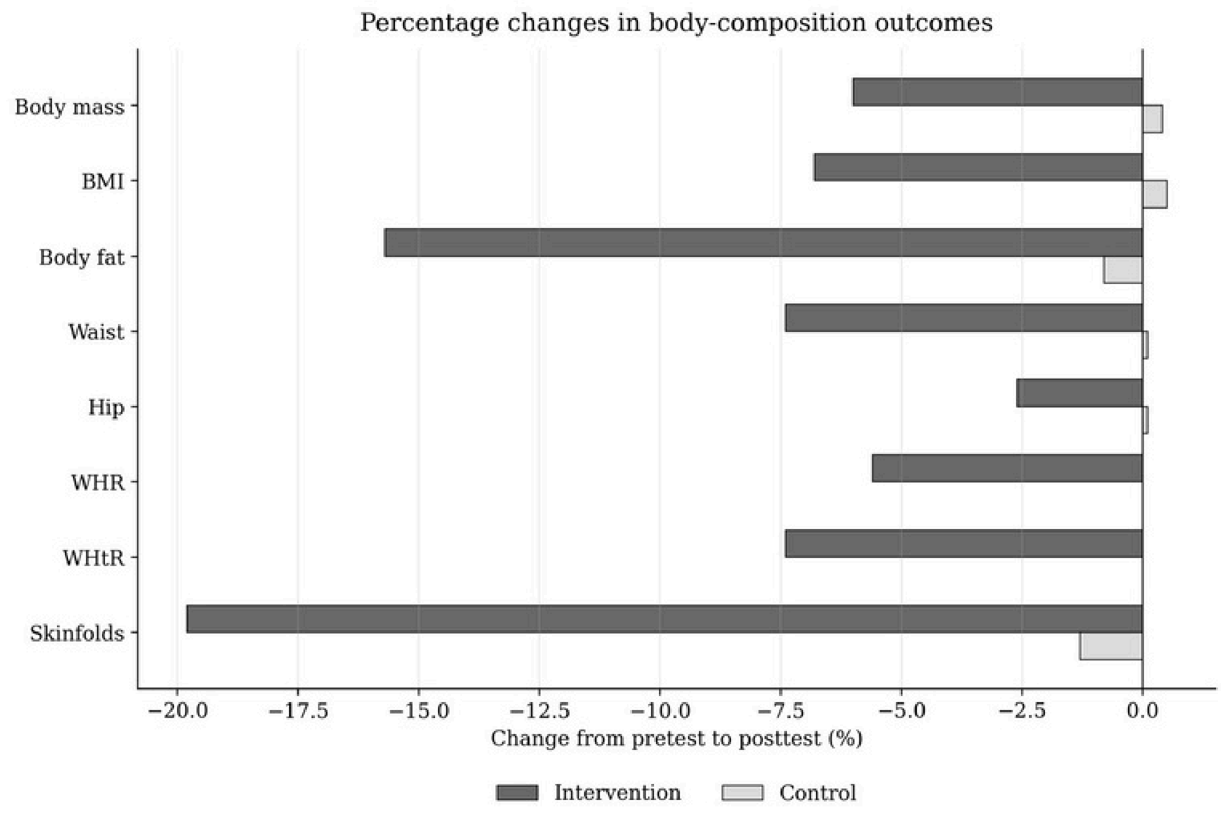
Figure 1

Percentage changes in body-composition outcomes from pretest to posttest.



3.2. *Cardiorespiratory-Fitness Outcomes*

Table 2 presents the cardiorespiratory-fitness outcomes. The intervention group showed substantial improvements in 20-m shuttle-run stages (+40.3%), number of completed shuttle runs (+45.1%), and estimated VO_2max (+18.7%). The control group showed only small descriptive increases.

Table 2

Cardiorespiratory-fitness outcomes at pretest and posttest

Variable	Group	Pretest M ± SD	Posttest M ± SD	Change
20-m shuttle-run stages	Intervention	25.8 ± 4.5	36.2 ± 5.3	+40.3%
20-m shuttle-run stages	Control	25.5 ± 4.8	26.1 ± 4.9	+2.3%
Number of shuttle runs	Intervention	28.6 ± 6.1	41.5 ± 6.9	+45.1%
Number of shuttle runs	Control	28.4 ± 6.0	29.1 ± 6.2	+2.5%
Estimated VO_2max (ml/kg/min)	Intervention	36.9 ± 3.2	43.8 ± 3.7	+18.7%
Estimated VO_2max (ml/kg/min)	Control	37.0 ± 3.4	37.4 ± 3.5	+1.1%

Note. VO_2max was estimated from the 20-m shuttle-run test.

Figure 2 illustrates the percentage changes in cardiorespiratory-fitness outcomes. The largest descriptive improvement occurred in the number of completed shuttle runs, followed by shuttle-run stages and estimated VO_2max.

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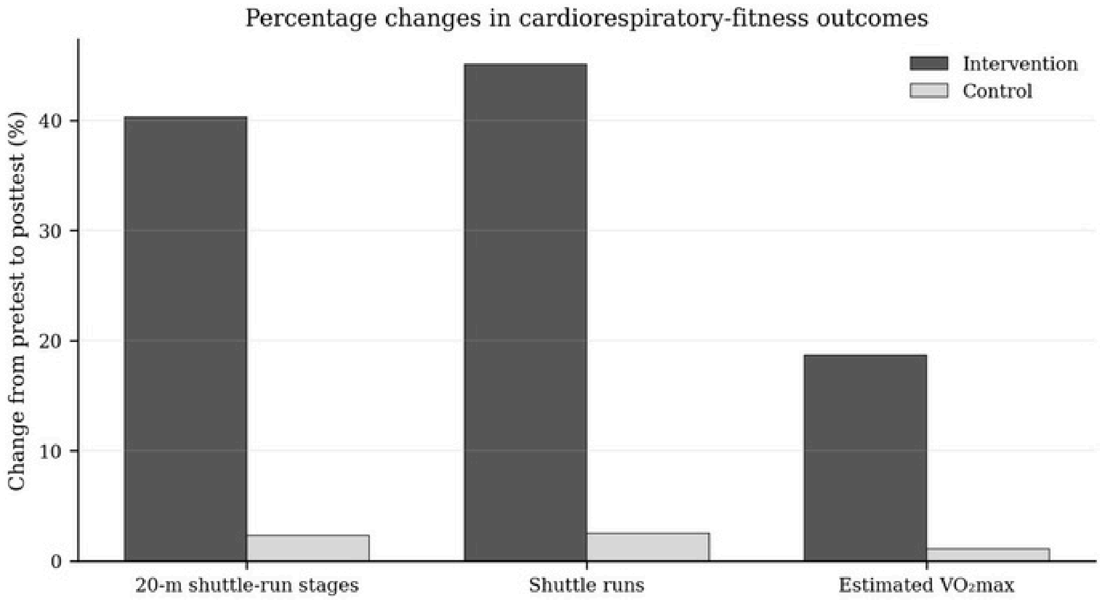
Figure 2

Percentage changes in cardiorespiratory-fitness outcomes from pretest to posttest.



3.3. Within-Group Changes

Paired-samples t tests showed significant pretest-posttest improvements in the intervention group for BMI, body-fat percentage, waist circumference, total skinfold thickness, estimated VO_2max, and 20-m shuttle-run performance (Table 3). In the control group, none of the assessed variables reached statistical significance ($p > .05$).

Table 3

Paired-samples t tests for within-group changes in the intervention group

Variable	t	p
BMI	6.84	.001
Body-fat percentage	8.76	.001
Waist circumference	7.93	.001
Total skinfold thickness	9.24	.001
Estimated VO_2max	10.11	.001
20-m shuttle-run performance	11.27	.001

3.4. Between-Group ANCOVA Results

ANCOVA controlling for pretest values indicated significant between-group differences for all measured outcomes (Table 4). The largest effects were observed for estimated VO_2max (partial $\eta^2 = .41$), 20-m shuttle-run performance (partial $\eta^2 = .39$), total skinfold thickness (partial $\eta^2 = .34$), and body-fat percentage (partial $\eta^2 = .31$), indicating large practical effects of the integrated intervention.

Table 4

ANCOVA results comparing posttest outcomes between groups after controlling for pretest values

Variable	F	p	Partial η²	Observed power
Body mass	8.12	.006	.14	.86
BMI	16.95	.001	.21	.96
Body-fat percentage	28.84	.001	.31	.99
Waist circumference	24.67	.001	.28	.98
Hip circumference	7.41	.008	.12	.83
WHR	12.53	.001	.18	.92
WHtR	18.71	.001	.23	.96
Total skinfold thickness	31.26	.001	.34	.99
20-m shuttle-run performance	37.88	.001	.39	.99
Estimated VO_2max	39.52	.001	.41	.99

Note. Pretest score was entered as the covariate for each respective outcome.

4. Discussion

This study examined whether a 12-week integrated school-based physical education and nutrition-education intervention could improve obesity indicators and cardiorespiratory fitness in elementary school boys. The findings supported the main hypothesis. Compared with the control group, the intervention group showed reductions in general and central obesity indicators and improvements in 20-m shuttle-run performance and estimated VO_2max.

The reduction in BMI, body-fat percentage, waist circumference, WHR, WHtR, and total skinfold thickness suggests that the intervention improved energy balance and reduced adiposity. Physiologically, regular moderate-to-vigorous physical activity increases energy expenditure and can enhance fat oxidation, insulin sensitivity, and metabolic regulation. When paired with nutrition education and modest energy-intake management, these adaptations are more likely to produce measurable changes in body composition. This interpretation is consistent with evidence that physical activity and fitness are associated with lower adiposity and better health indicators in school-aged youth (3, 4).

The present results are also consistent with systematic reviews showing that school-based physical activity interventions can improve physical fitness and selected health outcomes in children and adolescents (7, 8). However, the magnitude of change observed in the present study may be partly related to the integrated nature of the program. Harris et al. (2009) reported that school-based physical activity interventions alone may have limited effects on BMI (9). In the current study, physical education was combined with nutrition education, parental materials, weekly dietary monitoring, and a modest intended energy deficit, which may explain the stronger changes in adiposity-related measures.

The reductions in waist circumference and WHtR are particularly important. Central adiposity is more closely associated with cardiometabolic risk than body mass alone, and WHtR has been proposed as a simple screening measure for obesity-related health risk (10). The observed decreases in waist-based indicators therefore suggest that the intervention may have practical relevance for early prevention of cardiometabolic risk, although direct metabolic biomarkers were not measured.

Cardiorespiratory-fitness outcomes improved substantially. Estimated VO_2max increased from 36.9 ± 3.2 to 43.8 ± 3.7 ml/kg/min in the intervention group, and ANCOVA showed the largest effect size for VO_2max. These results align with the broader literature identifying cardiorespiratory fitness as an important health marker in youth (5, 12). Improvements in shuttle-run performance may reflect better aerobic capacity, improved movement efficiency, greater tolerance of intermittent running, and greater familiarity with repeated high-intensity school-based activity.

The large effect sizes for VO_2max and 20-m shuttle-run performance suggest that functional fitness may respond rapidly to a structured school-based program. This is plausible because children can adapt to repeated aerobic and mixed-activity stimuli through improved cardiovascular function, neuromuscular coordination, pacing, and exercise

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tolerance. The intervention used activities already feasible within school settings, such as shuttle running, rope skipping, team games, agility drills, and coordination exercises. This supports the practical value of using ordinary school infrastructure to produce health-related benefits. From a public-health perspective, the findings reinforce the role of schools as platforms for childhood-obesity prevention. The intervention did not require advanced equipment and was delivered through the school physical education setting with added nutrition education. Such programs may be particularly useful in contexts where children have declining physical activity levels and increasing exposure to energy-dense diets. For implementation, however, physical education should be supported by trained teachers, structured lesson plans, parental involvement, and monitoring of dietary messages to avoid inappropriate restriction during growth.

Practically, the findings suggest that schools can use structured physical education as a low-cost health-promotion strategy when sessions include sufficient moderate-to-vigorous activity and are delivered consistently. Nutrition education should be integrated with physical education rather than presented as an isolated message, and parent-facing materials with weekly monitoring may strengthen adherence. Health monitoring in schools should also extend beyond BMI by including waist circumference, WHtR, skinfold thickness, and field-based cardiorespiratory fitness tests, because these indicators provide a broader picture of child health. Energy-intake management in children should remain mild, supervised, and sensitive to growth, with emphasis on healthier food choices and avoidance of excess energy intake rather than severe dieting.

The findings should be interpreted in light of several limitations. The sample was limited to upper elementary school boys from one district of Tehran, which restricts generalizability to girls, other age groups, rural schools, and students from different socioeconomic contexts. Because the intervention combined physical education, nutrition education, and energy-intake management, the independent effect of each component cannot be isolated. Dietary intake outside school was not fully controlled and depended partly on parental cooperation. In addition, VO_2max was estimated from the 20-m shuttle-run test rather than measured directly by respiratory gas analysis, and the 12-week follow-up period does not clarify whether the observed changes would be maintained over time.

Future studies should use longer follow-up periods, include both boys and girls, recruit larger and more diverse samples, and compare physical activity alone with combined activity-nutrition approaches. Objective monitoring of physical activity and more detailed dietary assessment would also improve the precision of evidence on school-based obesity-prevention programs.

5. Conclusion

A 12-week integrated school-based program combining structured physical education, nutrition education, and mild energy-intake management improved body-composition indices and cardiorespiratory fitness in upper elementary school boys. The intervention reduced body mass, BMI, body-fat percentage, waist circumference, WHR, WHtR, and total skinfold thickness while increasing 20-m shuttle-run performance and estimated VO_2max. The findings support the use of multidimensional school-based health programs as feasible strategies for reducing obesity-related risk and improving functional fitness in children.

Authors' Contributions

All authors contributed substantially to the study and to manuscript development, and all approved the final version.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

Administrative permission was obtained from the Tehran District 5 Department of Education. Written informed consent was obtained from parents or legal guardians.

treated confidentially, and data were

Participation was voluntary, and participants were allowed to withdraw at any stage. The study was conducted in accordance with the Declaration of Helsinki.

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