ORIGINAL ARTICLE

Effects of a 12-week extracurricular resistance training program on physical fitness parameters in adolescents: a controlled quasi-experimental study

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Physical activity during adolescence is essential not only for healthy growth but also for maintaining mental balance and recovery from everyday stress. In India, many schools lack structured recreational fitness programs, which limits opportunities for students to engage in health-oriented activity. Resistance training, while often considered a performance method, may also function as a tool for recreation and rehabilitation. The aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and to examine its recreational and rehabilitative relevance for adolescents aged 13–16 years.

Material and Methods Ninety-nine students (IG = 50; CG = 49) from two public schools in North Delhi participated. The intervention group undertook three weekly 60-minute resistance training sessions for 12 weeks, while the control group continued regular school activities. Outcomes included muscular endurance, power, speed, aerobic capacity, balance, coordination, flexibility, and BMI. A 2×2 mixed MANOVA tested Group × Time effects, followed by repeated-measures ANOVAs and paired t-tests. Effect sizes were reported using η^2 and Cohen's d.

Results Significant Group × Time interactions were observed for muscular endurance and power, including sit-ups ($\eta^2 = 0.23$, $p < 0.001$), push-ups ($\eta^2 = 0.19$, $p < 0.001$), and broad jump ($\eta^2 = 0.26$, $p < 0.001$). Speed improved significantly in the 20-m sprint ($\eta^2 = 0.14$, $p < 0.001$). Within the intervention group, large effect sizes were found for sit-ups (d = 1.20), push-ups (d = 1.07), and broad jump (d = 1.35). Moderate gains were detected in countermovement jump, aerobic capacity, lateral jumps, and balance. Flexibility and BMI did not change, confirming that adaptations were domain-specific.

Conclusions A structured 12-week resistance training program proved safe, feasible, and effective in enhancing strength, power, speed, and endurance among adolescents. Beyond physiological outcomes, the program demonstrated recreational and rehabilitative value by providing a supportive context for recovery, stress reduction, and long-term engagement in active lifestyles. These findings support the integration of resistance training into school-based physical education as a model for recreation- and rehabilitation-oriented practice.

Keywords: adolescents, resistance training, school-based program, physical fitness, recreation, rehabilitation, health promotion

Introduction

Adolescence represents a period characterized by pronounced physical, psychological, and social changes. During this time, lifestyle habits are formed that can influence health and well-being later in life. Increasing sedentarism, driven by academic pressures, screen-based activities, and limited opportunities for structured exercise, creates challenges for maintaining adequate fitness among adolescents. These difficulties have broad implications for health and daily functioning.

In this context, physical education extends beyond instructional teaching. It is a dynamic and interdisciplinary domain that intersects with psychological, social, and scientific dimensions of adolescent development [1]. Participation in sports and physical exercise supports musculoskeletal growth and offers experiences that enhance both physical and emotional well-being [2]. Regular activity during adolescence is essential for promoting fitness, including cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility [3]. However, several studies have documented a secular decline in youth fitness levels over recent decades [4].

Childhood and adolescent obesity is recognized as a major public health challenge with far-reaching implications for health and functional capacity. Evidence shows that obesity is associated with poor overall well-being, functional limitations, and long-term risks [5, 6, 7]. The relationship between physical health and psychological outcomes is equally important, as adolescents with poor health are more

doi:10.15561/physcult.2025.0204

vulnerable to emotional distress [8]. Adolescence is also a period of rapid growth and maturation, during which puberty leads to marked changes in body size, composition, and physiology [9, 10]. For example, longitudinal monitoring has shown that obese teenagers may develop increasing arterial stiffness and elevated diastolic blood pressure [11]. Mental health challenges among youth are likewise associated with reduced physical activity, often compounded by social isolation, stigma, academic pressures, and illness [12, 13, 14].

At the same time, global childhood obesity rates have escalated in parallel with declining participation in vigorous physical activity [15, 16, 17]. Active lifestyles during early life are therefore essential for healthy growth, favorable body composition, and psychological well-being [18, 19]. After-school programs (ASPs) help overcome barriers such as cost, transportation, and time constraints. They also make use of social and environmental facilitators [20, 21, 22, 23]. Beyond improving fitness, such programs may enhance psychosocial outcomes and even academic performance [24, 25, 26, 27].

The rising prevalence of overweight and obesity among adolescents is a serious concern. Excess weight often persists into adulthood, where it increases the risk of chronic disease [28, 29]. Overweight adolescents sometimes demonstrate higher absolute strength due to greater muscle mass recruitment. However, this advantage does not necessarily translate into better functional fitness [30, 31]. In India, studies have documented high rates of physical inactivity and low fitness levels among school-going adolescents [32], highlighting the urgent need for accessible interventions.

Resistance training represents one such intervention. It contributes to weight management by increasing lean mass and basal metabolic rate [33], and it also improves bone strength, posture, cardiovascular health, body composition, and self-esteem [34, 35]. Compared to low-intensity activities, resistance training requires higher energy expenditure and is particularly effective in addressing adolescent obesity [36, 37, 38]. Long-term adaptations include muscle hypertrophy, metabolic efficiency, and improved endurance, which together support greater engagement in physical activity [39, 40, 41, 42]. Research has consistently shown 30–50% strength gains over 8–20 weeks, reinforcing motivation and positive exercise experiences [43, 44, 45]. Meta-analyses confirm that after-school resistance training programs are safe and effective. They enhance strength, power, and motor skills, while also reducing metabolic risks [46, 47]. Accordingly, global guidelines recommend that school-aged youth participate in muscle-strengthening activities several times per week [48, 49].

The pedagogical value of structured resistance training extends beyond physical health. Improved muscular fitness supports motor competence, confidence, and self-efficacy, which in turn encourage lifelong engagement in physical activity [19, 20]. Integrating resistance-based interventions into school curricula aligns with the goals of physical education, including the promotion of physical literacy, resilience, and holistic student development [21]. However, many Indian schools do not offer such programs, leaving a significant gap in the curriculum.

Although extensive evidence from Europe and North America has confirmed the benefits of resistance training for youth in enhancing strength, power, and coordination [4, 47, 50], these findings remain largely underexplored in South Asian populations. In India, particularly in government-run public schools with limited resources, structured resistance training opportunities for adolescents are rare.

Analysis of research findings has shown that resistance training can significantly improve strength, motor competence, and overall health outcomes in adolescents. Researchers emphasize that structured programs implemented in school environments provide not only physiological but also pedagogical benefits, contributing to confidence, resilience, and long-term engagement in physical activity. At the same time, the lack of systematic integration of such interventions into school practice continues to limit their potential impact, which creates the basis for further applied research in this area.

In addition to their training benefits, after-school resistance programs can be considered a form of recreational activity that provides adolescents with opportunities to recover from academic stress and sedentary routines. Such structured recreational formats help to maintain physical and mental health, creating a foundation for resilience and long-term well-being.

The present study does not claim methodological innovation but rather contextual novelty, as it adapts established EUROFIT-based approaches to an underrepresented demographic. By implementing a structured after-school program for boys and girls in real-world school environments, the research evaluates feasibility, effectiveness, and potential integration into school-based physical education. Building on these considerations, the aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and to examine its recreational and rehabilitative relevance for adolescents aged 13–16 years. It was hypothesized that participants in the intervention group would demonstrate greater improvements across fitness parameters compared to peers engaged solely in routine school activities.

Materials and Methods

Participants

Initially, 112 secondary school students aged 13–16 years were screened from two public schools in North Delhi. After applying inclusion and exclusion criteria, 99 healthy students (52 boys and 47 girls) were retained. The intervention group included 50 participants, and the control group included 49.

A priori power analysis was conducted using G*Power 3.1.9.7 for repeated-measures ANOVA (within–between interaction). Based on an expected medium effect size ($f = 0.25$), $\alpha = 0.05$, power = 0.80, correlation among repeated measures = 0.5, and $\varepsilon = 1$, the required total sample size was 82 participants. The final sample of 99 exceeded this threshold, ensuring sufficient statistical power to detect moderate Group × Time effects.

The inclusion criteria were: age between 13 and 16 years, enrollment in the school's after-school program, medical clearance for moderate-intensity physical activity, and willingness to participate in all training and testing sessions. Each participant provided written informed assent, accompanied by parental or guardian consent. Two participants (one in each group) withdrew for personal reasons unrelated to the intervention. All remaining participants completed at least 90% of sessions.

Table 1 presents the baseline characteristics of participants in the intervention (IG) and control (CG) groups. Both groups were comparable in terms of age, sex distribution, and BMI categories. The majority of participants were within the healthy weight range (74% in IG; 73% in CG). No significant between-group differences were observed (all $p > 0.20$), indicating equivalence before the intervention.

Table 1. Participant demographics

Demographic	Intervention (n = 50)	Control (n = 49)
Age (years)	14.6 ± 1.1	14.4 ± 1.2
Age range (years)	13–16	13–16
Gender (M/F)	26 / 24	26 / 23
BMI category: Underweight	3 (6%)	2 (4%)
BMI category: Normal weight	37 (74%)	36 (73%)
BMI category: Overweight	6 (12%)	7 (14%)
BMI category: Obese	4 (8%)	4 (8%)

The data presented in Table 1 show that BMI categories were defined using age- and sex-specific percentiles. The majority of participants fell within the healthy weight range (5th–85th percentile). The proportions of underweight and overweight/obesity were small and comparable between groups. No significant between-group differences were found for any demographic variable (all $p > 0.20$), supporting the comparability of IG and CG at baseline.

Study Design

This study employed a quasi-experimental pre–post controlled design with intact class allocation. Two school classes were assigned as the Intervention Group (IG) and Control Group (CG), without randomization, to minimize disruption to school routines. Baseline equivalence between groups was confirmed before the intervention.

The 12-week program was structured not only as a resistance training intervention but also as a recreational activity designed to counter sedentary behavior, alleviate academic stress, and promote recovery and resilience. This framing allowed the study to assess the feasibility of integrating resistance training into school practice as a health-oriented approach consistent with recreational and rehabilitative objectives.

The recruitment and allocation process is illustrated in Figure 1.

Allocation and Bias Mitigation

Participants were assigned to either the Intervention Group (IG) (n = 50) or the Control Group (CG) (n = 49) by intact class allocation, to minimize disruption to school routines. While this quasi-experimental approach may introduce potential selection bias, baseline equivalence was confirmed: there were no significant between-group differences in age, gender distribution, BMI categories, or baseline fitness measures (all $p > 0.10$). To further mitigate bias, statistical adjustments were applied using mixed MANOVA/ANOVA models, and exact p-values with effect sizes were reported. Although full participant blinding was not feasible in this school-based intervention, all outcome assessments were performed by trained evaluators blinded to group allocation. Data entry and statistical analyses were conducted independently by a researcher not involved in training supervision, thereby reducing detection and reporting bias.

The exclusion criteria included the presence of any musculoskeletal, cardiovascular, or neurological condition contraindicating physical exercise; a history of significant injury in the last three months that could affect performance; current participation in any external structured resistance or athletic training program; and irregular school attendance likely to interfere with adherence to the intervention. During screening, 13 students were excluded: 6 due to recent injuries, 3 due to lack of parental consent, and 4 due to predicted dropout risk based on high absenteeism.

All 99 participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and were found eligible for inclusion. Baseline demographic information confirmed that participants were

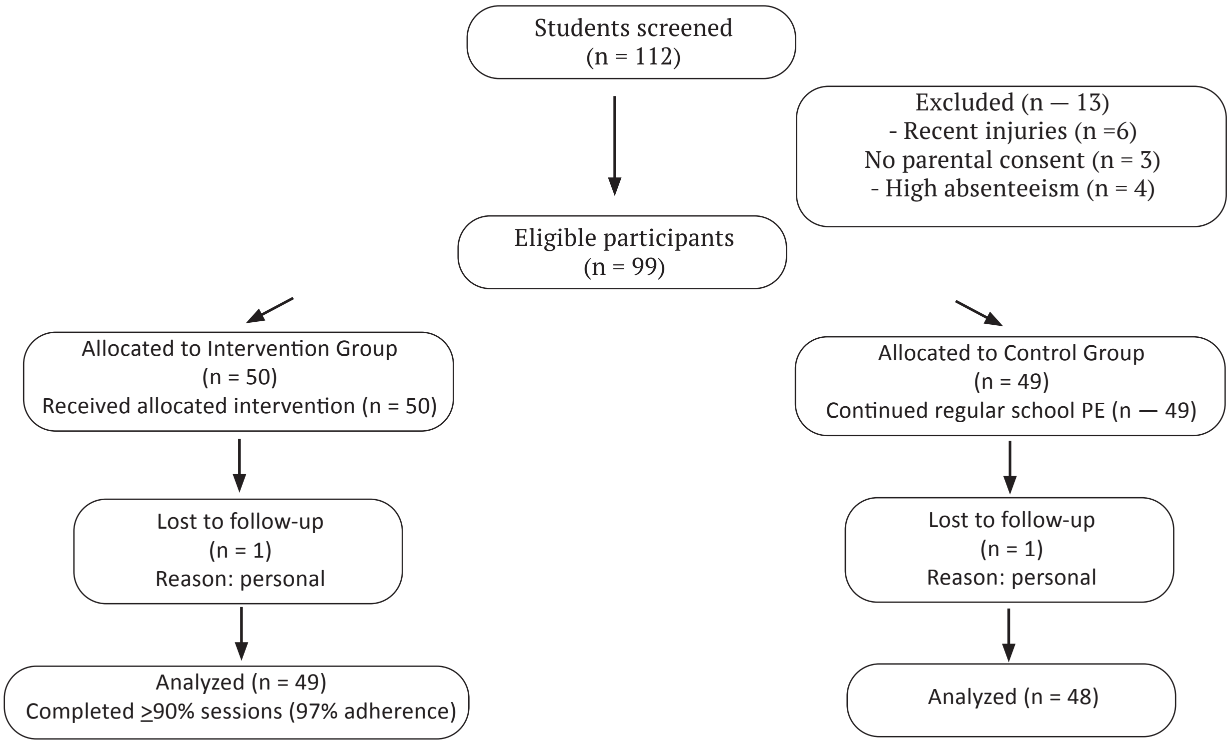

Figure 1. Participant Recruitment and Selection

comparable in age, gender distribution, and body mass index categories across groups. The research was organized in accordance with the recommendations for clinical research provided by the World Health Organization (WHO) within the Helsinki Declaration.

The resistance training program was delivered over 12 weeks in an after-school setting and followed a structured, progressive model. Training sessions were conducted three times per week on non-consecutive days and included bodyweight and circuit-based resistance exercises (squats, lunges, push-ups, planks, and plyometric jumps). Progression was systematically introduced by increasing sets, repetitions, and perceived exertion on a biweekly basis, with rest intervals adjusted accordingly. Exercise intensity was monitored using the Rating of Perceived Exertion (RPE, Borg scale 0–10), with participants encouraged to maintain proper technique before progressing in load or volume. Trainers ensured gradual overload while emphasizing safety and adherence. Table 2 provides the weekly breakdown of exercise prescription, including sets, repetitions, rest, intensity, and specific progression notes to enhance replicability. The overall design and progression strategy were consistent with recommendations for youth resistance training reported by Behringer et al. [47] and Stricker et al. [46].

The control group continued with their standard school-based physical education curriculum throughout the 12-week period. This curriculum consisted of two 40-minute sessions per week and included general calisthenics, aerobic games (e.g., relay races, football), and flexibility exercises. It did not include any structured resistance or strength training components. Attendance was monitored to ensure compliance with the control condition.

Outcome Measure

Anthropometry and Body Composition: Height (stadiometer) and weight (digital scale) were measured to compute BMI (kg/m²). Skinfold thickness was taken at triceps and subscapular sites (calipers) to estimate body fat percentage. BMI was categorized as underweight, normal, overweight, or obese using CDC criteria. Together, these measures provided a health-related profile of participants.

Muscular Endurance: (1) Sit-ups: maximum number of bent-knee sit-ups in 30 seconds. (2) Push-ups: maximum number of standard push-ups in 30 seconds (for girls, modified knee push-ups). Both are reliable measures of core and upper-body endurance.

Muscular Power and Strength: (1) Standing Broad Jump: horizontal jump distance from a standing start, reflecting lower-body power. (2) Countermovement Jump (CMJ) Height: vertical jump measured with a jump mat or Vertec. (3) Medicine Ball Throw (seated): distance thrown with a 2-kg ball, assessing upper-body power (optional).

Aerobic Capacity: 6-Minute Run: distance covered in 6 minutes on an indoor track, estimating cardiorespiratory endurance.

Speed and Agility: 20-Meter Sprint: time to sprint 20 meters from a standing start (electronic timing if available).

Table 2. Intervention Protocol (Exercises: Squats, Lunges, Push-ups, Plank, Plyometric Jumps)

Week	Sets	Reps	Rest (sec)	Intensity (RPE)	Progression Notes
1	2	10–12	60	5–6	Familiarization, focus on technique
2	2	10–12	60	5–7	Maintain technique, gradual adaptation
3	3	12–15	60–75	6–7	Increase reps slightly each week
4	3	12–15	60–75	6–7	Add one extra set for main lifts
5	3	12–15	60–75	6–7	Introduce simple plyometric variations
6	3	12–15	60–75	6–7	Increase RPE to 6–7, ensure safe form
7	3–4	15–18	75–90	7–8	Progress reps and volume steadily
8	3–4	15–18	75–90	7–8	Introduce partner/bodyweight resistance
9	3–4	15–18	75–90	7–8	Add core circuit elements
10	3–4	15–18	75–90	7–8	Sustain 3–4 sets, RPE 7–8
11	4	18–20	90	8	Peak volume, close to 18–20 reps
12	4	18–20	90	8	Maintain intensity, prepare for post-test

Note. RPE = Rating of Perceived Exertion. Exercises remained constant throughout the program (squats, lunges, push-ups, plank, plyometric jumps).

Balance and Coordination: (1) Balance Backward: number of steps along a 6-m beam performed backward. (2) Lateral Jump: number of side-to-side jumps over a line in 15 seconds. (3) Rapid Alternating Foot Movement: number of taps across a line in 15 seconds. These tests are part of the EUROFIT battery and assess dynamic balance and coordination [51].

Flexibility: Sit-and-Reach: trunk flexion test, distance reached beyond toes. EUROFIT protocols were followed to ensure standardization. Scores from both legs or trials were averaged where appropriate.

All tests employed in this study are standardized field measures that have previously demonstrated acceptable validity and reliability in adolescent populations, particularly within the EUROFIT framework and related youth fitness protocols [51].

All training sessions were supervised by two certified strength and conditioning specialists (Master's in Physical Education, NSCA-CSCS certified). They completed a pre-intervention workshop to ensure standardized delivery. Fidelity was monitored using weekly checklists and attendance logs. Physical fitness assessments were conducted by blinded evaluators with postgraduate training. Inter-rater reliability was established during a pilot phase (ICC > 0.90). Data entry and analysis were performed using anonymized codes to minimize bias. Participants were unaware of group allocation until study completion. Trainers had no role in data analysis, thereby reducing expectancy and confirmation bias.

Statistical Analysis

All analyses were performed using SPSS, version 26 (IBM Corp., Armonk, NY, USA). The assumption of normality was verified for each variable using the Shapiro–Wilk test. Descriptive statistics are presented as mean ± standard deviation (SD). To examine the intervention effects, a 2 × 2 mixed-model MANOVA was conducted with Group (Intervention vs. Control) as the between-subjects factor and Time (pre-test vs. post-test) as the within-subjects factor. When significant Group × Time interactions were observed, follow-up analyses included mixed-model ANOVAs for each outcome variable, as well as paired-sample t-tests to identify within-group changes. Effect sizes were reported as partial eta squared (η^2) for ANOVA models and as Cohen's d for paired comparisons. Bonferroni adjustments were applied within fitness domains to control for multiple comparisons. Statistical significance was set at $\alpha = 0.05$.

Results

A total of 99 adolescents completed the study, with high adherence observed in the intervention group (97%). Two participants, one from each group, withdrew due to personal reasons unrelated to the intervention. Baseline analyses confirmed that the intervention and control groups were comparable in age, gender distribution, and fitness status. Over the 12 weeks, the intervention group demonstrated clear improvements in multiple domains of physical fitness, while the control group showed minimal or no changes.

Mean performance values (± SD) across all fitness tests at baseline and post-intervention for IG and CG are presented in Table 3. The IG demonstrated marked improvements in sit-ups, push-ups, broad jump, countermovement jump, sprint, and aerobic capacity, whereas CG showed negligible changes.

In Table 3, the intervention group demonstrated clear improvements in muscular endurance (sit-ups, push-ups), power (broad jump, countermovement jump), speed (20-m sprint), aerobic capacity (6-min run), and coordination (lateral jumps). Balance showed only minor gains, while flexibility (sit-and-reach) and BMI remained largely unchanged in both groups, suggesting that these parameters were not sensitive to the 12-week training period.

Table 4 reports the inferential statistics for Group × Time interactions across fitness variables. Large effects were observed for muscular endurance (sit-ups, push-ups) and power (broad jump, CMJ).

In Table 4, significant improvements were also found in sprint performance, aerobic capacity, and motor coordination (lateral jumps, balance). Non-significant outcomes for flexibility and BMI confirm that the intervention produced domain-specific effects rather than generalized changes across all parameters.

The improvements observed in muscular strength, endurance, speed, and coordination highlight not only physical fitness gains but also outcomes relevant to recreational and rehabilitative practice. Enhanced balance, motor control, and aerobic capacity suggest that such programs may contribute to recovery from sedentary routines, reduction of school-related stress, and the development of resilience in adolescents. The absence of adverse changes in BMI and flexibility further indicates the safety of implementing resistance-based recreation as a health-oriented practice in school environments.

Table 5 presents within-group pre–post comparisons for IG participants. Large to very large improvements were seen in sit-ups (d = 1.20), push-ups (d = 1.07), broad jump (d = 1.35), and sprint (d = 0.85).

Moderate improvements were observed in CMJ, the 6-min run, lateral jumps, and balance. Flexibility and BMI showed no significant changes, reinforcing the specificity of resistance training adaptations.

The intervention group showed large improvements in muscular endurance (sit-ups, push-ups), muscular power (broad jump,

Table 3. Pre- and post-intervention performance

Measure	Intervention Pre	Intervention Post	Control Pre	Control Post
Sit-ups (reps/30s)	28.4 ± 7.2	37.5 ± 8.1 **	27.9 ± 6.8	28.7 ± 7.0
Push-ups (reps/30s)	22.1 ± 5.4	28.3 ± 6.2 **	22.3 ± 5.6	23.0 ± 5.7
Broad Jump (cm)	190.5 ± 15.8	213.1 ± 18.4 **	191.2 ± 16.2	192.4 ± 16.0
Countermovement Jump Height (cm)	29.4 ± 4.5	31.9 ± 4.8 **	29.7 ± 4.2	30.0 ± 4.4
20-m Sprint (s)	3.72 ± 0.18	3.54 ± 0.15 **	3.70 ± 0.19	3.68 ± 0.20
6-min Run (m)	1260 ± 85	1338 ± 92 *	1255 ± 80	1259 ± 84
Lateral Jumps (n/15s)	47.0 ± 5.5	50.8 ± 5.9 **	46.5 ± 5.2	47.1 ± 5.3
Flexibility (Sit-and-Reach, cm)	30.0 ± 4.0	31.5 ± 3.5	29.8 ± 4.1	30.5 ± 3.7
Body Composition (BMI, kg/m²)	19.8 ± 2.5	19.7 ± 2.4	20.1 ± 2.6	20.0 ± 2.5
Balance and Coordination (Backward Steps, n)	7.0 ± 2.5	7.3 ± 2.4	6.8 ± 2.7	7.0 ± 2.5

Note. Values are mean ± SD. *p < 0.05; **p < 0.01, within-group changes in the Intervention group (paired t-test). Group × Time ANOVA interactions were significant for all starred measures.

Table 4. Summary of Repeated Measures ANOVA Results (Group × Time Interaction)

Fitness Measure	F(1,95)	p-value	Partial η²
Sit-ups (reps/30s)	28.4	<0.001	0.23
Push-ups (reps/30s)	22.1	<0.001	0.19
Broad Jump (cm)	34.7	<0.001	0.26
CMJ Height (cm)	12.8	0.001	0.12
6-min Run (m)	4.2	0.044	0.04
20-m Sprint (s)	15.6	<0.001	0.14
Lateral Jumps (15s)	7.3	0.008	0.07
Balance – Backward Steps	4.1	0.045	0.04
Flexibility – Sit-and-Reach (cm)	0.34	0.56	0.01
Body Composition – BMI (kg/m²)	0.15	0.70	0.00

Note. Bold values indicate statistically significant interactions at p < 0.05. Partial eta squared (η^2): ⩾ 0.14 = large, ⩾ 0.06 = medium, ⩾ 0.01 = small. CMJ = countermovement jump.

Table 5. Within-Group Paired t-test Summary for the Intervention Group (n = 50)

Measure	Pre (Mean ± SD)	Post (Mean ± SD)	t(49)	p-value	Cohen's d
Sit-ups (reps/30s)	28.4 ± 7.2	37.5 ± 8.1	9.21	<0.001	1.20
Push-ups (reps/30s)	22.1 ± 5.4	28.3 ± 6.2	8.73	<0.001	1.07
Broad Jump (cm)	190.5 ± 15.8	213.1 ± 18.4	10.11	<0.001	1.35
CMJ Height (cm)	29.4 ± 4.5	31.9 ± 4.8	4.72	<0.001	0.68
6-min Run (m)	1260 ± 85	1338 ± 92	2.22	0.03	0.32
20-m Sprint (s)	3.72 ± 0.18	3.54 ± 0.15	6.11	<0.001	0.85
Lateral Jumps (n/15s)	47.0 ± 5.5	50.8 ± 5.9	3.98	<0.001	0.56
Balance (Backward Steps, n)	7.0 ± 2.5	7.3 ± 2.4	2.05	0.045	0.29
Flexibility (Sit-and-Reach, cm)	30.0 ± 4.0	31.5 ± 3.5	1.81	0.075	0.25
BMI (kg/m²)	19.8 ± 2.5	19.7 ± 2.4	0.56	0.58	0.08

countermovement jump), and speed (20-m sprint). Moderate improvements were also observed in aerobic capacity (6-min run), balance, and coordination (lateral jumps). Flexibility and BMI did not change significantly. In contrast, the control group showed minimal or no changes across fitness measures.

These within-group gains demonstrate that structured resistance training can be safely applied as a form of recreational activity that promotes functional recovery, supports resilience, and enhances overall well-being in adolescents. The improvements in balance, coordination, and aerobic performance are particularly relevant from a rehabilitative perspective, as they reflect adaptations that help counteract sedentary behavior and reduce vulnerability to health risks in adolescents.

Discussion

The aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and its broader recreational and rehabilitative relevance for adolescents aged 13–16 years. The intervention group demonstrated clear improvements in muscular endurance, power, speed, aerobic capacity, and coordination compared to the control group, while flexibility and BMI remained unchanged. These findings indicate that a school-based resistance training program can selectively enhance multiple domains of physical fitness in adolescents and, at the same time, function as a recreational format that supports recovery, resilience, and long-term health in educational settings.

This study demonstrates that a 12-week after-school resistance training program can substantially improve physical fitness in Indian adolescents. While numerous studies across Europe and North America have established the effectiveness of youth resistance training in enhancing muscular strength, power, and coordination [4, 47, 50], evidence from South Asian contexts remains scarce. To our knowledge, few investigations have examined structured resistance training among Indian adolescents, particularly within low-resource public-school environments, where the recreational and rehabilitative potential of such programs is especially relevant.

The novelty of the present study lies not in the training model itself, which builds upon established international protocols such as EUROFIT, but in its contextual application. Specifically, this research demonstrates the feasibility of implementing a structured after-school resistance training program among Indian adolescents of both genders, showing how such interventions can be adapted within resource-constrained educational settings. By documenting outcomes across multiple domains of physical fitness, the study contributes pedagogical insights relevant to school-based health promotion in India, while also emphasizing the recreational and rehabilitative value of resistance training as a means to counter sedentary routines, reduce stress, and support adolescent resilience. Thus, rather than methodological innovation, the contribution of this work is situated in addressing an underrepresented demographic, validating global recommendations in a novel setting, and offering practical evidence for integrating resistance training into physical education as a recreational and rehabilitative strategy.

The intervention group showed marked gains in muscular endurance, strength, and power, whereas the control group exhibited no comparable changes. These findings corroborate previous work, with Kretschmann [4] reporting strength gains after 8 weeks in German youth and Velez et al. [50] observing similar improvements in Hispanic adolescents. Together, these studies and our results highlight the cross-cultural validity of resistance training as a scalable intervention. Our findings also extend Indian evidence of low adolescent fitness [5, 20], underscoring the need for structured programs.

Aerobic capacity showed modest improvement, suggesting indirect benefits through better muscle efficiency. This outcome is consistent with findings in adolescent rugby players [52]. Flexibility and BMI remained unchanged, which is expected for a short, strength-focused program. These results align with meta-analytic evidence on progressive strength gains [47] and international guidelines promoting youth resistance exercise [46, 48]. No injuries occurred, supporting the safety of supervised training [35].

Overall, the observed improvements have practical value. Stronger adolescents can more effectively participate in daily activities and sports, while also counteracting health risks associated with poor fitness, inactivity, and obesity [9, 15, 18, 20]. In addition, the gains in balance, coordination, and aerobic performance highlight outcomes that are relevant to recreational and rehabilitative practice, as they contribute to recovery from sedentary routines, reduction of school-related stress, and promotion of resilience in adolescents. These results support the view that structured resistance training can serve not only as a method of fitness enhancement but also as a health-oriented approach integrated into recreational and rehabilitative frameworks.

By extending the program to 12 weeks, participants achieved large effect sizes in core endurance and upper-body strength, with sit-ups and push-ups showing improvements of approximately 32% and 28% (Cohen's d ≈ 1.1–1.2). These outcomes are consistent with meta-analytic findings that strength gains in adolescents increase with longer training periods [47]. The results also align with international recommendations that youth engage in muscle-strengthening activity at least three times per week [46, 48]. The program was well-tolerated and safe: no injuries occurred, supporting the view that supervised, age-appropriate resistance training poses minimal risk [35].

Performance gains extended across several domains. Improvements in jump distance (+12%) and sprint time (−5%) indicate enhanced lower-body power and neuromuscular function, while modest increases in the 6-minute run (+6%) suggest secondary aerobic benefits. Balance and coordination also improved slightly, demonstrating transfer to general motor skills. In contrast, flexibility remained unchanged, which is expected given that it was not a target of the regimen. BMI and skinfold measures likewise showed no significant changes, consistent with evidence that meaningful alterations in body composition require longer training periods, higher intensities, or dietary modification [26]. Importantly, maintenance of BMI alongside possible gains in lean mass (not directly measured here) may still reflect positive health adaptations.

These findings have practical implications. Stronger and more powerful adolescents are better equipped to participate in sports and daily activities, and may benefit from increased self-efficacy and confidence [46]. The school-based format addresses common barriers to adolescent fitness in India, including limited access to safe exercise environments, and provides a feasible pathway for integrating structured resistance training into public education.

In addition to these physiological outcomes, the observed improvements carry clear recreational and rehabilitative significance. Gains in endurance, power, and coordination contribute to restoring functional capacity, reducing the negative impact of sedentary school routines, and supporting stress recovery in adolescents. The safe and feasible school-based design also highlights the potential of such programs to be integrated as part of recreational and rehabilitative strategies aimed at sustaining health and resilience in adolescents.

Previous research supports these conclusions. A 12-week resistance program produced significant strength gains in exercises such as bench press, seated row, shoulder press, and squats [50]. Improvements in cardiorespiratory fitness have been reported through Shuttle Run Test and VO_2max [53], while other studies document benefits in agility, flexibility, and repetitive strength [54]. Moreover, resistance training has been linked to reductions in cardiovascular risk factors, including triglycerides, LDL, blood glucose, and systolic blood pressure, alongside decreases in body fat and increases in lean mass [55]. Beyond physical outcomes, positive effects on self-concept, competence, and global self-worth have also been demonstrated [50].

Resistance training has been shown to significantly increase muscular strength in adolescents, with documented improvements in bench press, seated row, shoulder press, and squats [50]. Functional strength training also produced gains in curl-ups and pull-ups, reflecting enhanced muscular endurance [56]. Increases in lower-body strength have been associated with better sprint performance, particularly in rugby players [52], and improved jump performance further highlights adaptations in muscular power [52]. Functional movement quality, including balance and coordination, has also improved under resistance training, as evidenced by higher scores in the Functional Movement Screen protocol [56]. While the benefits are clear, program design and supervision remain critical to ensure safety and maximize effectiveness. Collectively, these positive outcomes underscore the role of resistance training as a valuable component of physical education curricula, supporting the development of lifelong fitness habits among adolescents [57].

In addition to supporting physical education, resistance training can be viewed as a recreational and rehabilitative approach that helps adolescents recover from sedentary routines and academic stress while strengthening their overall functional capacity. The documented improvements in endurance, coordination, and movement quality indicate that such programs not only enhance fitness but also promote resilience, psychological well-being, and long-term health maintenance in adolescents. This dual role underscores the potential of resistance training to serve simultaneously as an educational strategy and a practical tool for recreation- and rehabilitation-oriented practice in school settings.

A study showed that participation in structured exercise programs improved adolescents' quality of life and physical well-being, while fostering a positive attitude toward physical activity [54]. Putera [58] reported that plyometric training, including countermovement jumps (CMJ), significantly enhanced strength and power in adolescent students, supporting the effectiveness of explosive lower-body training. Our findings also align with Kumar et al. [59], who observed that obese children demonstrated reduced competence in object control and rolling/turning tasks, suggesting that excess weight can limit motor skill acquisition. Recent evidence further indicates that integrated training methods combining core and plyometric exercises improve agility, balance, and sport-specific skills in youth tennis players [50, 56, 60]. These converging results support the scalability of our model and challenge misconceptions that Indian adolescents are inherently weak or that resistance training should be restricted to athletes. Our findings are consistent with recent evidence showing that integrated training methods combining core and plyometric exercises significantly enhance agility, dynamic balance, and sport-specific skills in young tennis players [61].

Taken together, these findings emphasize that structured training formats can provide adolescents not only with measurable improvements in strength, agility, and coordination but also with recreational opportunities that promote recovery, reduce stress, and support psychosocial well-being. By integrating resistance and functional exercises into school settings, such programs can be positioned as rehabilitative practices that counteract the negative effects of sedentary lifestyles and academic load, thereby contributing to the holistic development and resilience of adolescents.

Pedagogical, Recreational, and Rehabilitative Relevance

Beyond physiological adaptations, this study highlights clear educational, recreational, and rehabilitative benefits. Gains in muscular endurance, power, and coordination directly support physical literacy, which is a central goal of school physical education. At the same time, structured after-school resistance programs function as a form of health-oriented recreation, providing adolescents with opportunities to reduce stress, restore energy, and enhance psychological well-being. Improved fitness gives students the confidence and competence to engage in lifelong physical activity, while the recreational format fosters psychosocial outcomes such as self-efficacy, resilience, and peer engagement. The program's reliance on minimal equipment (bodyweight, resistance bands, medicine balls) and its emphasis on close supervision ensure feasibility in low-resource schools. Taken together, resistance training can be regarded not only as a fitness strategy but also as a pedagogical and rehabilitative model for integrating health-oriented practices into education. The results contribute context-specific evidence from Indian adolescents and highlight the broader integration of resistance training into school-based physical education, recreation, and rehabilitation activities.

Limitations

This study used a quasi-experimental design with intact class allocation, which may introduce selection bias despite baseline equivalence. The sample was limited to urban schools, and the intervention lasted only 12 weeks, which restricts the ability to evaluate longer-term adaptations. In addition, outcomes directly related to recreation and rehabilitation, such as indicators of recovery, stress reduction, and quality of life, were not measured, limiting the scope of conclusions about the broader health-oriented effects of the program.

Future Research Directions

Future studies should explore the role of structured resistance training as a component of recreational and rehabilitative practice. Particular attention should be paid to long-term outcomes, including sustained recovery, resilience, and maintenance of health-related quality of life. Expanding research to diverse adolescent populations and different educational environments will strengthen evidence on how such programs can be applied as practical tools for recreation and rehabilitation in school settings.

Conclusions

Structured resistance training demonstrates strong potential as a school-based strategy for promoting adolescent health, recreation, and educational development. Beyond its physiological effects, such programs enhance motor competence, confidence, and long-term engagement in physical activity. Implemented in supportive school environments, resistance training enriches physical education by combining fitness enhancement with pedagogical value and by creating opportunities for recovery and stress reduction. The findings suggest that school-based resistance training can serve as a practical model of recreational and rehabilitative practice, contributing to sustained health, working capacity, and holistic well-being of adolescents.

Acknowledgment

The authors express their sincere gratitude to all the students who participated in this study for their time, effort, and cooperation during the training and testing process.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Cite this article as:
Choudhary S, Choudhary PK. Effects of a 12-week extracurricular resistance training program on physical fitness parameters in adolescents: a controlled quasi-experimental study. *Physical Culture, Recreation and Rehabilitation*, 2025;4(2):90–101.
https://doi.org/10.15561/physcult.2025.0204

Received: 14.08.2025
Accepted: 27.09.2025; Published: 30.12.2025