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The effect of interval training and push-up exercises on cardiorespiratory endurance and upper body strength in adolescents

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Abstract

Adolescent physical fitness is a crucial determinant of health and long-term well-being, yet global data show that most adolescents fail to achieve recommended activity levels. This study aimed to evaluate the effectiveness of combining interval training with push-up exercises in enhancing specific components of physical fitness, namely cardiorespiratory endurance and upper body strength. A quasi-experimental one-group pretest–posttest design was employed with 29 adolescents who met predetermined inclusion criteria. Physical fitness was assessed using the 12-minute run test (Cooper test) to measure aerobic endurance and a 1-minute push-up test to assess upper-body muscular strength. Data analysis included parametric and non-parametric tests based on normality results. The findings demonstrated a significant increase in VO_2Max from 44.7 to 47.8 ml/kg/min ($p = 0.002$), alongside a meaningful improvement in push-up performance ($p = 0.019$). These outcomes confirm that the six-week intervention program effectively enhanced both aerobic endurance and muscular strength. The study concludes that interval training and push-ups, when combined, offer a practical, low-cost, and adaptable exercise model for adolescent fitness development. Beyond the statistical results, the contribution of this study lies in demonstrating how two simple training modalities can be systematically integrated to address key aspects of adolescent health and performance, with direct implications for school-based physical education and youth sports programs.

Keywords: Interval training, push-up exercise, adolescents, cardiorespiratory endurance, upper body strength.

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INTRODUCTION

Physical fitness is widely recognized as a key determinant of health and quality of life during adolescence, a critical developmental stage that lays the foundation for adulthood. Physical fitness is widely recognized as a fundamental determinant of adolescent health, not only because of its immediate impact on cardiovascular efficiency and musculoskeletal development, but also because of its predictive role in long-term health outcomes. Physical fitness plays a pivotal role in shaping adolescent health and laying the foundation for lifelong well-being. WHO's Global Status Report on Physical Activity shows that over 80% of adolescents worldwide fail to meet recommended physical activity guidelines (Organisation, 2022). Lancet's pooled analysis corroborates this, finding that approximately 81% of adolescents do not engage in sufficient moderate-to-vigorous activity (García-Hermoso et al., 2022). This alarming trend has direct consequences for adolescent health—leading to increased risks of chronic diseases, poorer cardiovascular and musculoskeletal function, and lower psychological resilience (Wickramarachchi et al., 2023). Moreover, long-term studies confirm that lower adolescent fitness correlates with poorer functional independence and accelerated ageing (García-Hermoso et al., 2022; Suetani et al., 2017). Thus, the urgency to develop low-cost, scalable, and context-sensitive interventions that go beyond general recommendations is clear, especially in environments where traditional, resource-intensive programs are unfeasible.

At this age, higher fitness levels are consistently linked to reduced risks of chronic diseases, improved cardiovascular function, stronger musculoskeletal systems, and enhanced psychological well-being (Wickramarachchi et al., 2023). Evidence also suggests that maintaining adequate youth fitness levels is associated with long-term benefits, including functional independence and healthy ageing (García-Hermoso et al., 2022; Suetani et al., 2017). Despite these benefits, global surveys indicate that adolescents frequently fail to meet recommended physical

activity levels. The World Health Organisation (WHO) reports that more than 80% of adolescents aged 11–17 years do not achieve daily activity guidelines, contributing to persistently low fitness levels worldwide. This issue underlines the urgency of developing evidence-based exercise interventions that are effective, accessible, and adaptable. While previous literature has examined the general benefits of physical activity extensively, there remains a need for specific, low-cost approaches that can be implemented in school or community settings where resources are limited. Therefore, the discussion of adolescent fitness should shift from broad generalizations to targeted solutions that directly address the most pressing deficits.

While the global decline in adolescent fitness is concerning, the situation in Indonesia presents additional challenges, as national surveys reveal alarming declines in aerobic capacity and muscular strength among youth. Arfanda et al. (2025) reported that aerobic function among Indonesian adolescents falls below international standards, suggesting inefficient oxygen utilization during exercise. This has direct implications for performance, as lower aerobic fitness impairs endurance, delays recovery, and increases susceptibility to fatigue-related injuries (de Andrade Gonçalves et al., 2015; Waluyo, 2023). In addition, structural limitations such as the absence of systematic physical education programs and the growing prevalence of sedentary lifestyles have exacerbated the decline in fitness levels. Addressing these problems requires scalable interventions that can be implemented within schools and communities without reliance on expensive facilities. Compared to laboratory-based programs, simple bodyweight exercises and interval training are more practical and cost-effective alternatives. These modalities are well-suited for the Indonesian context, where logistical and economic barriers often limit the feasibility of resource-intensive training methods. By focusing on accessible strategies, research can support adolescent health while considering contextual realities.

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

Cardiorespiratory endurance, commonly assessed by maximal oxygen uptake (VO_2Max), represents a critical indicator of overall fitness and health. VO_2Max reflects the integrated capacity of cardiovascular and respiratory systems to deliver oxygen to working muscles, a fundamental factor for sustaining physical activity (Kalinowski et al., 2021). International studies have consistently demonstrated that High-Intensity Interval Training (HIIT) is an effective method for enhancing VO_2Max in adolescents, as their developmental stage supports accelerated physiological adaptations (Atakan et al., 2021; Costigan et al., 2015). Unlike continuous endurance training, HIIT involves repeated high-intensity bouts with short recovery periods, yielding significant improvements in aerobic function over shorter durations. Meanwhile, muscular strength, particularly in the upper body, contributes not only to overall physical fitness but also to posture, efficiency, and sports performance. Push-up exercises are widely utilized as a practical field test for upper body strength and endurance because they target large muscle groups such as the chest, shoulders, arms, and core (Hashim et al., 2018). Although both modalities are well researched independently, their combined application has rarely been examined in adolescent populations. This raises the need to study how their integration could address multiple fitness domains simultaneously.

Although research on HIIT and push-up exercises has grown, most prior studies have examined them separately, creating a gap in understanding their combined effects. Some investigations highlight HIIT as the most efficient method for improving aerobic performance (Atakan et al., 2021; Costigan et al., 2015), while others emphasize resistance-based protocols such as push-ups for improving muscular endurance (Ajisafe, 2019). However, little is known about whether their integration can produce synergistic benefits in aerobic and strength outcomes, particularly within adolescent populations in low-resource settings such as Indonesia (Chaeroni et al., 2021; Rozi et al., 2021). Moreover, much of the literature emphasizes statistical results without offering practical insights for physical

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11 (2) 2025| 321-335

education or school health programs. This study positions its novelty in filling this gap by investigating a combined HIIT and push-up program as a simple, low-cost, and scalable intervention. Doing so aims to provide actionable evidence to support curriculum development and youth health initiatives. The contribution lies in demonstrating statistical significance and translating findings into practical strategies that educators and policymakers can adopt.

Based on these considerations, the present study aims to analyze the impact of combining interval training with push-up exercises on adolescents' aerobic endurance and upper body strength. Using a quasi-experimental one-group pretest–posttest design with 29 adolescent participants, outcomes were measured through the 12-minute run test (Cooper test) for VO_2Max and the 1-minute push-up test for muscular endurance. The central objective is to determine whether a six-week intervention can produce statistically and practically meaningful improvements in fitness performance. This research extends the literature by providing empirical evidence on the feasibility and effectiveness of combined exercise modalities in school and community settings. It also contributes theoretically by offering integrated insights into how aerobic and resistance training complement each other. Ultimately, the study highlights a feasible intervention that addresses adolescent health concerns, reinforces the importance of structured physical education, and supports long-term youth development. Therefore, this study examines the combined effects of interval training and push-up exercises on adolescents' VO_2Max and upper body strength, while exploring its feasibility as a school-based intervention.

METHOD

This study employed a quasi-experimental design using a one-group pretest–posttest approach. Although no control group was included, this design was chosen to provide preliminary evidence of the intervention's effectiveness. The absence of a comparison group limits causal inference. However, it was considered appropriate due to practical and ethical

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

considerations, such as the limited number of participants and the concern of withholding potentially beneficial training from some adolescents.

The study involved 29 adolescent participants (17–20 years old, mean age 19 years; 18 males and 11 females) with an average body weight of 69 kg, height of 175 cm, and BMI of 22.6. Participants were recruited using purposive sampling based on inclusion criteria: (1) physically healthy and free from injury, (2) engaged in physical activity at least twice a week, and (3) willingness to follow the intervention program in full. Exclusion criteria included a history of cardiovascular or musculoskeletal disorders, involvement in other structured training programs, or inability to commit to the training schedule.

Two validated field-based instruments were employed. Aerobic capacity was measured using the 12-minute run test (Cooper Test), which has high validity and reliability for estimating VO_2Max. Upper body muscular endurance was assessed using the 1-minute push-up test, which records the maximum number of correct push-ups performed in one minute. These instruments were chosen due to their practicality, low cost, and applicability to adolescent populations in school or community settings.

The six-week intervention consisted of structured interval training and push-up exercises. Interval training was conducted thrice weekly, with participants completing 12 repetitions of 400 m runs. In weeks 1–3, the target completion time was 105 seconds, while in weeks 4–6, the target was reduced to 95 seconds, with 150 seconds of rest between repetitions. Push-up sessions were conducted four times weekly, including two sets of 50 standard push-ups and three sets of 15 diamond push-ups. To ensure consistency, all sessions included 10-minute warm-up and cool-down routines. Attendance was recorded at each session, and average compliance exceeded 92%, indicating high participant engagement. Qualified instructors supervised all sessions to monitor technique and safety.

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

Pretest and posttest assessments were conducted under standardized conditions on the same outdoor track with comparable weather. During interval training, heart rate monitors were used to ensure participants maintained the target intensity (85–95% of maximum heart rate). Data collection sheets were verified after each session and double-entered into SPSS to minimize input errors.

Data analysis was performed using IBM SPSS version 26. Normality was checked prior to hypothesis testing. Paired-samples t-tests were used for normally distributed data, and Wilcoxon signed-rank tests were applied for non-normally distributed variables. In addition to significance values ($p < 0.05$), effect sizes (Cohen's d and r) were calculated to strengthen interpretation. Descriptive statistics, including means and standard deviations, were also reported to provide an overview of data distribution.

Table 1. Overview of the intervention program

Exercise Type	Measurement Test	Duration	Frequency	Program Description
Interval Training	12-minute run (Cooper)	6 weeks	3x/week	12 reps of 400 m; Weeks 1–3: 105 sec; Weeks 4–6: 95 sec; 150 sec rest
Push-Ups	1-minute push-up test	6 weeks	4x/week	2 sets × 50 standard push-ups; 3 sets × 15 diamond push-ups

RESULTS

Before hypothesis testing, data were processed and checked for completeness, with all 29 participants completing both the pretest and posttest. Normality testing was performed to determine the appropriate statistical approach. For the 12-minute run test, the results showed significance values of 0.140 (pretest) and 0.227 (posttest), both above the 0.05 threshold, indicating normally distributed data. In contrast, push-up test results had significance values of 0.025 (pretest) and 0.001 (posttest), classifying them as not normally distributed. Accordingly, the paired sample t-test was applied to the run test, and the Wilcoxon signed-rank test was applied to the push-up test.

Analysis of the 12-minute run test showed that the average VO_2Max increased from 44.7 ml/kg/min in the pretest to 47.8 ml/kg/min in the posttest, reflecting a gain of 3.1 ml/kg/min. The paired t-test confirmed that

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

this improvement was statistically significant (p = 0.002). In practical terms, this increase in VO_2Max, though modest, is meaningful because each 1 ml/kg/min improvement is associated with reduced cardiovascular risk and enhanced endurance capacity in adolescents. The Pearson correlation coefficient between pretest and posttest scores was 0.475, indicating a moderate positive relationship that supports the reliability of the intervention's effect.

The paired samples test further confirmed the effectiveness of the intervention, with a one-sided p-value of 0.001 and a two-sided p-value of 0.002, both below the 0.05 threshold. The negative mean difference (-3.141) demonstrated that posttest scores were higher than pretest scores, reinforcing the conclusion that interval training successfully improved

aerobic endurance. These results highlight the capacity of structured HIIT-based programs to produce measurable cardiorespiratory benefits in adolescents within a relatively short period.

For the push-up test, the Wilcoxon signed-rank test showed significant improvement (p = 0.019). The average number of push-ups increased from 39.9 at pretest to 41.8 at posttest, with 13 participants showing improvement, 12 maintaining the same score, and 4 experiencing a decline. This trend reflects a general enhancement in upper-body muscular endurance. The improvement is statistically significant and practically relevant, as stronger upper body muscles support posture, breathing efficiency, and movement stability during endurance activities such as running.

Table 2 summarises the mean scores of pretest and posttest results for both the 12-minute run test (VO_2Max) and push-up performance. Figure 1 provides a bar chart visualizing these changes, offering a more precise comparison of aerobic and muscular endurance improvements after the six-week intervention program.

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

Table 2. Summary of Pretest and Posttest Results

Test	Pretest (Mean)	Posttest (Mean)
VO_2Max (ml/kg/min)	44.7	47.8
Push-Ups (repetitions)	39.9	41.8

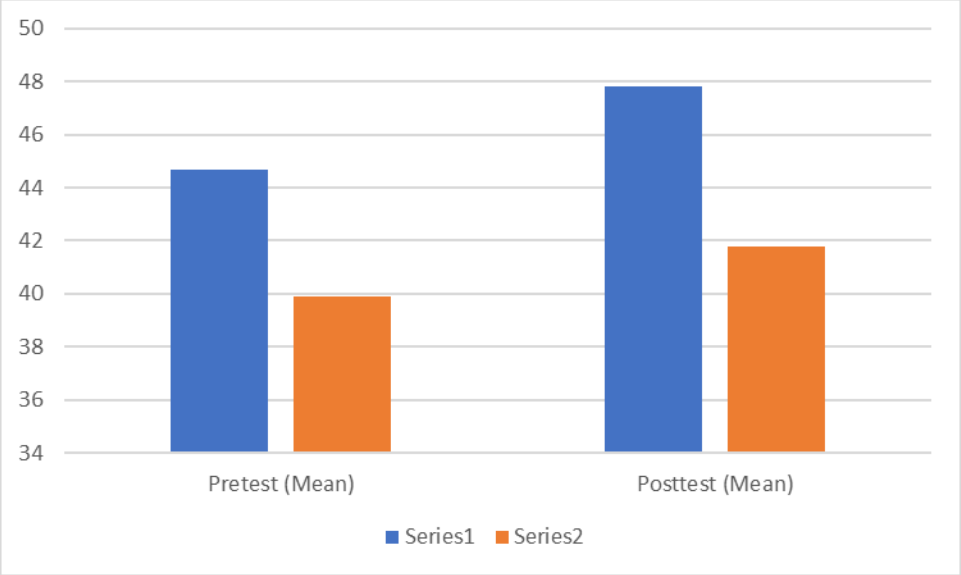

Figure 1. Comparison of Pretest and Posttest Results

The findings demonstrate that the six-week intervention program combining interval training and push-up exercises effectively enhanced both aerobic and muscular endurance in adolescents. The visual comparison in Figure 1 reinforces the statistical results by clearly illustrating the upward trend from pretest to posttest scores. Specifically, the average VO_2Max increased from 44.7 ml/kg/min at pretest to 47.8 ml/kg/min at posttest, representing a gain of 3.1 ml/kg/min. At the same time, the mean push-up performance rose from 39.9 repetitions to 41.8 repetitions, an increase of nearly 2 repetitions. Although the magnitude of these improvements was moderate, they are practically meaningful, since even a 1 ml/kg/min increase in VO_2Max has been associated with reduced cardiovascular risk. These results confirm that structured, low-cost training interventions can make a measurable difference in adolescent physical fitness. The combination of interval training for cardiorespiratory capacity and push-up exercises for upper body strength offers a feasible and adaptable model that can be applied in school-based physical education

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

programs and community health initiatives, supporting the promotion of healthier lifestyles and improved physical performance in youth.

DISCUSSION

The findings of this study confirm that interval training significantly improved cardiorespiratory endurance in adolescents, as indicated by increases in VO_2Max following the six-week intervention. The physiological basis of the observed improvements can be explained by the repeated high-intensity bouts that characterize HIIT, which stimulate both central cardiovascular adaptations, including increased stroke volume and cardiac output, and peripheral muscular adaptations, such as enhanced capillary density and mitochondrial efficiency (Buchheit & Laursen, 2013; Gibala et al., 2012). These dual mechanisms enable the body to deliver and utilize oxygen more effectively, thereby improving VO_2Max. Compared with prior studies, such as Atakan et al. (2021) and Costigan et al. (2015), the magnitude of VO_2Max improvement in this study was slightly smaller. This discrepancy may be attributed to factors such as the relatively short six-week duration, variations in training intensity, or differences in participants' baseline fitness levels (Bauer et al., 2022). Such comparisons underscore the importance of program design, training load, and individual conditioning in shaping the size of physiological adaptations.

Upper body muscular endurance also demonstrated significant improvement following push-up training, as evidenced by increased repetition counts in the posttest. Push-up exercises target multiple major muscle groups, including the chest, shoulders, arms, and core, making them effective for developing muscular endurance (Hernawan & Putra, 2023). This finding supports the results of Lee et al. (2018), who confirmed the reliability of push-ups as a field-based tool for strength and endurance development. Beyond isolated gains in muscular performance, stronger upper body muscles likely contributed indirectly to enhanced aerobic outcomes during the 12-minute run by stabilizing posture, improving arm swing mechanics, and increasing breathing efficiency (Eather et al., 2023; Yin et al., 2025). This interaction illustrates the principle of aerobic–

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

resistance synergy, where resistance training adaptations augment endurance capacity by reducing energy cost and improving movement economy (Hita, 2020; Rejeki et al., 2023).

Therefore, the combined use of interval training and push-ups provides dual and complementary benefits, addressing two critical components of adolescent fitness—aerobic capacity and muscular strength. Unlike studies that examined HIIT or resistance training in isolation (Pontes-Silva & Lopes, 2024; Zhang et al., 2025), the present findings highlight the added value of integrating both modalities into a single program. The novelty of this approach lies in its simplicity, cost-effectiveness, and scalability, making it particularly relevant for school and community settings in Indonesia, where limited resources and declining fitness levels among youth present ongoing challenges. A practical implication is that PJOK teachers could integrate two weekly sessions that combine short HIIT running drills and structured push-up sets into their curriculum. At the same time, extracurricular activities could adopt similar formats to reinforce physical development further. By translating research outcomes into implementable strategies, this study contributes to sports science literature and practical health promotion in adolescent populations.

Despite these promising findings, limitations must be acknowledged. Although ethically and practically justified, the one-group pretest–posttest design restricts the strength of causal inference due to the absence of a control group. The small sample size (29 participants) also limits generalizability, and characteristics such as age distribution, gender balance, and initial fitness levels may have influenced the results. Furthermore, while adequate to show initial improvements, the relatively short six-week duration may not capture long-term physiological adaptations or the program's sustainability. Nevertheless, participant compliance was high, with average attendance above 92%, reinforcing the intervention outcomes' reliability despite these constraints.

https://doi.org/10.29407/js_unpgri.v11i2.26379
11 (2) 2025| 321-335

In conclusion, the present study demonstrates that combining interval training with push-up exercises produces meaningful improvements in VO_2Max and upper body muscular endurance among adolescents. By critically comparing the results with previous studies, situating the findings within the framework of aerobic–resistance synergy, and offering concrete implementation strategies for schools, this research contributes both scientifically and practically to adolescent fitness development. The study's novelty lies in its focus on dual-component interventions within the Indonesian context, where cost-effective and scalable approaches to physical fitness remain an urgent priority.

CONCLUSION

This study demonstrated that six weeks of combined interval training and push-up exercises significantly improved adolescent physical fitness. The program increased VO_2Max by 3.1 ml/kg/min and enhanced push-up performance by an average of 1.9 repetitions, indicating meaningful gains in aerobic endurance and upper body muscular strength. These findings highlight the contribution of simple, low-cost, and accessible exercise models that can be feasibly implemented in schools and youth programs, particularly in contexts with limited resources. The practical implication is that integrating such routines into physical education can effectively address declining fitness levels among adolescents while supporting healthy growth and performance. In addition, the results emphasize the importance of combining aerobic and resistance-based exercises rather than focusing on a single modality. Stronger upper body muscles improve push-up performance and support better posture and breathing efficiency during endurance activities. This synergy underlines the value of designing integrated programs that address multiple fitness components simultaneously. Despite the limitations of sample size and the absence of a control group, the study strengthens the evidence that structured, combined training interventions can be a feasible strategy to enhance adolescent health and fitness outcomes.

https://doi.org/10.29407/js_unpgri.v11i2.26379
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11 (2) 2025| 321-335