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Effects of a sit-to-stand plus heel raise exercise program on predicted maximal oxygen consumption in sedentary adolescents

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ABSTRACT

Background: Sedentary behaviour in adolescents is associated with lower cardiorespiratory fitness and higher cardiometabolic risk. Simple functional exercises may represent a practical and accessible way of improving aerobic fitness in school settings. This study aimed to examine the effects of a sit-to-stand plus heel-raise (STS-HR) exercise program on maximal oxygen consumption (VO_2max) in inactive male adolescents.

Methods: This single-blind randomized controlled trial was conducted in a high school in Surabaya, Indonesia from July to November 2025. Inactive males aged 15-17 years were randomly assigned to either a control group that did not participate in organized exercise or an intervention group that underwent 8-week supervised STS-HR program three times per week. Predicted VO_2max was assessed before and after the intervention using the Chester Step Test by blinded assessors.

Results: Thirty-seven of 39 randomized participants completed the trial. The STS-HR group had a significant increase in predicted VO_2max (36.14 ± 8.53 to 46.52 ± 7.90 mL·kg-1·min-1; $p < 0.001$) whereas the control group did not (41.48 ± 8.24 to 41.33 ± 9.23 mL·kg-1·min-1; $p = 0.911$). The between-group difference in change in VO_2max was 10.53 mL·kg-1·min-1 (95% confidence interval: 6.89 to 14.17; $p < 0.001$). No adverse events, exercise-related discomfort, or injuries were reported during the intervention.

Conclusion: An 8-week supervised STS-HR program led to a significant increase in predicted VO_2max in inactive male adolescents. These results provide evidence that simple functional exercises may be an effective and low-cost feasible school-based strategy to improve cardiorespiratory fitness in inactive youth.

Keywords: adolescent, cardiorespiratory fitness, exercise testing, muscle strength, sedentary behavior.

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INTRODUCTION

Sedentary lifestyle and lack of physical activity among teenagers have become a serious public health concern worldwide. The World Health Organisation (WHO) reports that nearly 80% of teenagers do not engage in the sufficient amount of physical activity daily, contributing to the global problem of non-communicable diseases.[1,2] The global cost of healthcare related to inactivity is estimated at about US$27 billion annually and is expected to continue to increase in the future years, which adds a significant economic burden to the problem. Adolescent sedentary behaviour is widespread in Indonesia. Previous studies have found that only 12.2–52.3% of teenagers get adequate exercise and many of those teens spend more than three hours daily on sedentary activities such as staring at a screen, playing video games, or using their smartphones.[3] The use of digital devices greatly increases the likelihood of adolescents leading sedentary lifestyles.[4,5]

Inactivity may have an impact on the cardiovascular and musculoskeletal systems. Decreased aerobic capacity and increased inactivity are associated with an increased risk of metabolic and cardiovascular disease.[6,7] A common measure of cardiorespiratory fitness is the maximal oxygen consumption (VO_2max), which reflects the body's ability to transport and use oxygen during exercise.[8] Lower levels of VO_2max are associated with lower cardiovascular fitness and lower exercise tolerance. The average VO_2max in adolescents in Indonesia is still relatively low. The Sport Development Index found an average VO_2max of 30.33 ml/kg/min for men and 25.56 ml/kg/min for women, which is lower than the global reference values. These findings suggest the need to provide access to simple, feasible and easily implementable fitness programs for inactive teenagers.[9]

Functional exercises like the sit-to-stand (STS) and heel-raise movements are common and mimic daily activities. In the sit-to-stand exercise, the lower extremities' muscles, particularly the glute and quadriceps muscles, are given an opportunity to be exercised.[10] Repeated STS movements increase energy expenditure and total muscular activity. The heel raise exercise targets the gastrocnemius and soleus muscles that support walking performance, balance, and ankle stability. In addition, the venous return may be stimulated through the calf muscle pump mechanism as the calf muscles contract repeatedly.[11]

Research suggests that workouts like STS and heel raises might boost strength and functional ability. Nevertheless, there is currently a lack of consistent and sufficient information addressing their impact on cardiorespiratory fitness.[10,11] It is possible that the exercise stimulus alone will not be enough to cause a significant amount of aerobic adaptation. A more comprehensive activation of lower-extremity muscles via functional movement repetitions may be achieved by combining the two exercises. This synergy has the ability to improve oxygen delivery and utilization by increasing venous return and circulation efficiency when exercising.[12] Aerobic metabolism-related peripheral adaptations, such as enhanced capillary perfusion and oxidative capability, may be induced, in part, by repetitive muscular activity. Because of their lack of conditioning, adolescents with poor fitness levels to begin with may react more strongly, even too little activity.[13,14]

Few studies have examined the impact of sit-to-stand and heel-raise exercises on cardiorespiratory fitness in inactive teenagers. Hence, the purpose of this research was to examine the impact on VO_2max of an exercise program that included both sit-to-stand and heel raises in inactive male adolescents. The hypothesised improvement in VO_2max would be larger in the exercise intervention group than in the control group.

METHODS

This study utilized a randomized controlled trial with a two-group pretest-posttest design. Student and teacher monitoring occurred at a school in Surabaya, Indonesia from July to November 2025. The outcome assessors were blinded to group allocation of the participants throughout the trial.

The study was comprised of male students aged 15–17 years that were sedentary based on the Indonesian version of the International Physical Activity Questionnaire (IPAQ). Sedentary status was determined using the IPAQ low-activity category based on total physical activity levels < 600 MET-minutes/week. Also, participants reported spending >3 h/day in sedentary behaviors not related to school (e.g., gaming, prolonged sitting, or screen time). The classification enabled the detection of adolescents with inactive lifestyles. Subjects with a history of musculoskeletal, neurological, cardiovascular, pulmonary, or metabolic disorders that could influence physiological responses during training or restrict exercise participation were excluded. Written informed consent was obtained from all participants and their parents or legal guardians before enrollment. Ethical approval for this study was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia (No. (197/EC/KEPK/FKUA/2025).

Eligible students were selected using simple random sampling. The randomization was performed using computer-generated random sequence in Microsoft Excel with 1:1 allocation ratio. Simple randomization was used instead of block randomization because of the relatively small sample size and the expectation of balanced group allocation. Outcome assessments were conducted by an evaluator who was unaware of participants' group assignments (single-blind design). Blinding of participants and supervisors was not feasible because of the nature of the intervention.

The intervention group participated in supervised sit-to-stand and heel-raise (STS-HR) exercise sessions three times per week for eight weeks. Each session began with a warm-up and was followed by three training circuits consisting of sit-to-stand and double-leg heel-raise exercises. There was a 30 s interval between STS and HR exercises and a 1 min rest period between circuits. A metronome was set at 30 beats per minute, equivalent to one movement every 2 s, to standardize exercise pace. Training volume increased progressively throughout the intervention period, with 8 repetitions per set during weeks 1-2, 10 repetitions during weeks 3-4, 13 repetitions during weeks 5-6, and 15 repetitions during weeks 7-8. Vital signs of the participants were monitored before, during, and after each exercise session. Exercise intensity was monitored via Borg's Rating of Perceived Exertion (RPE). The target RPE was between 9 and 11. This intensity was chosen for several reasons: the low baseline fitness levels of the participants, sedentary lifestyles and the need for a low to moderate intensity in the early training phase to ensure safety, to minimize excessive fatigue and to enhance exercise adherence. Large lower-extremity muscle groups were kept engaged through repetitive sit-to-stand and heel-raise movements with progressive increases in training volume despite the relatively low perceived exertion. The researchers expected this would be feasible, well tolerated within a school setting, and effective in producing improvements in cardiorespiratory fitness. Participants in the control group were asked to maintain their usual daily activities and not to begin any structured exercise program during the study period. Both groups completed the same monitoring questionnaires on dietary intake and physical activity performed outside the classroom.

The primary outcome was predicted VO_2max (mL·kg-1·min-1) measured by the Chester Step Test (CST). The CST was performed on a 20-cm step box using a metronome-guided stepping cadence that progressed through five stages (15, 20, 25, 30, and 35 steps/minute), each lasting two minutes. Heart rate and rating of perceived exertion were recorded at the end of each stage. The test was terminated when participants reached approximately 80% of their age-predicted maximum heart rate or symptoms or other predefined stopping criteria occurred. Predicted values of VO_2 max were calculated according to standard procedures of the CST. Assessments were performed at baseline and within a few days after the end of the intervention. During the intervention period, session RPE scores (Borg scale), pain intensity (Wong-Baker FACES scale), adverse events, and exercise discontinuation signals were recorded and monitored. Sample size calculation indicated that at least 12 participants per group were needed to detect a clinically meaningful difference in VO_2 max changes between groups with 80% statistical power and an alpha level of $\alpha = 0.05$. With an expected attrition rate of 20%, the target sample size was increased to 15 participants per group.

Data were analysed using SPSS version 26. Continuous variables are presented as mean ± standard deviation (SD) and 95% confidence intervals (CI), where appropriate. Normal distribution was tested with the Shapiro-Wilk test. Within-group comparisons between pre- and post-intervention measurements were performed using paired *t*-tests or Wilcoxon signed-rank tests when normality assumptions were not met. Between-group comparisons were performed using independent *t*-tests or Mann-Whitney U tests, as appropriate. Statistical significance was established at a two-tailed *p*-value of less than 0.05. The primary analysis included all participants who completed the follow-up assessment.

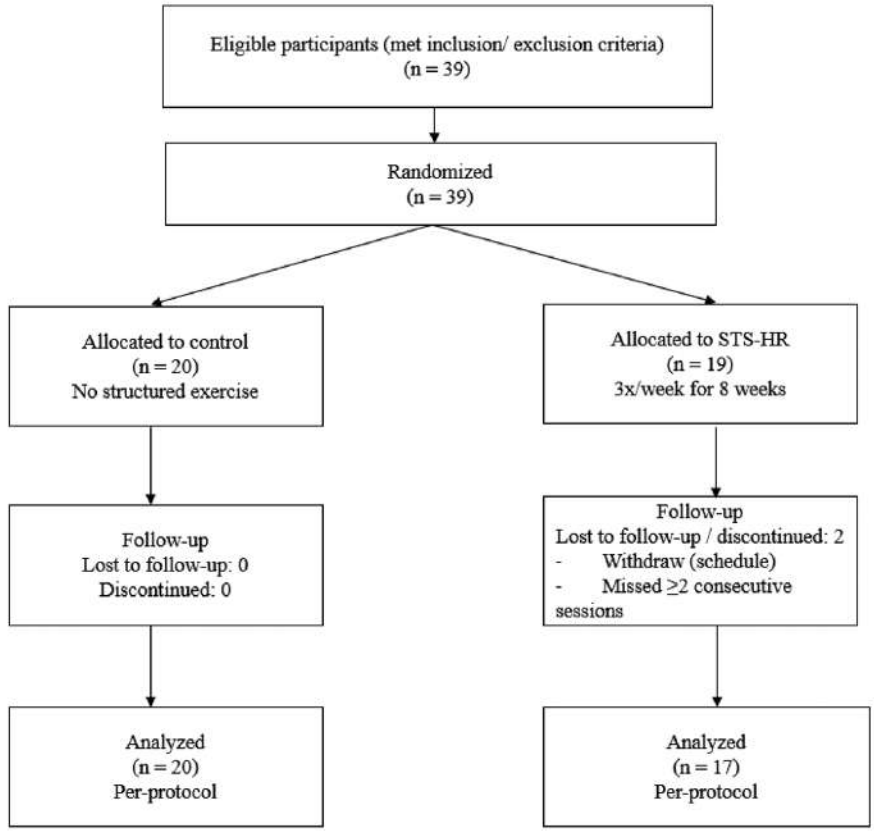

Figure 1. The consolidated standards of reporting trials (CONSORT) flow diagram

Table 1. Baseline characteristics of 37 participants in both control and sit-to-stand high repetition (STS-HR) groups

Characteristic	Control (n=20)	STS-HR (n=17)	*p*-value
Age (years), median (min-max)	16 (15-17)	15 (15-16)	0.013
Height (cm), mean ± SD	166.8 ± 6.2	167.1 ± 4.2	0.891
Weight (kg), mean ± SD	62.0 ± 14.6	61.4 ± 12.6	0.868
BMI (kg/m²), mean ± SD	22.1 ± 4.4	21.9 ± 4.0	0.899
METs (pre), mean ± SD	10.1 ± 2.0	9.8 ± 2.3	0.061
VO_2max (pre), mean ± SD	41.48 ± 8.24	36.14 ± 8.53	0.094
Energy intake (kcal/day), mean ± SD	1887.49 ± 278.02	2057.63 ± 301.03	0.085
Protein (g/day), mean ± SD	52.71 ± 13.57	55.12 ± 12.14	0.571
Fat (g/day), mean ± SD	68.05 ± 23.33	76.40 ± 21.99	0.271
Carbohydrate (g/day), mean ± SD	271.55 ± 55.16	268.26 ± 80.93	0.888

BMI, body mass index; kcal, kilocalories; max, maximum; METs, metabolic equivalents; min, minimum; SD, standard deviation; VO_2max, maximal oxygen consumption.

RESULTS

The randomization procedure is shown in **Figure 1**. A total of 39 participants were randomly assigned to the control group (n=20) or the STS-HR group (n=19). Thirty-seven participants completed the study for the final analysis, 20 in the control group and 17 in the STS-HR group. Two participants were lost to follow-up due to scheduling conflicts and missing two or more training sessions consecutively. Participants who completed the STS-HR program had 100% attendance.

As presented in **Table 1**, the only significant difference between the groups at baseline was age, with a median age of 16 years in the control group and 15 years in the STS-HR group (p=0.013). Baseline anthropometric characteristics, cardiorespiratory fitness measures and dietary intake variables were not significantly different between groups. There was no significant change in VO_2max in the control group from baseline to post-intervention measurements (41.48 ± 8.24 vs 41.33 ± 9.23 mL·kg^{-1}·min^{-1}; p = 0.911) (**Table 2**).

However, the STS-HR group had a significant improvement in VO_2max from 36.14 ± 8.53 to 46.52 ± 7.90 mL·kg^{-1}·min^{-1} (p < 0.001). As shown in **Figure 2**, the change in VO 2 max was significantly larger in the STS-HR group than in the control group (mean change: +10.38 ± 6.24 vs. −0.15 ± 4.12 mL·kg −1 ·min −1 ; p=0.004). At the end of the 8-week intervention, the estimated VO_2max of the STS-HR group was significantly higher than that of the control group. Induced significant improvements in cardiorespiratory fitness with a mean between-group difference of 10.53 mL·kg −1 ·min −1 (95% CI: 6.89-14.17; p<0.001).

Training sessions were conducted at an RPE within the target light-to-moderate intensity range (Borg Rating of Perceived Exertion score 9-11). No participant reported any discomfort during the intervention, and no adverse events were observed. Moreover, Wong-Baker FACES Pain Rating Scale scores remained at 0 throughout the study period indicating no pain during training sessions.

DISCUSSION

The baseline VO_2max values of both groups were similarly lower than the worldwide reference requirements for teenage males.[15,16] It is reasonable to offer targeted exercise programs in this cohort, since this finding is in line with the individuals' sedentary profile. On the other hand, there was no discernible increase in aerobic capacity in the control group during the course of the research. Some individuals may have experienced a temporary drop in cardiovascular fitness due to a lack of scheduled physical exercise, which has been linked to lower plasma volume, cardiac output, and oxidative enzyme activity in the past.[17–19]

Compared to other exercise trials that included teenagers, this one found a much bigger improvement in the intervention group. After comparable intervention periods, resistance-based or bodyweight exercise regimens often show VO_2max gains ranging from around 6-14%.[20,21] Participants' low fitness levels at the start of the trial may account, at least in part, for the bigger response shown here. When starting an exercise program, those who are physically unfit tend to be more receptive in the beginning stages, when even little increases in activity levels may cause noticeable changes in their bodies.[22,23]

There are a number of possible explanations for why VO_2max improved after the STS-HR intervention. When it comes sit up and then stand up again, it works out the quadriceps, gluteals, and hamstrings, which increases metabolic activity and blood supply to the muscles that work. The use of oxygen during exercise may be enhanced by repeatedly activating the muscles, which may increase vascular adaptation.[24]

An additional way by which the heel-raise component contributes is by engaging the soleus and gastrocnemius muscles, which are crucial to the calf muscle pump. Preload, stroke volume, and circulatory efficiency during exercise may be enhanced by repetitively contracting these muscles, which aids venous return from the lower limbs.[25,26] It follows that the circulatory stimulation may be greater when lower-limb exercises involving both proximal and distal motions are performed simultaneously rather than separately.[27]

Peripheral adaptations in skeletal muscle may also be induced by exercise training. These adaptations include increased capillary perfusion, mitochondrial efficiency, and oxidative enzyme activity. These changes tend to show up more in those who have never exercised before, and they might help with aerobic performance in the beginning before the bigger changes in the heart and lungs take place.[28]

The gradual increase in training volume throughout the intervention period is another possible explanation for the observed response. It is possible that inactive teenagers may have maintained excellent exercise tolerance and adherence with incremental increases in repetition volume, even while exercise intensity was within a light-to-moderate range.[29,30]

This study has several strengths. The randomized controlled trial design enhanced internal validity and allowed for a more accurate evaluation of the effects of the STS-HR program on VO_2max. The intervention was simple, low-cost, and easily implemented within a school setting, making it highly applicable for adolescent health promotion programs. Furthermore, outcome assessments were conducted by a blinded assessor to minimize measurement bias, and the training protocol was standardized in terms of exercise pace, frequency, progression,

Table 2. Predicted maximal oxygen consumption (VO_2max) outcomes

Outcome	Control (n=20)	STS-HR (n=17)	Between-group *p*-value	Estimate
VO_2max pre (mL·kg-1·min-1)	41.48 ± 8.24	36.14 ± 8.53	0.094	Cohen's d 0.63
VO_2max post (mL·kg-1·min-1)	41.33 ± 9.23	46.52 ± 7.90	0.074	Cohen's d 0.60
ΔVO_2max	-0.15 ± 4.12	+10.38 ± 6.24	0.004	10.53 (Δ) 6.89-14.17 (CI 95 %)

Δ, change (post-intervention minus pre-intervention); CI, confidence interval; Cohen's d, standardized effect size; $mL·kg^{-1}·min^{-1}$, milliliters of oxygen per kilogram of body weight per minute; STS-HR, sit-to-stand high repetition.

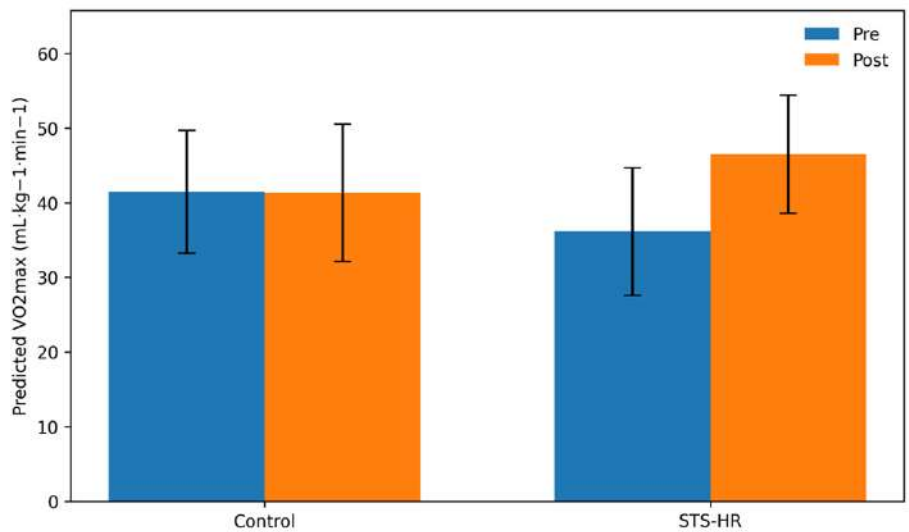

Figure 2. Mean predicted maximal oxygen consumption (VO_2max) before and after the intervention (error bars represent standard deviation).

and perceived intensity. From a practical perspective, the observed improvement in VO_2max exceeded the threshold for clinical relevance, highlighting the potential effectiveness of the intervention.

Nevertheless, several limitations should be considered when interpreting the findings. First, the levels of physical activity and dietary intake outside the supervised sessions were measured using self-report questionnaires, which may not have accurately reflected the participants' real behaviours. Thus, differences in non-intervention factors such as habitual physical activity, fatigue, hydration status and nutritional intake could have influenced exercise performance and training response. Future studies should consider the use of objective monitoring devices such as wrist-worn accelerometers or pedometers, along with structured dietary assessments to better control for these potential confounders. Second, the Chester Step Test is somewhat effort and motivation dependent. The motivation, familiarity with the testing protocol, or expectation of the intervention may have affected the performance outcomes. Although standardized testing procedures were applied and assessors were blinded, the possibility of performance bias cannot be entirely excluded. Third, smoking behavior was not strictly controlled during the study period. Fourth, outcome measures were only collected at the end of the 8-week intervention period. Undetected smoking behaviour among participants may have adversely affected aerobic capacity and contributed to the heterogeneity found in VO_2max outcomes. Therefore, the findings reflect mainly short-term training adaptations and it is unknown whether the observed VO_2max improvements are sustainable over a longer period. Finally, the study sample consisted only of inactive male adolescents with normal body mass index and baseline fitness levels. Therefore, caution needs to be exercised when generalizing these findings to other populations, including females, physically active adolescents, individuals with obesity, athletes, older adults, or those with underlying medical conditions.

Findings suggest that the STS-HR program may represent a practical and efficacious method for improving cardiorespiratory fitness in sedentary adolescents, with the exercises being space and equipment friendly, thus being especially pertinent to school-based physical activity programs, especially in resource-limited settings. Future studies should include more heterogeneous populations, use objective measures of physical activity and lifestyle behaviours during the intervention, and include long-term follow-up assessments to determine whether the improvements in VO_2max are sustained.

CONCLUSION

The current study showed a statistically significant increase in estimated VO_2max in sedentary male adolescents after the 8-week STS-HR exercise program performed three times a week. The intervention group exhibited clinically relevant improvements in cardiorespiratory fitness relative to the control group, indicating the efficacy of this simple functional exercise method. As the STS-HR program is low cost, requires minimal equipment, and is easy to implement, it provides a feasible and attainable approach to improve cardiorespiratory fitness in the school and community settings, especially for sedentary youth. Nevertheless, caution should be exercised when interpreting the results because of the relatively small sample size and relatively short duration of the intervention. Further studies are needed with larger and more heterogeneous samples, objective measures of physical activity and longer follow-up to confirm the long-term effectiveness and wider applicability of this intervention.

ETHICAL CONSIDERATION

Conducting this study in accordance with all relevant national regulations and institutional policies, as well as the principles of the Declaration of Helsinki, was essential to obtaining ethical approval from the Health Research Ethics Committee, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia (No. 197/EC/KEPK/FKUA/2025), issued on July 24, 2025.

CONFLICT OF INTEREST

There is no concealed bias or conflict of interest among the authors of this study.

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AUTHOR CONTRIBUTIONS

JHW was in charge of gathering data, creating methodologies, and writing the paper. Research ideation, planning, supervision, and critical review were all overseen by YDP. NS helped with gathering data, organizing it, and writing the paper. A offered technical assistance and helped with data collecting. The final document was authorized by all writers who had a hand in writing it.

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