# Regular training has a greater effect on aerobic capacity, fasting blood glucose and blood lipids in obese adolescent males compared to irregular training[☆]

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## ARTICLE INFO

## ABSTRACT

*Background/objective:* It is not clear whether the regularity of training affects the outcomes of aerobic exercise. This study aimed to compare the effects of regular with irregular training on aerobic fitness, blood markers, and anthropometric characteristics of obese adolescent males.
*Methods:* Twenty three male students between 16 and 17 years old were randomly assigned into regular exercise (RE) group and performed exercises on specific time and days each week, or irregular exercise (IE) group and performed exercise on randomly selected days each week. The intervention programs consisted of self-paced progressive running program (20 min in week one and 44 min in week 8), three times per week for eight weeks. Anthropometric characteristics, blood lipids, fasting blood glucose, and aerobic capacity were assessed before and after the intervention using a two-way ANOVA.
*Results:* There was a significant interaction of time and condition on total cholesterol (TC) $F(1, 21) = 5.427$, $p = 0.030$, $\eta_P^2 = 0.205$, and high-density lipoprotein to low-density lipoprotein ratio (HDL)/(LDL) $F(1, 21) = 5.951$, $p = 0.024$, $\eta_P^2 = 0.221$), with a greater reduction observed in RE group. LDL decreased only in RE group demonstrating a significant effect of time $F(1, 21) = 4.897$, $p = 0.038$, $\eta_P^2 = 0.189$. Body mass, body mass index (BMI), and waist circumference decreased, and $VO_{2peak}$ increased in both groups with no significant difference between groups. There was no significant effect of time or condition on waist to hip ratio (WHR), fasting blood glucose (FBG), triglycerides (TG), HDL, TC/HDL, or TG/HDL ($p > 0.05$).
*Conclusion:* Although both RE and IE improved $VO_{2peak}$ and some anthropometric measures, changes in TC, LDL, and HDL/LDL were more predominant in response to RE. Therefore, to achieve greater adaptations to aerobic exercise, overweight and obese adolescents should perform exercise regularly.

## Introduction

Obesity in children and adolescents is a major health concern in the 21st century. Over 340 million children and adolescents worldwide were reported overweight or obese in 2016,[1] and this epidemic is on the rise. This rate of obesity does not only affect affluent nations, but also has a large impact on low- and -middle-income countries.[2] Data shows a dramatic increase in obesity, and this trend suggests that by 2022, the world will have more obese children and adolescents than underweight.[3] The implications are that obese children and adolescents are at a higher risk of being

obese adults[4] who suffer from comorbidities associated with excess weight.

Recommendations for reducing the risk of obesity include eating healthier food and increasing the level of physical activity through active recreation and sports.[5,6] Physical activity, besides diminishing the risk of obesity and improving physical and mental health, enhances cardiovascular and respiratory functions in children and adolescents.[7,8] Furthermore, exercise improves blood lipids profile, fasting blood glucose, and insulin sensitivity by increasing daily energy expenditure that regulates metabolic activities and energy balance.

Nevertheless, positive adaptations to exercise depend on a balance between several training variables such as frequency, intensity, and recovery between exercise sessions. For example, the dose-response relationship between physical activity and health benefits suggests that greater health benefits are achieved in response to a larger training volume.[9,10] Indeed, the guidelines for healthy growth and development for children and young people between the ages of 5-17 years suggests a minimum of 60 min of moderate to vigorous activity per day involving aerobic activities.[11] As a result of these recommendations, typical training programs involve blocks of sustained medium to high-intensity activity on defined days - a model that is difficult to adhere to in modern life.[12] This lack of adherence to regular physical activity could be the result of limited unstructured free play options, availability of playgrounds and open spaces, and proximities to training facilities and fitness centres.

Previous researchers have identified several barriers that may jeopardise the sustainability of daily exercise in children and adolescents. Technology related activities, academic priorities, family and social responsibilities, lack of self-confidence and motivation, and the cost of organised activities have been listed as barriers to regular physical activity.[13,14] Moreover, lack of time was reported as the top barrier to physical activity in most research on adolescents.[13−17] Hence, strategies to mitigate the influence of these barriers (i.e. flexible training time) may enhance adherence to physical activity.

Availability of activities and flexibility in training time may enhance adherence to physical activity. Flexible training (exercising when possible) likely encourages more individuals to be physically active and could lead to a greater training volume per week. However, flexibility (exercising irregularly) may also have drawbacks. That is, irregular exercise may not be as effective because of variability in stimuli or inadequate recovery between exercise sessions.[18]

A balance between training stimuli and recovery is essential for improving subsequent training quality[19,20] and prevention of injuries.[18] This recovery time is essential for the removal of metabolic by-products, restoration of glycogen stores, repair of muscle damage, and rehydration. Inadequate recovery may reduce the quality of subsequent training sessions and potentially blunt training adaptations.[21]

No previous study has compared the outcomes of load-equated regular training with irregular training in obese adolescents. Therefore, this study compared aerobic fitness, body composition, and blood lipids profile of obese high school male students who participated in strictly scheduled regular training vs. more flexible irregular training. We hypothesized that regular training that requires adhering to specific training time results in greater health

and fitness adaptations than irregular training.

## Methods

This study adopted a single-blind randomised controlled trial design in which participants were not aware of the alternative training group. Participants were randomly assigned to one of two groups using a random sequence generator and performed either regular or irregular training for eight weeks. The subsequent analyses were used to assess the effectiveness of training regularly or irregularly on health benefits and cardiovascular outcomes.

### Participants

In this study, non-probability convenience sampling was used. For this purpose, invitations for expression of interest were distributed through flyers in community centres and on schools' noticeboards for three weeks, and 31 male students aged 16−17 years, enquired about the study. The inclusion criteria were having a BMI over 25 kg.m$^{-2}$, no chronic diseases, no use of medication, and no regular exercise (more than once a week) in the past six months before the study. Four individuals did not meet these inclusion criteria and were excluded (Fig. 1.). The remaining participants were informed about the benefits and risks involved in this study, read the plain language statement, and provided signed informed consent. This research project was approved by the relevant Human Ethics Committee (approval number: IR.LUMS.-REC.1397.045) and was performed in accordance with the declaration of Helsinki.

### Anthropometric assessments

Height was measured with participants barefoot on a flat surface using a standard stadiometer to the nearest 0.01 m. Body mass was measured with participants in lightweight clothing to the nearest 0.1 kg using a calibrated digital scale. Body mass index (BMI) z-scores were calculated using the following formula[22]:

Z-score (or SD-score) = (observed value - median value of the reference population)/standard deviation value of reference population

Waist and hip circumferences were measured to the nearest 0.01 m following the procedure outlined by the International Society for the Advancement of Kinanthropometry (ISAK).[23] Anthropometric measurements were taken 72 h before the first and 72 h following the final training session. Following anthropometrical assessments, participants were randomly assigned to regular exercise (RE; n = 13) and irregular exercise (IE; n = 14) groups.

### Assessment of the maximum aerobic capacity

Participants performed a 2.4 km run on an outdoor 400 m polyurethane track following a 10-min warm-up (brisk walking, jogging and low-intensity static stretches). The researchers encouraged participants verbally to complete the test in the shortest possible time (recorded in minutes and decimal seconds), and this time was used to estimate the maximum aerobic capacity ($VO_{2peak}$) of participants using the following formula.[24]

$$VO_{2peak} = 65.404 + 7.707 \times (male = 1; female = 0) - 0.159 \times body\ mass\ (kg) - 0.843 \times elapsed\ exercise\ time\ (min)$$
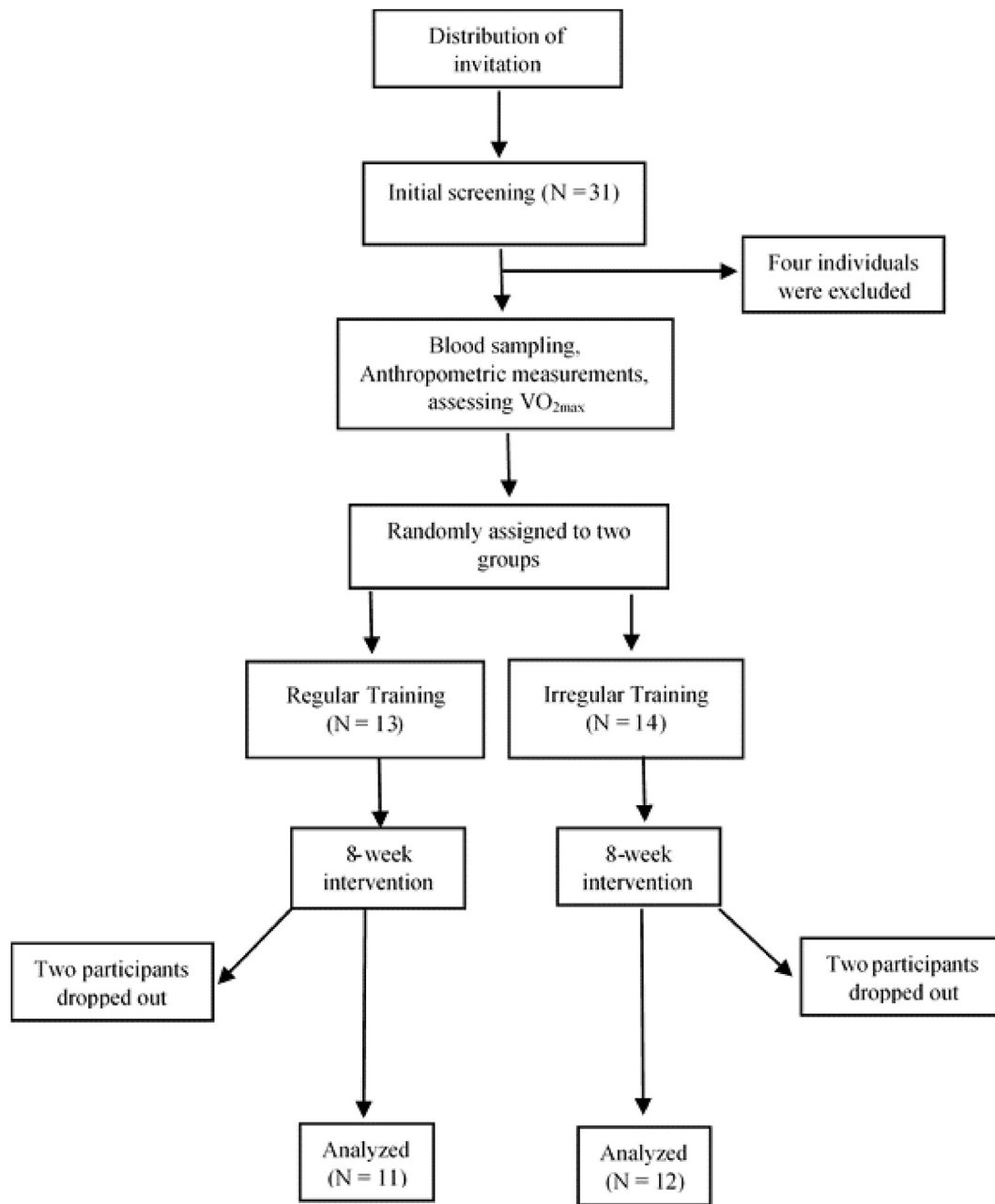
**Fig. 1.** The flowchart for the study protocol.

*Blood sampling and analysis*

Blood samples were collected after an 8–10 h overnight fast, between 0730 to 0830 from the median antecubital vein. The samples were collected 48 h before the intervention and 48 h following the final training session. Serum was separated by spinning the blood samples at 3000 rpm for 15 min in a refrigerated centrifuge and stored at $-80^{\circ c}$ for later analyses. Triglycerides (TG), glucose, total cholesterol (TC), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) were analysed using commercially available enzyme-linked immunosorbent assay (ELISA) kits (Audit Diagnostics, Ireland) following protocols supplied alongside the kits. Each sample was measured in duplicate and the mean value used in subsequent analyses.

*Exercise protocol*

The regular exercise (RE) group trained at 1700 on specific days (Mondays, Wednesdays, and Fridays) every week. However, as demonstrated in Table 1, the irregular exercise (IE) group performed three exercise sessions on randomly selected days each week. That is, the exercise days for IE group were selected by a random generator and there was no pattern for the selection of exercise days. Accordingly, the recovery time between regular training sessions was between 48 and 72 h, whilst the recovery time in irregular training group varied from 24 to 120 h. Both RE and IE groups performed three exercise sessions per week at the same intensity (as assessed by the Borg scale) and volume under the supervision of a qualified fitness coach.

Each exercise session consisted of a 10-min warm-up and cool-

**Table 1**
Training days for the irregular exercise group was selected randomly for eight weeks.

| Weeks | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| Week 1 | | | * | | * | * | |
| Week 2 | * | * | | * | | | |
| Week 3 | | | | | * | * | * |
| Week 4 | * | | * | * | | | |
| Week 5 | | | * | | * | * | |
| Week 6 | | * | | * | | | * |
| Week 7 | * | * | | | | * | |
| Week 8 | * | | | * | | | * |

down (brisk walking and static stretching) with the main exercise period of 20 min running on a track. Following the initial exercise session, each subsequent main exercise period was increased by 1 min, thus the final session had a 44-min main exercise period. The intensity was controlled via the rating of perceived exertion (RPE), with participants encouraged to maintain an intensity of 13–14 on the Borg scale.[25]

The protocols used in this study have not been previously prescribed. These protocols developed by the authors while considering the initial fitness level of the participants, and the availability of fitness facilities and equipment. We aimed to develop a training protocol that required minimum equipment and could be performed outdoor with minimum to no supervision.

*Statistics*

Data were analysed using SPSS 24.0 (SPSS Inc, Chicago, IL) and the results are presented in mean and standard deviation (SD). A two-way (time × condition) analysis of variance (ANOVA) was used to compare differences within and between the two groups. The effect sizes (ES) were calculated and reported as $\eta_P^2$ and values 0.01, 0.09 and 0.25 considered small, medium, and large, respectively.[26] The relationship between physiological changes and blood markers were assessed using Pearson's bivariate correlation. The probability level of statistical significance was set at $p \leq 0.05$ for all analyses. To estimate the number of participants needed in the study, a sample size calculation was performed using G*Power Software version 3.1.9.6 (Düsseldorf, Germany) for repeated measure within-between interaction, using a rejection criterion of 0.05 and 0.9 (1-β) power, and large effect (f = 0.4).[29] The power calculation indicated that a minimum of 18 participants was required to be able to find such an effect.

**Results**

Two participants from RE group and two participants from IE group did not complete 90% of all training sessions or dropped out of the study. The results presented in this study were collected from the remaining 23 participants in RE group (N = 11; age: 17.3 ± 0.6 years; height: 1.8 ± 0.1 m) and IE group (N = 12; age: 16.8 ± 0.6 years; height: 1.8 ± 0.1 m).

There was a significant effect of time on body mass $F(1, 21) = 16.34$, $p = 0.001$, $\eta_P^2 = 0.438$, BMI $F(1, 21) = 16.38$, $p = 0.001$, $\eta_P^2 = 0.438$, BMI Z-score $F(1, 21) = 15.73$, $p = 0.001$, $\eta_P^2 = 0.428$, and waist circumference $F(1, 21) = 12.37$, $p = 0.002$, $\eta_P^2 = 0.371$. Further analysis of these results showed that body mass, BMI, BMI Z-score and waist circumference were decreased in both groups with no significant differences observed between groups (Table 2). Furthermore, there was a significant effect of time on $VO_{2peak}$ and participants in both groups experienced an increase in aerobic capacity. However, the difference between the two groups was not statistically significant.

The analyses of blood variables demonstrated a significant interaction of time and condition effect on cholesterol $F(1, 21) = 5.427$, $p = 0.030$, $\eta_P^2 = 0.205$ and HDL/LDL $F(1, 21) = 5.951$, $p = 0.024$, $\eta_P^2 = 0.221$. Both cholesterol and HDL/LDL were reduced in RE group but did not change in response to IE. Similarly, LDL decreased only in RE group demonstrating a significant effect of time on LDL $F(1, 21) = 4.897$, $p = 0.038$, $\eta_P^2 = 0.189$.

There was no significant effect of time or condition on WHR, FBG, TG, HDL, TC/HDL, or TG/HDL ($p > 0.05$).

**Discussion**

Previous research highlighted the positive effects of exercise on cardiorespiratory factors, body composition, and blood lipids among overweight and obese children and adolescents.[30] However, it was not clear whether these positive changes are affected by the regularity of training stimuli. This study compared the effectiveness of regular training with irregular training on aerobic capacity and cardiovascular markers in overweight and obese adolescent males. The results of this study showed that despite no statistical differences between the two groups, the magnitude of changes in RE group were greater than IE group in body mass (2.2% vs. 1.6%), BMI (2.1% vs. 1.7%), and waist circumference (1.9% vs. 0.9%). Similarly, the magnitude of changes in response to regular training was greater in FBG (3.8% vs. 1%), cholesterol (8.8% vs. 0.1%), TG (13.2% vs. 10.2%), LDL (16.2% vs. 1.8%), HDL (4.7% vs. 1.6%), and HDL/LDL (12.2% vs. 0.0%). In addition, participants in RE group experienced a greater improvement in $VO_{2peak}$ compared to participants in IE group (5.3% vs. 3.3%).

Despite greater changes in RE group compared to IE group, training irregularly also resulted in positive changes in anthropometric characteristics, aerobic capacity and blood lipids. Therefore, irregular training could be considered a suitable training option for individuals with limited time and those who cannot commit to regular training. Previous research has consistently indicated a lack of time to be a major barrier to engagement and adherence to exercise programs.[31] Flexible training, therefore, may be an option for casual employees with unpredictable rosters, shift workers, and time-poor individuals.

Loss in weight may be the result of reduced fat mass, water volume or muscle mass, the variation of which depends to some extent on the exercise intervention. Aerobic based interventions tend to reduce weight to a larger degree with a more even distribution between the aforementioned factors, whereas resistance based interventions tend to maintain or increase muscle mass but reduce fat mass resulting in typically lower absolute weight loss.[32] The loss in weight in the current study was significant though minor with an average of 2.2% reduction in RE group and 1.6% reduction in IE group. A major limitation of the current study was the lack of information regarding the body composition of participants. However, a significant reduction in waist circumference in this study may indicate a reduction of abdominal fat which has proven health benefits.

**Table 2**
Changes in anthropometrical and blood lipids measures in response to an 8-week regular or irregular training.

| | Regular (N = 11) | | | Irregular (N = 12) | | |
|---|---|---|---|---|---|---|
| | Pre | post | ES | Pre | Post | ES |
| Cholesterol (mg/dl) | 158.27 ± 29.07 | 144.27 ± 30.14 | 0.47 | 151.25 ± 30.25 | 151.17 ± 33.08 | 0.00 |
| TG (mg/dl) | 154.45 ± 98.65 | 134.09 ± 63.97 | 0.25 | 113.00 ± 39.55 | 101.42 ± 41.10 | 0.29 |
| LDL (mg/dl) | 103.09 ± 27.19 | 86.36 ± 21.86 | 0.68 | 102.00 ± 27.10 | 100.17 ± 33.64 | 0.06 |
| HDL (mg/dl) | 38.45 ± 6.35 | 36.64 ± 5.82 | 0.30 | 41.08 ± 10.52 | 40.42 ± 8.60 | 0.07 |
| HDL/LDL | 0.41 ± 0.18 | 0.46 ± 0.20 | 0.30 | 0.44 ± 0.19 | 0.44 ± 0.17 | 0.01 |
| Glucose (mg/dl) | 97.18 ± 8.69 | 93.45 ± 7.16 | 0.47 | 91.17 ± 9.10 | 90.25 ± 5.08 | 0.13 |
| Body mass | 101.55 ± 9.04 | 99.36 ± 8.18 | 0.25 | 98.75 ± 15.18 | 97.17 ± 15.30 | 0.10 |
| BMI (kg/m$^2$) | 31.79 ± 2.92 | 31.11 ± 2.55 | 0.25 | 31.84 ± 4.04 | 31.31 ± 4.00 | 0.13 |
| BMI Z-Score | 2.04 ± 0.30 | 1.97 ± 0.29 | 0.24 | 2.05 ± 0.45 | 1.98 ± 0.48 | 0.14 |
| Waist Circumference (cm) | 102.18 ± 7.03 | 100.27 ± 5.26 | 0.31 | 99.67 ± 7.76 | 98.75 ± 8.21 | 0.11 |
| WHR | 0.94 ± 0.03 | 0.94 ± 0.04 | 0.03 | 0.93 ± 0.04 | 0.93 ± 0.04 | 0.06 |
| VO$_{2peak}$ (ml/kg/min) | 39.98 ± 3.63 | 42.09 ± 3.61 | 0.58 | 41.73 ± 4.35 | 43.10 ± 4.10 | 0.32 |

TG = triglyceride; LDL = low density lipoprotein; HDL = high density lipoprotein; BMI = body mass index; WHR = waist-to-hip ratio; VO$_{2peak}$ = peak oxygen uptake.

A common BMI classification for children and adolescent is the Z-score or standard deviation classification. In this study, the z-scores decreased significantly after the intervention ($p \leq 0.05$) with a greater reduction observed in RE group. According to the world health organization (WHO) classification, participants in RE and IE groups were classified obese prior to the intervention program. However, after the 8-week training intervention, participants in both groups were less than 2SD above the reference population and hence classified overweight.[33] This change, although small, may have significant implications in reducing risk factors associated with excess weight in adolescent males.

The aerobic capacity of participants in this study was improved by 5.3% in RE group and by 3.3% in IE group. This improvement in aerobic capacity following the intervention remained clinically minor for both groups, with no significant difference between groups. Previous intervention studies have recorded greater improvements in aerobic capacity.[30,34] However, the current study was limited in duration and evidence suggests a non-linear change over time in aerobic capacity.[30] Training volume, intensity, and initial level of fitness are factors that affect the magnitude of adaptation to aerobic exercise.[35] The data of this study showed that in addition to these factors, the regularity of exercise may also affect the magnitude of changes. Improvements in aerobic capacity in the current study could additionally be confounded by weight loss and improvement in running economy − factors which both influence performance in the 2.4 km test.[35]

An important finding of the current study was a significant reduction in circulatory blood lipids in response to training intervention. Similar to other variables measured in this study, the changes in blood lipids were greater in RE group compared to IE groups. The exact mechanisms for greater adaptations in RE group compared to IE group remain unknown. However, acute inflammatory markers may be responsible for these differences. Researchers showed that the level of inflammatory markers remained elevated even two days after an acute bout of game-based activity.[36] It has been suggested that affecting specific inflammatory signalling pathways may interfere with the signalling pathway for glucose uptake.[37] Furthermore, regular exercise could have a positive effect on homeostasis of cells, by reducing the basal levels of oxidative damage and increasing resistance to oxidative stress.[38] In fact, regular exercise causes adaptations in the antioxidant capacity, protecting cells against the harmful effects of oxidative stress, thus preventing cellular damage.[39,40] It is plausible that regular training, which offers a better balance between training and recovery, results in greater adaptations compared to irregular training by diminishing the negative effects of oxidative stress and inflammatory responses.

The effects of exercise on cholesterol appear dependent upon the type, duration and intensity of exercise.[41] Aerobic exercises are more common due to availability, ease of use and minimal equipment needed. Within aerobic training, however, low- to moderate intensity training improves LDL levels, while high-intensity training also improves HDL levels.[41] This is in line with the results from the current study, where only moderate-intensity training was undertaken, and only LDL significantly improved. Like glucose metabolism, however, there is no evidence why regular exercise may be superior to irregular exercise.

The aforementioned differences in change for key biomarkers may reflect the use of the Borg-scale as a measure of intensity for regular and irregular exercise. It is noteworthy that exercise sessions, in the current study, were conducted after school hours. Previous research in school children showed that mental fatigue builds linearly through the school day.[42] Mental fatigue is known to influence physical performance and has been noted to particularly raise perceived exertion.[43] Therefore, though participants were encouraged to maintain an RPE of 13−14 (assumed to be equivalent to a heart rate of 130−140bpm), the objective load may be up to 16% lower.[44] In the case of the irregular exercise group, consecutive days of exercise and resultant progressive fatigue may have altered their perception of effort further, resulting in a greater objective difference in training load.[45]

The current study was limited by a lack of dietary information and non-exercise physical activity which may underscore key differences noted between the groups. Future studies should control for these variables and compare the effect of regular exercise with irregular exercise in a more robust design. Furthermore, is it not clear how sex could affect adaptations to regular and irregular exercise, and future research should also consider including female participants.

### Conclusion

This is the first study to address the potential issue of the irregularity of exercise in response to adopting a flexible training schedule to overcome the time barrier for physical activity. Both regular and irregular training groups displayed significant improvements in anthropometric characteristics, aerobic capacity and some blood lipids. Regular training, however, appeared to result in greater adaptations compared to irregular training. Regular training also showed significantly greater improvements in cholesterol, LDL, and HDL/LDL compared to irregular training. Thus, the current study suggests performing regular training when possible. However, irregular training could also offer lesser benefits and should still be considered by time-poor individuals or those unable to perform training regularly.

## References

1. World Health Organization. Obesity and overweight. WHO Web site. http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed November 14, 2020.
2. World Health Organization. Childhood overweight and obesity. WHO Web site. http://www.who.int/dietphysicalactivity/childhood/en/. Accessed November 17, 2020.
3. World Health Organization. Tenfold increase in childhood and adolescent obesity in four decades: new study by Imperial College London and WHO. WHO Web site. http://www.who.int/news-room/detail/11-10-2017-tenfold-increase-in-childhood-and-adolescent-obesity-in-four-decades-new-study-by-imperial-college-london-and-who. Accessed November 17, 2020.
4. Serdula MK, Ivery D, Coates RJ, et al. Do obese children become obese adults? A review of the literature. *Prev Med*. 1993;22:167–177.
5. Bocarro J, Kanters MA, Casper J, et al. School physical education, extracurricular sports, and lifelong active living. *J Teach Phys Educ*. 2008;27:155–166.
6. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents. *Annu Rev Publ Health*. 2001;22:337–353.
7. Meyer AA, Kundt G, Lenschow U, et al. Improvement of early vascular changes and cardiovascular risk factors in obese children after a six-month exercise program. *J Am Coll Cardiol*. 2006;48:1865–1870.
8. dos Santos Alves VL, Stirbulov R, Avanzi O. Impact of a physical rehabilitation program on the respiratory function of adolescents with idiopathic scoliosis. *Chest*. 2006;130:500–505.
9. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phy*. 2010;7. Available from: https://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-7-40. Accessed November 18, 2020.
10. Atlantis E, Barnes E, Singh MF. Efficacy of exercise for treating overweight in children and adolescents: a systematic review. *Int J Obes*. 2006;30:1027–1040.
11. The Department of Health. Australia's physical activity and sedentary behaviour guidelines and the Australian 24-hour movement guidelines. Web site. https://www1.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-strateg-phys-act-guidelines#npa517. Accessed October 19, 2020.
12. Fishman E, Böcker L, Helbich M. Adult active transport in The Netherlands: an analysis of its contribution to physical activity requirements. *PloS One*. 2015;10. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0121871. Accessed November 18, 2020.
13. Arzu D, Tuzun EH, Eker L. Perceived barriers to physical activity in university students. *J Sports Sci Med*. 2006;5:615–620.
14. Dwyer JJ, Allison KR, Goldenberg ER, et al. Adolescent girls' perceived barriers to participation in physical activity. *Adolescence*. 2006;41:75–90.
15. Sleap M, Wormald H. Perceptions of physical activity among young women aged 16 and 17 years. *Eur J Phys Educ*. 2001;6:26–37.
16. Robbins LB, Pender NJ, Kazanis AS. Barriers to physical activity perceived by adolescent girls. *J Midwifery Wom Health*. 2003;48:206–212.
17. Saxena R, Borzekowski DL, Rickert VI. Physical activity levels among urban adolescent females. *J Pediatr Adolesc Gynecol*. 2002;15:279–284.
18. Hansen M, Bangsbo J, Jensen J, et al. Protein intake during training sessions has no effect on performance and recovery during a strenuous training camp for elite cyclists. *J Int Soc Sport Nutr*. 2016;13:1–11.
19. Vaile J, O'Hagan C, Stefanovic B, et al. Effect of cold water immersion on repeated cycling performance and limb blood flow. *Br J Sports Med*. 2011;45:825–829.
20. Stanley J, Peake JM, Buchheit M. Consecutive days of cold water immersion: effects on cycling performance and heart rate variability. *Eur J Appl Physiol*. 2013;113:371–384.
21. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and performance in sport: consensus statement. *Int J Sports Physiol Perform*. 2018;13:240–245.
22. WHO Expert Committee. *Physical Status: The Use and Interpretation of Anthropometry*. Geneva, Switzerland: World Health Organization; 1995.
23. Stewart A, Marfell-Jones M, Olds T, et al. *International Standards for Anthropometric Assessment*. New Zealand: Lower Hutt; 2011.
24. Larsen GE, George JD, Alexander JL, et al. Prediction of maximum oxygen consumption from walking, jogging, or running. *Res Q Exerc Sport*. 2002;73:66–72.
25. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377–381.
26. Cohen J, Cohen P, West SG, et al. *Applied Multiple Regression/correlation Analysis for the Behavioral Sciences*. Mahwah, New Jersey: Lowrence Erlbaum Associates, Inc; 2013.
29. Faul F, Erdfelder E, Lang AG, et al. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39:175–191.
30. García-Hermoso A, Ramírez-Vélez R, Ramírez-Campillo R, et al. Concurrent aerobic plus resistance exercise versus aerobic exercise alone to improve health outcomes in paediatric obesity: a systematic review and meta-analysis. *Br J Sports Med*. 2018;52:161–166.
31. Martins J, Marques A, Sarmento H, et al. Adolescents' perspectives on the barriers and facilitators of physical activity: a systematic review of qualitative studies. *Health Educ Res*. 2015;30:742–755.
32. Swift DL, Johannsen NM, Lavie CJ, et al. The role of exercise and physical activity in weight loss and maintenance. *Prog Cardiovasc Dis*. 2014;56:441–447.
33. World Healh Organisation. Growth reference 5-19 years. Web site. https://www.who.int/toolkits/growth-reference-data-for-5to19-years/indicators/height-for-age. Accessed November 19, 2020.
34. Kelley GA, Kelley KS, Pate RR. Exercise and BMI z-score in overweight and obese children and adolescents: a systematic review and network meta-analysis of randomized trials. *Evid Base Med*. 2017;10:108–128.
35. Mayorga-Vega D, Bocanegra-Parrilla R, Ornelas M, et al. Criterion-related validity of the distance-and time-based walk/run field tests for estimating cardiorespiratory fitness: a systematic review and meta-analysis. *PloS One*. 2016;11.
36. Dring KJ, Cooper SB, Morris JG, et al. Cytokine, glycemic, and insulinemic responses to an acute bout of games-based activity in adolescents. *Scand J Med Sci Sports*. 2019;29:597–605.
37. Röhling M, Herder C, Stemper T, et al. Influence of acute and chronic exercise on glucose uptake. *J Diabetes Res*. 2016;2016. https://doi.org/10.1155/2016/2868652.
38. Cooper C, Vollaard NB, Choueiri T, et al. Exercise, free radicals and oxidative stress. *Biochem Soc Trans*. 2002;30:280–285.
39. Urso ML, Clarkson PM. Oxidative stress, exercise, and antioxidant supplementation. *Toxicology*. 2003;189:41–54.
40. Sen CK. Oxidants and antioxidants in exercise. *J Appl Physiol*. 1995;79:675–686.
41. Mann S, Beedie C, Jimenez A. Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. *Sports Med*. 2014;44:211–221.
42. Sievertsen HH, Gino F, Piovesan M. Cognitive fatigue influences students' performance on standardized tests. *Proc Natl Acad Sci U S A*. 2016;113:2621–2624.
43. Van Cutsem J, Marcora S, De Pauw K, et al. The effects of mental fatigue on physical performance: a systematic review. *Sports Med*. 2017;47:1569–1588.
44. Brownsberger J, Edwards A, Crowther R, et al. Impact of mental fatigue on self-paced exercise. *Int J Sports Med*. 2013;34:1029–1036.
45. Fusco A, Sustercich W, Edgerton K, et al. Effect of progressive fatigue on session RPE. *J Funct Morphol Kinesiol*. 2020;5:15.