**Advances in Applied Physiology**
2020; 5(2): 30-36
http://www.sciencepublishinggroup.com/j/aap
doi: 10.11648/j.aap.20200502.14
ISSN: 2471-9692 (Print); ISSN: 2471-9714 (Online)

# Effects of High Intensity Interval Training on Physiological Variables of University Students

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**To cite this article:**
Assegid Ketema. Effects of High Intensity Interval Training on Physiological Variables of University Students. *Advances in Applied Physiology*. Vol. 5, No. 2, 2020, pp. 30-36. doi: 10.11648/j.aap.20200502.14

**Received**: September 18, 2020; **Accepted**: October 5, 2020; **Published**: October 13, 2020

**Abstract:** The purpose of this study was to evaluate the effects of high-intensity interval training (HIIT) on university students' physiological variables. 40 male sports science students with an age range between 18-25 years were randomly assigned to the HIIT group (n=20) and control (C) group (n=20). The experiment group underwent eight weeks of HIIT, whereas, C group do not. Pre and posttest measurements of physiological variables like resting heart rate (RHR), respiratory rate (RR), recovery heart rate (RcHR), breath holding time (BHT), $VO_2$ max and blood pressure BP) were made for all subjects before and after the intervention. To compare the mean physiological variables between the experiment and control groups, an independent sample t-test was employed. The statistical significance was set at $p<0.05$. Following the exercise intervention, the experiment group shows significantly better improvements than the control group in, RHR, RR, BHT, $VO_2$ max, and systolic blood pressure ($p<0.05$). Thus, it was concluded that eight weeks of HIIT show a significant improvement in the physiological variables of university students.

**Keywords:** High-Intensity Interval Training, Resting Heart Rate, Recovery Rate (RR), Breathe Hold, Maximal Oxygen Uptake, Blood Pressure

## 1. Introduction

High-intensity interval training (HIIT) is a well-known, time-efficient training method for improving cardiorespiratory and metabolic function and, in turn, physical performance in athletes [1-2]. High-intensity training relative to the individual's maximal oxygen uptake is feasible even in elderly patients with chronic heart failure and severely impaired cardiovascular function [3]. Interval Training Periods of intense activity interspersed with moderate to low energy expenditure characterize many sports and life activities [4]. High-intensity interval training (HIT) is defined as either repeated short (<45 s) to long (2–4 min) bouts of rather high- but not maximal-intensity exercise, or short (<10 s, repeated-sprint sequences [RSS]) or long (>20–30 s, sprint interval session [SIT]) all-out sprints, interspersed with recovery periods [1, 5, 6].

A person trains at an inordinately high exercise intensity with minimal fatigue that would normally prove exhausting if done continuously. Rest-to-exercise intervals vary from a few seconds to several minutes depending on the energy system (s) overloaded [4]. Despite the fact that exercise at a high relative intensity seems to induce larger beneficial adaptation in the cardiovascular system, we do not know whether this type of training is safe in larger patient cohorts and whether it affects complication rates in patients more favorably than exercise at low-to-moderate intensity [7]. Exercise intensity may have an important role in preventing and controlling hypertension, as shown by the greater benefits of high-intensity interval training than Continuous moderate-intensity exercise training for reversing key alterations present in the physiopathology of this disease in both hypertensive patients and normotensive subjects at high familial for hypertension [8]. Taken as a whole, in overweight/obese populations, performing high-intensity interval training results in significant, positive, physiological adaptations that improve cardio-metabolic health and may reduce the development and progression of disease-related risk factors that are associated with overweight/obesity and low aerobic fitness. Short-term high-intensity interval training beneficially influenced waist circumference, $VO_2$ max, fasting glucose, and diastolic blood pressure, whereas Long-term high-intensity interval training, was found to beneficially influence waist circumference, percent of body fat, $VO_2$ max, resting heart rate, systolic blood pressure, and diastolic blood pressure in overweight/obese populations [6, 9-13].

Long-term high-intensity interval training to significantly decrease resting heart rate in overweight/obese populations, but not in normal-weight populations subjected to Long-term high-intensity interval training and in normal weight/overweight/obese populations subjected to Short-term high-intensity interval training [9]. The respiratory rate, i.e., the number of breaths per minute is highly regulated to enable cells to produce the optimum amount of energy at any given occasion. A complex the nervous system of nerve tissues regulates the rate of oxygen inflow and carbon dioxide outflow and adjusts it accordingly in conditions that tend to derange partial gas pressures in blood [14]. Respiratory rate is an early, an extremely good indicator of physiological conditions such as hypoxia (low levels of oxygen in the cells), hypercapnia (high levels of carbon dioxide in the bloodstream), metabolic and respiratory acidosis [15]. Heart rate recovery (HRR) is commonly defined as the decrease of heart rate at 1 minute after cessation of exercise and is an important predictor of all-cause mortality and death associated with coronary artery disease. The decreased Heart rate recovery at 10 seconds after the cessation of exercise is a superior predictor of outcome compared with HRR at later time intervals [16]. Surface breath holds were associated with a decreased $O_2$ uptake from the lung to the blood, and breath-hold dives were associated with a large transient increase of $O_2$ uptake at a depth which resulted in a restoration of the time-averaged $O_2$ uptake to the panic control level: these changes reflected changes in tissue $O_2$ stores [17]. The current absolute world record for depth in breath-hold diving is 150 m. Its further improvement depends upon how far the equilibrium between starting oxygen stores, the overall rate of energy expenditure, the fraction of energy provided by anaerobic metabolism and the driving speed can be pushed, with consciousness upon emersion [18]. High-intensity interval training may constitute an effective training protocol for improving $VO_2$ max and several cardio metabolic risk factors such as waist circumference, % body fat, resting heart rate, systolic blood pressure, and diastolic blood pressure and fasting glucose in overweight/obese populations. Notably, Short-term high-intensity interval training and Long-term high-intensity interval training improves $VO_2$ max in normal weight and overweight/obese populations with larger gains observed for longer training periods. This has implications for the use of high-intensity interval training as part of lifestyle modification strategies and is consistent with training responses to stimuli. Short-term high-intensity interval training showed no significant effect on systolic blood pressure and diastolic blood pressure in normal-weight populations. It is possible that longer high-intensity interval training intervention periods are required to produce a significant effect on systolic blood pressure in this population [9].

The objectives of physical training are to increase the athlete's physiological potential and to develop bio motor abilities to the highest standards [19]. University students represent the future of families, communities, and countries. They face the stresses during the attempts of achieving success in their academic goals and are likely to become future leaders in their society whether in the economy, education, or politics. It has been argued that health is an important factor in academic achievement at school and in higher education. In this context, implementing a student health survey program during their academic development is important which assists schools and universities in creating a healthier educational environment. As indicated in the background and above section, youth or adolescents can be benefited by performing exercise or training in developing they are various physiological. Youth or adolescent training in a dynamic world and sports activities that needs understanding and solving problems of training to create and make them well fit for performance improvement to compete in a frequently changing environment and to maintain their wellbeing [8].

According to the results above on high-intensity interval training has a positive effect on physiological variables. The outcome of this study may be important for physical education teachers, fitness trainers and coaches should incorporate a variety of high-intensity interval training methods for the physiological variables for enhancing the physical fitness level of their trainees.

## 2. Methodology

### *2.1. Research Design*

In this study, a true experimental design was employed. According to Guetterman et al., and Bryman, such design helps to generalize and predict from a sample population so that inferences can be made about the result of the study of the population to formulate a research instrument and they discussed how it's administered [20-21]. Hence, the present study was undertaken to study the effect of high-intensity interval training on selected physiological variables at Dilla University male sport science students.

### *2.2. Sample and Sampling Technique*

In the study area, 103 male sports science students are currently found. Among them, 40 sample students were selected by using a simple random sampling technique.

To achieve the purpose of the study the untrained male sport science students from those who were not in any of the game and sports team or any training program and also free from deformities and ailments were selected. They were assigned randomly into two groups, namely, the high-intensity interval training group (HIIT) (n=20) and control group (CONG) (n=20). Group, I was trained with HIIT and for the control group were not given any treatment.

### *2.3. Administration of the Test*

The requirement of the project was explained to all the subjects and all of them agreed voluntarily to undergo the testing and training program. A thorough orientation of the rigid requirements of the experimental procedure testing as well as the exercise protocol was well explained to all the participants to calm uneasiness and written informed consent was obtained from them. So, there was no ambiguity of what effort was required on their part and what hardships they had to endure.

Blood pressure was recorded while students in a comfortable sitting position with the right arm fully exposed and resting on a supportive surface at the heart level; a mercury sphygmomanometer was used with an appropriately sized cuff. At the same time, three resting heart rate measurements (radial pulse) were taken after 5, 10, and 15 minutes of being in a sitting position, and the mean was calculated. Resting heart rate was recorded by a physician over a 1-min period [22].

Wash hands with soap and water to Gain the students in a comfortable position. Maintain a constant temperature remove bulky clothing and observing depth, symmetry, and pattern of breathing. If the students are sitting, their feet must be flat on the floor. Allow the students to rest, if possible, for 20 minutes before taking the measurement. When measuring respiratory rate the students were blinded to the specific aims of the study and the simulated students not specifically advised when the respiratory rate was being measured. Using a stopwatch with a second hand, count breaths (number of times the chest moves up and down) for a full minute. This length of time is needed as changes can occur in the respiratory pattern and rate. Record the respiratory rate on the recording paper [23–24].

To collect breath-hold data primarily fill the plastic bag. With a nose clip in place, have the students take a large breath of room air and then exhale into a previously empty plastic bag, closing the bag so that it stays full. Once the bag is full of expired air, have the students resume normal breathing in and out of the closed bag. Have the time recorder start the stopwatch when the participant begins to rebreathe. The participant should continue to rebreathe until their depth of breathing causes the bag to collapse or until the students reach their limit of tolerance. The observer should terminate the test if the participant exhibits any signs or symptoms of discomfort or dizziness. In our experience, rebreathing should be limited to no longer than 2 min. The duration of rebreathing should be recorded in the data collection sheet, along with any observations of changes in rate and depth of breathing [25].

The students took a light breakfast 2-3 hours before the test and refrained from any energetic physical activity for that period. The students had no history of any major disease and undertook no physical conditioning program except for some recreational sports. The maximum oxygen uptake of each subject was determined by indirect methods, Subjects were asked to take rest at least half an hour prior to the exercise. Subjects ran on a 400-meter round track for a total duration of 12 min. They were highly motivated to run as many laps as possible. The total number of laps was counted and the finishing point was marked. The total distance (in meters) covered in 12 min was calculated by multiplying the number of complete laps with 400 plus the distance covered (in meters) in the final incomplete lap. The distance in meters was converted into km and the following equation was used to predict the $VO_2$ max.

$$VO_2 \text{ max } (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = (22.351 \times \text{distance covered in kilometers}) - 11.288$$ [26–27]

### *2.4. Statistical Techniques*

The data collected on the selected physiological variables in pre and post-test were analyzed, interpreted and tabulated into a meaningful way by using computerized software analyses were performed using IBM-SPSS version 20 (IBM, Armonk, NY, United The states of America) and analysis of independent T-test was used. Mean difference, standard error, Tests, degree of freedom, significant, confidence interval were used in order to compare components of the variable levels among the experimental and control groups. For the study, the significance level for all data was $p<0.05$.

## 3. Results

The demographic characteristics of the participants were explained in table 1. The mean age, body mass, height, body mass index of the experimental groups were 21.15 years, 62.93 k.g., 1.69 meters, and 22.34 respectively, whereas the control groups were with 20.95 years, 62.45 k.g., 1.69 meters, and 21.81 respectively. Thus, the groups were well matched at the entry-level. Different research output indicates that body mass index is a useful tool to screen the general population to determine health risk and recommended body mass. The acceptable body mass index for general population range is 18.5 to 24.99kg/m$^2$ [28].

***Table 1.*** *Participants demographic characteristics.*

| Variables | N | Minimum | | Maximum | | Mean | | Std. Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| | | Exper. | Contr. | Exper. | Contr. | Exper. | Contr. | Exper. | Contr. |
| Age | 20 | 19 | 19 | 25 | 24 | 21.15 | 20.95 | 1.872 | 1.669 |
| Body mass | 20 | 61.00 | 61.60 | 68.00 | 64.00 | 62.9300 | 62.4500 | 1.87311 | .77832 |
| Height | 20 | 1.60 | 1.59 | 1.76 | 1.78 | 1.6800 | 1.6940 | .04542 | .04773 |
| Body mass index | 20 | 20.62 | 20.01 | 26.23 | 24.41 | 22.3375 | 21.8060 | 1.30126 | 1.15423 |

# 4. Between Group Comparisons After the Intervention

Results of between group comparisons were explained in table 2. The result of the study showed that there was a significant difference in resting heart rate, respiratory rate, recovery heart rate, breath-hold, vo2-max, and systolic between HIIT and Control group.

Significant difference was observed in the mean resting heart rate with MD=-13.80, P-value <0.001, 95% CI -18.52 to -9.07 which indicate that the HIIT group had a lower resting heart rate than the control group. Similarly, significant differences were observed in the mean of respiratory rate with MD=-5.55, P-value <0.001, 5% CI -7.05 to -4.05, recovery heart rate with MD=-21.0, P-value <0.001, 95% CI -27.34 to -14.85, and systolic with MD=-6.0, P-value <0.001, 95% CI -11.68 to -0.32 which also indicate that the HIIT group had a lower respiratory rate, recovery heart rate, and systolic than the control group. Besides, the study showed that HIIT could significantly improve $VO_2$-max (MD=15.57, P-value <0.001, 95% CI: 9.68 to 21.47) and breath (MD=18.87, P-value <0.004, 95% CI: 6.34 to 31.40) than the control group.

***Table 2.*** *Changes in outcome between the intervention group doing high-intensity interval training and the control group within 8 weeks of follow-up.*

| Variables | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mean Difference | Std. Error Difference | T | Df | Sig. (2-tailed) | 95% Confidence Interval of the Difference | |
| | | | | | | Lower | Upper |
| Resting heart rate | -13.80 | 2.33 | -5.91 | 38 | .001 | -18.52 | -9.07 |
| Respiratory rate | -5.55 | 0.74 | -7.49 | 38 | .001 | -7.05 | -4.05 |
| Recovery heart rate | -21.10 | 3.08 | -6.84 | 38 | .001 | -27.34 | -14.85 |
| Breath hold | 18.87 | 6.19 | 3.04 | 38 | .004 | 6.34 | 31.40 |
| Vo2-max | 15.57 | 2.91 | 5.35 | 38 | .001 | 9.68 | 21.47 |
| Systolic | -6.00 | 2.80 | -2.14 | 38 | .039 | -11.68 | -0.32 |

t-Test, df- degree of freedom, sig- significant, MD- mean difference, se- standard error, CI- confidence interval.

# 5. Discussions

The purpose of this study was to evaluate the effects of high-intensity interval training (HIIT) on university students' physiological variables. The result of the study showed that there was a significant difference in resting heart rate, respiratory rate, recovery heart rate, breath, vo2-max, and systolic between HIIT and Control group.

Previous studies on RHR reported that HIIT changes, resting heart rate [23–24]. This change may occur due to the effect of the training improved cardiovascular and performance capacity related to an increased stroke volume and cardiac output. The mechanisms also enhanced diastolic filling parameters at the highest heart rates associated with maximal exercise. There is also a component of peripheral blood flow adjustment to training that contributes to the enhanced exercise capacity post-training. A modest increase in the ability to extract oxygen as assessed by arteriovenous oxygen difference. These findings are similar to the current study. This is likely due to changes in the ability to preferentially re-route blood flow to active muscle tissues, a greater capillarization of active skeletal muscle beds, and the enhanced oxygen extraction capability of the trained muscle cells with greater numbers of mitochondria and oxidative enzymes. Therefore, increasing the efficiency of heart rate muscles, ventricular cavity size, and stroke volume, or neural adaptation to decrease sympathetic tone to the sinoatrial node and increase parasympathetic tone which plays a role in reducing the resting heart rate [24]. Similarly, this study reported a significant difference in respiratory rate between HIIT groups and the control groups following the eight-week intervention. This finding is in agreement with High-intensity interval training that may constitute an effective training protocol for improving $VO_2$ max and cardiovascular endurance [9].

The study pieces of evidence indicate that high-intensity interval training has positive improvement in respiratory rate [29–31]. This may be due to the effect of the training on improving in ventilation pre- and post-training, at rest and during low-intensity exercise and changes in tidal volume, respiratory rate, and ventilatory volume of maximal aerobic exercise. Maximal respiratory rate and maximal tidal volume increase post-training for a profound effect upon maximal ventilatory volume [32–34].

Based on different study findings, the effect of high-intensity interval training on recovery heart rate shows better efficiency on students' physiology [35–36]. Thus heart rate recovery contributed positively to the results for two reasons. First, the short recovery period would have meant the anaerobic energy production systems would have had inadequate time to fully restore. As a result of each subsequent repetition, the aerobic system would have been called on to make a greater contribution to energy production. If sufficient repetitions of this form of training are performed, energy production from aerobic metabolism will be challenged regularly enough for a training effect to take place. Second, it has been found that a passive recovery is a more effective strategy to adopt when performing supra-maximal HIIT.

In both, participants were able to maintain the training intensity and perform greater workloads per effort with a passive rather than active recovery strategy. Due to the high energy demands of supra-maximal interval training, oxygen demands for each subsequent interval is too high for any oxygen to be used in the shorter recovery period. It can be postulated that the recovery strategy used in the current study contributed to the improvement in aerobic power, as more oxygen was theoretically available for the subjects to maintain the required intensity. The shorter recovery time would have progressively required a significant contribution from the aerobic system to meet energy demand [37–38].

After the breath-holding test the research data revealed that high breathe holding capacity and significant improvement was observed in the HIIT group when compared with the control group. This may be due to the improvement in the efficiency of respiratory muscles which increase the tidal volume and increase the number, size, and metabolic capacity of mitochondria to increase consumption of oxygen by the cells respectively [32, 39].

The data indicated that high increment and better improvement in $VO_2$ max were seen in the HIIT group when compared with the control group. This may be due to the intensity exercises enhances the activity of the cardiovascular system as well as the developed oxidative capacity of the skeletal muscles which leads to an increase in the delivery of oxygen to the working muscles. The above result was also confined to the study of [40–42]. This may be due to the effect of the training on the vascularity of blood vessels or decreasing stiffness of arteries. The decreased resting blood pressure makes it easier for the left ventricle to pump blood because it must develop less force to eject blood into the peripheral circulation. A reduction in both systolic and diastolic blood pressure (BP) may be due to the reduced sympathetic nervous activity as well as an increased nitric oxide-mediated vasodilation from exercise. It has been postulated that the mechanism involved in lowering blood pressure from undertaking aerobic exercise specifically, maybe be due to the hormones norepinephrine and epinephrine, as regular exercise has been shown to reduce the level of norepinephrine, limiting vasoconstriction of the arteriole enabling a reduce blood pressure. Furthermore, this reduction in the sympathetic neural activity that may help to reduce the blood pressure from undertaking aerobic exercise [35, 43–48].

Evidence supports the idea that physiological performance can be improved if individuals are incorporating HIIT in their training schedule [7, 9]. The present study recommended that physical education teachers, fitness trainers, and coaches should incorporate a variety of high-intensity interval training methods to enhance the performance of their trainees. The present study recommended that physical education teachers, fitness trainers, and coaches should incorporate a variety of high and low-intensity interval training methods to enhance the performance of their trainees. Similar research can be carried out by increasing the duration and intensity of the training program, by involving female students, by including other variables for better performance enhancement in selected physiological variables.

# 6. Conclusions

Based on the analysis of data, interpretation of results, and discussion of major findings as well as possible limitations of the study the following point is mentioned as conclusions.

The present study has revealed that eight-week high-intensity interval training had shown a positive effect on physiological variables namely; resting heart rate, respiratory rate, breathe hold, $vo_2$ max, and systolic blood pressure compared to the control group.

# References

[1] M. Buchheit and P. B. Laursen, "High-Intensity Interval Training, Solutions to the Programming Puzzle," *Sport. Med.*, vol. 43, no. 5, pp. 313–338, May 2013, doi: 10.1007/s40279-013-0029-x.

[2] M. W. Driller, J. W. Fell, J. R. Gregory, C. M. Shing, and A. D. Williams, "The Effects of High-Intensity Interval Training in Well-Trained Rowers," *Int. J. Sports Physiol. Perform.*, vol. 4, no. 1, pp. 110–121, Mar. 2009, doi: 10.1123/ijspp.4.1.110.

[3] U. Wisløff *et al.*, "Superior Cardiovascular Effect of Aerobic Interval Training Versus Moderate Continuous Training in Heart Failure Patients," *Circulation*, vol. 115, no. 24, pp. 3086–3094, Jun. 2007, doi: 10.1161/CIRCULATIONAHA.106.675041.

[4] S. Ito, "High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol," *World J. Cardiol.*, vol. 11, no. 7, pp. 171–188, Jul. 2019, doi: 10.4330/wjc.v11.i7.171.

[5] G. A. Gaesser and S. S. Angadi, "High-intensity interval training for health and fitness: can less be more?," *J. Appl. Physiol.*, vol. 111, no. 6, pp. 1540–1541, Dec. 2011, doi: 10.1152/japplphysiol.01237.2011.

[6] K. A. Burgomaster, G. J. F. Heigenhauser, and M. J. Gibala, "Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance," *J. Appl. Physiol.*, vol. 100, no. 6, pp. 2041–2047, Jun. 2006, doi: 10.1152/japplphysiol.01220.2005.

[7] U. Wisløff, Ø. Ellingsen, and O. J. Kemi, "High-Intensity Interval Training to Maximize Cardiac Benefits of Exercise Training?," *Exerc. Sport Sci. Rev.*, vol. 37, no. 3, pp. 139–146, Jul. 2009, doi: 10.1097/JES.0b013e3181aa65fc.

[8] A. H. El Gilany, K. Badawi, G. El Khawaga, and N. Awadalla, "Physical activity profile of students in Mansoura University, Egypt," *East. Mediterr. Heal. J.*, vol. 17, no. 08, pp. 694–702, Aug. 2011, doi: 10.26719/2011.17.8.694.

[9] R. B. Batacan, M. J. Duncan, V. J. Dalbo, P. S. Tucker, and A. S. Fenning, "Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies," *Br. J. Sports Med.*, vol. 51, no. 6, pp. 494–503, Mar. 2017, doi: 10.1136/bjsports-2015-095841.

[10] J. E. DONNELLY, S. N. BLAIR, J. M. JAKICIC, M. M. MANORE, J. W. RANKIN, and B. K. SMITH, "Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults," *Med. Sci. Sport. Exerc.*, vol. 41, no. 2, pp. 459–471, Feb. 2009, doi: 10.1249/MSS.0b013e3181949333.

[11] M. L. Pollock *et al.*, "ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults," *Med. Sci. Sport. Exerc.*, vol. 30, no. 6, pp. 975–991, Jun. 1998, doi: 10.1097/00005768-199806000-00032.

[12] P. B. Laursen and D. G. Jenkins, "The Scientific Basis for High-Intensity Interval Training," *Sport. Med.*, vol. 32, no. 1, pp. 53–73, 2002, doi: 10.2165/00007256-200232010-00003.

[13] W. Kent, "The effects of sprint interval training on aerobic fitness in untrained individuals: a systematic review," *Br. J. Sports Med.*, vol. 45, no. 15, pp. A8–A8, Dec. 2011, doi: 10.1136/bjsports-2011-090606.26.

[14] C.. Chourpiliadis and A. Bhardwaj, *Physiology, Respiratory Rate*. Island: StatPearls, 2019.

[15] S. Rolfe, "The importance of respiratory rate monitoring," *Br. J. Nurs.*, vol. 28, no. 8, pp. 504–508, Apr. 2019, doi: 10.12968/bjon.2019.28.8.504.

[16] Y. J. van de Vegte, P. van der Harst, and N. Verweij, "Heart Rate Recovery 10 Seconds After Cessation of Exercise Predicts Death," *J. Am. Heart Assoc.*, vol. 7, no. 8, Apr. 2018, doi: 10.1161/JAHA.117.008341.

[17] M. H. Liner and D. Linnarsson, "Tissue oxygen and carbon dioxide stores and breath-hold diving in humans," *J. Appl. Physiol.*, vol. 77, no. 2, pp. 542–547, Aug. 1994, doi: 10.1152/jappl.1994.77.2.542.

[18] G. Ferretti, "Extreme human breath-hold diving," *Eur. J. Appl. Physiol.*, vol. 84, no. 4, pp. 254–271, Apr. 2001, doi: 10.1007/s004210000377.

[19] J. Fernandez-Fernandez, R. Zimek, T. Wiewelhove, and A. Ferrauti, "High-Intensity Interval Training vs. Repeated-Sprint Training in Tennis," *J. Strength Cond. Res.*, vol. 26, no. 1, pp. 53–62, Jan. 2012, doi: 10.1519/JSC.0b013e318220b4ff.

[20] T. C. Guetterman, M. D. Fetters, and J. W. Creswell, "Integrating Quantitative and Qualitative Results in Health Science Mixed Methods Research Through Joint Displays," *Ann. Fam. Med.*, vol. 13, no. 6, pp. 554–561, Nov. 2015, doi: 10.1370/afm.1865.

[21] A. Bryman, *Social research method,* 5th ed. new york, NY 100016: Oxford University press, 2008.

[22] F Rabbia *et al.*, "Assessing resting heart rate in adolescents: determinants and correlates," vol. 16, no. 1, pp. 327–332, 2002, doi: https://doi.org/10.1038/sj.jhh.1001398.

[23] S. Galka, J. Berrell, R. Fezai, L. Shabella, P. Simpson, and L. Thyer, "Accuracy of student paramedics when measuring adult respiratory rate: a pilot study," *Australas. J. Paramed.*, vol. 16, Apr. 2019, doi: 10.33151/ajp.16.566.

[24] Wheatley I, "Respiratory rate 3," *Nurs. Times,* vol. 114, no. 7, pp. 21–22, 2018.

[25] R. J. Skow, T. A. Day, J. E. Fuller, C. D. Bruce, and C. D. Steinback, "The ins and outs of breath holding: simple demonstrations of complex respiratory physiology," *Adv. Physiol. Educ.*, vol. 39, no. 3, pp. 223–231, Sep. 2015, doi: 10.1152/advan.00030.2015.

[26] K. H. Cooper, "A Means of Assessing Maximal Oxygen Intake," *JAMA*, vol. 203, no. 3, p. 201, Jan. 1968, doi: 10.1001/jama.1968.03140030033008.

[27] A. Bandyopadhyay, "Validity of Cooper's 12-minute run test for estimation of maximum oxygen uptake in male university students," *Biol. Sport*, vol. 32, no. 1, pp. 59–63, Oct. 2014, doi: 10.5604/20831862.1127283.

[28] S. W. K, Werner; A. Hoeger, *Fitness and Wellness*, 11th ed. Canada: Cengage Learing, 2014.

[29] S. Larsen *et al.*, "The effect of high-intensity training on mitochondrial fat oxidation in skeletal muscle and subcutaneous adipose tissue," *Scand. J. Med. Sci. Sports*, vol. 25, no. 1, pp. e59–e69, Feb. 2015, doi: 10.1111/sms.12252.

[30] V. H. Arboleda-Serna, Y. Feito, F. A. Patiño-Villada, A. V. Vargas-Romero, and E. F. Arango-Vélez, "Effects of high-intensity interval training compared to moderate-intensity continuous training on maximal oxygen consumption and blood pressure in healthy men: A randomized controlled trial," *Biomédica*, vol. 39, no. 3, pp. 524–536, Sep. 2019, doi: 10.7705/biomedica.4451.

[31] C. Dunham and C. A. Harms, "Effects of high-intensity interval training on pulmonary function," *Eur. J. Appl. Physiol.*, vol. 112, no. 8, pp. 3061–3068, Aug. 2012, doi: 10.1007/s00421-011-2285-5.

[32] Karen Birch, Keith George, and Don McLaren, *BIOS Instant Notes in Sport and Exercise Physiology*, 1st ed. London: Routledge, 2004.

[33] D. M. L. Prado *et al.*, "Effects of continuous vs interval exercise training on oxygen uptake efficiency slope in patients with coronary artery disease," *Brazilian J. Med. Biol. Res.*, vol. 49, no. 2, 2016, doi: 10.1590/1414-431X20154890.

[34] M. Chlif, A. Chaouachi, and S. Ahmaidi, "Effect of Aerobic Exercise Training on Ventilatory Efficiency and Respiratory Drive in Obese Subjects," *Respir. Care*, vol. 62, no. 7, pp. 936–946, Jul. 2017, doi: 10.4187/respcare.04923.

[35] A. Alansare, K. Alford, S. Lee, T. Church, and H. Jung, "The Effects of High-Intensity Interval Training vs. Moderate-Intensity Continuous Training on Heart Rate Variability in Physically Inactive Adults," *Int. J. Environ. Res. Public Health*, vol. 15, no. 7, p. 1508, Jul. 2018, doi: 10.3390/ijerph15071508.

[36] A. Al-Fehaid, S. Alkahtani, A. Al-Sunni, and T. Yar, "Role of the work-to-rest ratio in high-intensity interval exercise on heart rate variability and blood pressure in sedentary obese men," *Saudi J. Heal. Sci.*, vol. 7, no. 2, p. 83, 2018, doi: 10.4103/sjhs.sjhs_103_17.

[37] E. Rey, C. Lago-Peñas, L. Casáis, and J. Lago-Ballesteros, "The Effect of Immediate Post-Training Active and Passive Recovery Interventions on Anaerobic Performance and Lower Limb Flexibility in Professional Soccer Players," *J. Hum. Kinet.*, vol. 31, no. 1, Jan. 2012, doi: 10.2478/v10078-012-0013-9.

[38] D. L. Tomlin and H. A. Wenger, "The Relationship Between Aerobic Fitness and Recovery from High Intensity Intermittent Exercise," *Sport. Med.*, vol. 31, no. 1, pp. 1–11, 2001, doi: 10.2165/00007256-200131010-00001.

[39] T. Karlsen, B. M. Nes, A. E. Tjønna, M. Engstrøm, A. Støylen, and S. Steinshamn, "High-intensity interval training improves obstructive sleep apnoea," *BMJ Open Sport Exerc. Med.*, vol. 2, no. 1, p. bmjsem-2016, Feb. 2017, doi: 10.1136/bmjsem-2016-000155.

[40] T. Reilly, "An ergonomics model of the soccer training process," *J. Sports Sci.*, vol. 23, no. 6, pp. 561–572, Jun. 2005, doi: 10.1080/02640410400021245.

[41] I. TABATA *et al.*, "Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and ??VO2max," *Med. &amp Sci. Sport. &amp Exerc.*, vol. 28, no. 10, pp. 1327–1330, Oct. 1996, doi: 10.1097/00005768-199610000-00018.

[42] R. Duffield, J. Edge, and D. Bishop, "Effects of high-intensity interval training on the response during severe exercise," *J. Sci. Med. Sport*, vol. 9, no. 3, pp. 249–255, Jun. 2006, doi: 10.1016/j.jsams.2006.03.014.

[43] Gretchen K. Berland *et al.*, "Health information on the Internet," *Am. Med. Assoc.,* vol. 285, no. 20, pp. 2612–2621, 2001.

[44] S. J. Hardcastle, H. Ray, L. Beale, and M. S. Hagger, "Why sprint interval training is inappropriate for a largely sedentary population," *Front. Psychol.*, vol. 5, Dec. 2014, doi: 10.3389/fpsyg.2014.01505.

[45] J. L. Trilk, A. Singhal, K. A. Bigelman, and K. J. Cureton, "Effect of sprint interval training on circulatory function during exercise in sedentary, overweight/obese women," *Eur. J. Appl. Physiol.*, vol. 111, no. 8, pp. 1591–1597, Aug. 2011, doi: 10.1007/s00421-010-1777-z.

[46] T. Rankinen *et al.*, "AGT M235T and ACE ID polymorphisms and exercise blood pressure in the HERITAGE Family Study," *Am. J. Physiol. Circ. Physiol.*, vol. 279, no. 1, pp. H368–H374, Jul. 2000, doi: 10.1152/ajpheart.2000.279.1.H368.

[47] T. Rice *et al.*, "Genome-Wide Linkage Analysis of Systolic and Diastolic Blood Pressure," *Circulation*, vol. 102, no. 16, pp. 1956–1963, Oct. 2000, doi: 10.1161/01.CIR.102.16.1956.

[48] R. H. FAGARD, "Exercise characteristics and the blood pressure response to dynamic physical training," *Med. Sci. Sports Exerc.*, vol. 33, no. Supplement, pp. S484–S492, Jun. 2001, doi: 10.1097/00005768-200106001-00018.