Does High Intensity Interval Training Improve Aerobic Power Development More Than Endurance Training?

Arjun Jabbal* & Adam Baxter-Jones

Abstract

The purpose of this study was to determine whether high intensity interval training (HIIT) increases maximal aerobic power (VO_2 max) more than endurance training (ET). It is hypothesized that at the end of a four-week training program, the HIIT group will have a higher average improved VO_2 max percentage than the ET group. Recruited participants, 12 males aged 18-35, completed a baseline VO_2 max test followed by an intervention and then a post VO_2 max test. Participants were randomly assigned to either HIIT or ET, 20 minutes a day, three times a week for four weeks. Baseline mean VO_2 max for ET (n = 6) was 48.2 ml/min/kg compared to a mean VO_2 max of 51.7ml/min/kg in the HIIT (n = 6) group. Posttraining test VO_2 max for ET (n = 6) was 48.9ml/min/kg compared to a mean VO_2 max of 52.4ml/min/kg in the HIIT group (n = 4). There was a 3.4% improvement in VO_2 max in the HIIT group (n = 4), while the ET group (n = 6) had a 1.7% improvement in VO_2 max. There were no significant differences in height, weight, age, and VO_2 max between the two groups at baseline or post-test. Moreover, there were no significant differences in height, age, and VO_2 max for either of the groups from the post-test compared to the baseline test. The data suggests a promising trend that HIIT training may be better for improving aerobic power than ET.

Keywords: aerobic power, high intensity interval training, endurance training, aerobic development, cardiovascular fitness, cardiovascular health

The World Health Organization (WHO) predicts that by the year 2030 cardiovascular disease (CVD) will be responsible for approximately 23 million deaths annually around the world (WHO, 2012). Cardiorespiratory fitness has a direct relationship to cardiovascular disease risk (McMurray, Ainsworth, Harrell, Griggs, & Williams, 1998). Aerobic power is considered to be the best indicator of cardiorespiratory fitness, indexed by maximal oxygen uptake (VO_2 max) (Valim et al., 2002). VO_2 max is defined as the maximum volume of oxygen that can be utilized in

*College of Kinesiology, University of Saskatchewan, Saskatoon, SK, Canada
Correspondence: **asj511@mail.usask.ca**

one minute during maximal or exhaustive exercise (Day, Rossiter, Coats, Skasick, & Whipp, 2003). The higher an individual's VO_2 max, the lower the risk of developing cardiovascular disease. Traditionally, endurance training, defined as prolonged training at relatively low intensity, has been used to improve cardiorespiratory function and thus to increase VO_2 max (Gibala, Little, McDonald, & Hawley, 2012). However, high intensity interval training (HIIT) has recently become a popular mainstream exercise for increasing cardiovascular fitness. HIIT can be defined as a type of cardiovascular training in which short bursts of very high intensity intervals are alternated with longer, slower intervals (Laursen & Jenkins, 2012). However, the question remains: is HIIT superior in increasing VO_2 max compared to conventional endurance training? Considerable research has found that VO_2 max is significantly increased after a HIIT program (Astorino, Allen, Roberson, & Juranich, 2012). However, comparisons of VO_2 max improvement with endurance training with a comparable population are limited.

Age plays an important role in VO_2 max development. Compared to adults, children and adolescents have a high VO_2 max. For example at 12 years, boys have a VO_2 max in the region of 60 ml/kg/min which decreases to an average of approximately 35 ml/kg/min by the end of the fourth decade of life, suggesting VO_2 max during these ages is reflecting growth as much as fitness status (Cooper, Weiler-Ravell, Whipp, & Wasserman, 1984). Older adults, on the other hand, tend to have a lower VO_2 max compared to younger adults, which could influence VO_2 max development in training studies (Porter, Vandervoort, &Lexell, 1995). Participants in competitive endurance sports are likely to have high VO_2 max values with little room for improvement (Seiler, 2010) and therefore would not be ideal as there would be little change in VO_2 max values. Powers & Howley (2012) suggest that there are physiological sex differences between men and women with regards to VO_2 max as males typically have higher VO_2 max values than females. Overall, the optimal population sample for a study looking at improvements in aerobic fitness would be young to middle age adults who do not compete in competitive endurance sports.

Cardiovascular fitness has been a subject undergoing intense study in medical fields over the last decade, and the appropriate training required to improve it has gained much attention (McMurray et al., 1998). However, the effectiveness of new training regimes compared to ET is unknown. Therefore, the purpose of this study is to determine whether HIIT or endurance training programs are better for increasing VO_2 max over the same training period in a group of healthy males, not involved in competitive sports, 18 to 35 years of age. It was hypothesized that at the end of a four-week training program, the HIIT group will have a higher average improved VO_2 max percentage than the endurance training group.

Methods

Participants

This study was reviewed and approved by the University of Saskatchewan's ethics review committee. Twenty participants were recruited for the study through the University of Saskatchewan's PAWS announcements. The announcements included a brief description of the study on the university's news feed via university login accounts. Consent was obtained from all participants and a PARQ+ screening form was completed to determine if participants were sufficiently healthy to complete a test to exhaustion. Of the 20 participants, eight individuals failed the initial screen test before taking the baseline VO_2 max. During the study, two participants sustained injury not acquired from the study, but were unable to continue the program. Baseline data was taken from 12 participants and final data was taken from 10 participants and used for the results of the study. Participants in this age group were recruited because of the stability of aerobic power of individuals in their prime.

VO_2 max Measurements

Baseline and post training measurements of aerobic power were conducted for each participant, indexed by maximal oxygen uptake (VO_2 max). Participant height, weight, and age were recorded prior to testing in order to determine relative VO_2 max. Participant blood pressure (BP) and heart rate (HR) were also taken to determine if their levels were below the maximal values (BP: <144/94 mmHg, HR: <100 beats per minute) to participate in extraneous physical activity according to the Canadian Society for Exercise Physiology (CSEP) guidelines. Participants were instructed to follow the CSEP pre-testing exercise recommendations, including avoiding caffeine, alcohol and heavy exercise prior to the testing.

Participants were required to wear a Polar heart rate monitor throughout the test to observe percentage of maximal heart rate during the test. Maximum heart rate was estimated as 220 minus age at test. The Bruce Treadmill Test Protocol was used to elicit a VO_2 max of each participant. A metabolic cart was used to assess ventilation of expired air and the percentages of oxygen and carbon dioxide in the expired air; from this, the volume of oxygen consumed, and volume of carbon dioxide expired were determined. The metabolic cart used was the Vmax Encore Metabolic Cart which was calibrated and adjusted to current conditions in Saskatoon, Saskatchewan, Canada, before each participant was tested. The test required an individual to run as long as possible on a motorized treadmill; speed and slope grades were increased every three minutes. The treadmill was set and collaborated to the Bruce protocol prior to participant's arrival. The participants wore headgear that supported a mouthpiece to measure expired air. VO_2 max was assessed at 20-second intervals throughout the test. When the participants felt they could not run any longer due to exhaustion or pain, the test was stopped. Participants cooled down at 3km/h for five minutes.

Intervention Training Programs

Two types of training interventions were conducted: the endurance training group consisted of six individuals, while the HIIT group initially consisted of six individuals, with two of those individuals dropping out of the study due to injury. Injuries did not result from the training or VO_2 max test. Participants of both training groups met three times a week for four weeks under supervised training from the researcher. A training procedure was given to each participant who could not make a training session in order for them to make up the training in their own time, no more than five days after the scheduled training. If a participant did miss more than six training sessions, their data was discarded. In order to calculate exercise intensity, the Borg scale for perceived exertion (from 6 to 20) was used. The average rating for the endurance training group was 15 and ranged from 13 to 17. The average Borg rating for the HIIT group was 19 during sprinting, 12 during walking, and ranged from 17 to 20 and 10 to 14 respectively. These Borg ratings were consistent with the Borg ratings of different exercise intensities (Borg, 1982).

Endurance Training

The endurance group training session started with a five-minute, slow jog warm-up. Participants were encouraged to stretch before and after each training session, but due to the time constraints of an honours thesis, they were not required to do so. After the warm-up, participants were required to run 20 consecutive minutes at a moderate jogging pace; following that, they were given five minutes for a walking cool-down to decrease heart rate.

High Intensity Interval Training

As the endurance group did, the HIIT group training session started with a five-minute warm-up of slow jogging. Again, participants were encouraged, but not required, to stretch before and after each training session. The HIIT procedure used for the training program was 1 minute of rest, alternating with a 30-second all-out sprint, repeated 12 times for a total of 18 minutes. The researcher conducting the training sessions used a whistle to notify participants when to switch from rest to sprint, and sprint to rest, for the duration of the training. The one-minute rest period included either walking or a slow jog, whichever the participant felt was needed based on the individual's fitness level. The 30 seconds of sprint was as fast as the individual could perform. It was observed during training that the sprint speed got slower as the session proceeded. After the session was completed, five minutes were given for cool down at a walking pace in order to provide participants with adequate cool down to decrease heart rate.

Data Analysis

Means and standard deviations were calculated for age, weight, height, and relative VO_2 max values of all the participants from both the baseline test and the post-training test. Independent t-tests were performed to determine mean significant measures between the two training groups for the variables of height, weight, age, and relative VO_2 max at baseline. Paired t-tests were performed to determine significant changes from baseline to post-test VO_2 improvements; as well as height, and weight changes. The alpha value was set at a significance level of $p<0.05$.

Results

Participants

Ten participants completed the training program: six individuals from the ET group and four from the HIIT group. Participant supervised session attendance was 76%. However, if participants missed the supervised sessions, they would be required to complete the session at their own time and keep a log of when they completed the session. 100% of sessions were completed, including the unsupervised made up sessions.

Baseline VO_2 Max Results

Table 1: Baseline results.

Baseline HIIT	Baseline Endurance Training
n = 6	*n* = 6
Age: 22.5 ± 2.07 years	Age: 21.5 ± 2.43 years
Weight: 78.5 ± 11.1 kg	Weight: 78 ± 17.7 kg
Height: 178 ± 7.04 cm	Height: 181 ± 8.40 cm
VO_2 Max: 51.7 ± 8.10 ml/min/kg	VO_2 Max: 48.2 ± 6.48 ml/min/kg

Table 1 shows the results from the baseline VO_2 max testing. The table shows the average values and standard deviation of age, weight, height, and relative VO_2 max for each training group. No significant ($p > 0.05$) differences were found in age, height, weight, and relative VO_2 max between the two training groups.

Post Training VO_2 max Results

Table 2: Four-week post training intervention results.

Post-test HIIT	Post-test Endurance Training
n = 4	*n* = 6
Age: 23.25 ± 2.06 years	Age: 21.5 ± 2.43 years
Weight: 86.25± 8.16 kg	Weight: 79.2 ± 17.2 kg
Height: 178 ± 7.04 cm	Height: 181 ± 8.40 cm
VO_2 Max: 52.4 ± 6.34 ml/min/kg	VO_2 Max: 48.9 ± 6.38 ml/min/kg

Table 2 illustrates the results after four-week training, which show the average and standard deviation values after the four-week training program, for age, weight, height, and relative VO_2 max for each training group. Again, the analysis indicated no significance ($p > 0.05$) between the two groups for weight, height, or relative VO_2 max. From baseline to post-test, the ET group showed no significant difference ($p > 0.05$) in height, weight, age, or relative VO_2 max. The HIIT group, however, showed a significant difference ($p < 0.05$) in weight, between the baseline and post-training tests. But there was no significant difference ($p > 0.05$) shown in height, age, or relative VO_2 max from baseline to post test. Overall, there were no significant changes from the baseline results to the post test results, except a change in weight from the HIIT group. This increase in mass resulted in a non-significant increase in relative aerobic power (ml/min/kg), as well absolute aerobic power (L/min) (p=0.053).

Figure 1 illustrates the VO_2 max improvements (y-axis) for each individual from baseline to post-training test (x-axis). The red lines of the graph represent the individuals in the HIIT group and the blue lines represent the individuals in the ET group. As shown, there was much variability between participants; some individuals improved, some stayed the same, and some declined. The most improved participant in the HIIT group improved by 10.7%, while the most improved participant in the ET group improved by 11.1%. The most deteriorated participant in the HIIT group had a 4.0% decrease, while the most deteriorated participant in the ET group had a 3.1% decrease in VO_2 max.

Figure 2 shows the VO_2 max average improvements for both training groups from the baseline test to the post training test. There was a 3.4% improvement in the HIIT group with a standard deviation of 8.4%, while the ET group had a 1.7% improvement with a 5.6% standard deviation. Although it would appear that the HIIT grouped improved more, the high standard deviations meant no significant differences ($p > 0.05$) in VO_2 max improvements from baseline to post-training tests. The graph trend suggests a larger improvement in the HIIT group than the ET group, but these results are not statistically significant ($p > 0.05$).

Figure 1: Individual VO_2 max improvements from baseline to post-test.

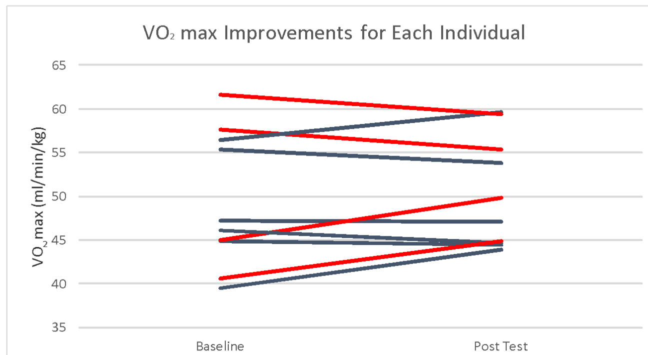
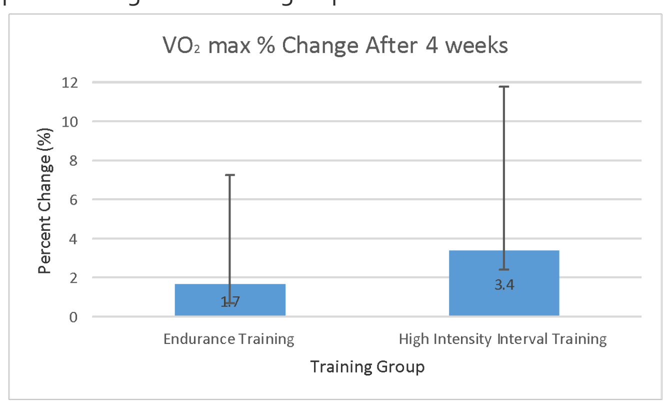


Figure 2: Percent change results averages from baseline to post training test of each group.



Discussion

This study sought to investigate the relationship between two forms of training on VO_2 changes over a four week training program in healthy male individuals. The results from the study indicates that the research hypothesis is rejected. Although the data did show a trend that correlates with the hypothesis, HIIT training improves VO_2 max more than ET over a four-week training intervention, but the increase is not statistically significant ($p > 0.05$).

Previous literature has suggested that HIIT may be better for increasing aerobic power than ET. A study done by Roxburgh, Nolan, Weatherwax, and Dalleck (2014) concluded that HIIT training was better for increasing aerobic power than ET in a group of sedentary participants over a 12-week training intervention. Another study concluded that high intensity training was better for improving aerobic power compared to a moderate intensity training group over a six-week study (Tabata et al., 1996). More research by Helgerud et al. (2007) and Daussin et al. (2008) showed similar trends wherein HIIT was better for increasing aerobic power than ET. However, the data from this study did not show significant results ($p > 0.05$), but a trend in these studies suggested that HIIT is better for increasing aerobic power.

There are a few possible reasons why this study was not consistent with previous literature. One reason may be related to training length. Previous literature suggested that in order to observe significant improvements in VO_2 max, training intervention length should be in a range of 6 to 12 weeks (Roxburgh et al., 2014) (Tabata et al., 1996) (Helgerud et al., 2007). The study training intervention was originally projected to take place over a six-week time period, since previous literature indicated this was enough time to show significant aerobic power improvements in young male individuals (Tabata et al., 1996). However, because of time restrictions, the study had to be shortened to four weeks. This was possibly not enough time for individuals to have significant aerobic adaptations to the training. The low participant number increased variation within the groups, which may have also contributed to inconsistency with previous literature. Previous literature suggested that more participants would decrease variation and lead to significant results (Roxburgh et al., 2014). The study only included 10 participants and only four in the HIIT group, which increased the amount of variability, since an outlier in one of the groups would lead to a drastic change in the results. To further improve the study, it could be repeated with the same measures, but a larger number of participants and a longer training intervention will be needed. This would serve to lower variability in the results and would give more time for the participants to have significant aerobic adaptations. Furthermore, the study results showed no significant difference in aerobic power from baseline to post-training VO_2 max test in both the ET group and HIIT group, but a review of literature showed that both ET and HIIT have beneficial qualities to improving aerobic power. The trend of this study suggests that both ET and HIIT improve aerobic power in healthy male individuals, but the data was not significant. Another limitation was the scale used to assess training intensity. Due to resource restriction, the Borg scale of perceived exertion was used, although it relies on self-reported measurements, and as such, may not be as reliable as other ways to measure intensity such as heart rate monitoring. The study can be repeated using a more stable measurement of intensity. If the participants missed a training session, they were to make-up the training on their own time. This is another limitation, because there is no way to ensure that the participants made up the session. This could alter the results, as the participants who made up the sessions would not get as much training as the participants that did not make up any sessions. However, the participants gave verbal confirmation of made up sessions. One hundred percent of sessions were reported completed for the participants that did make up sessions. As shown from previous literature, aerobic power decreases by an average of 1% of VO_2 max per year after the age of 40 (Powers & Howley, 2012). Powers and Howley (2012) suggested that the aerobic power prime for male individuals ranges from 18 to 35 years of age. This prime suggests the least physiological adaptation occurring during this time. This study utilized this measure and used participants who were a part of the prime. Since aerobic power is measured by VO_2 max, the results from participants' VO_2 max indicated their aerobic power. It is well known that aerobic power is the single most important factor in predicting running distance and performance (Powers & Howley, 2012). This was shown from the study, as individuals who ran the longest during the VO_2 max test also had the highest aerobic power. It has been shown that increasing aerobic power decreases the risk of cardiovascular disease (McMurray et al., 1998). Cardiovascular training to increase aerobic power has also been shown to decrease hypertension, vascular resistance, low-density lipoprotein (LDL) levels, and increase high density lipoprotein (HDL) levels (Cornelissen & Fagard, 2005). While there was no significant difference in aerobic power between the two groups, the results show a trend suggesting that both groups improved aerobic power and therefore decreased risk of cardiovascular disease and other risk factors. Again, a longer training intervention may confirm significant results of the trend and demonstrate the increase of aerobic power from cardiovascular training.

In conclusion, neither training program showed a significant increase in aerobic power. However, the findings of this study suggest that there was a promising trend that HIIT may be better for improving aerobic power than ET, although this trend could have been due to chance, as it did not show significant results. Future studies should repeat the study design with a longer training program and more participants to decrease variability.

Acknowledgements

Dr. Adam Baxter-Jones – Supervisor
Dr. Jonathan Farther – Honors Coordinator
Jessica Murphy – Data Collection
Mojtaba Kaviani – Data Collection
Shane Schwanbeck – Data Collection

References

Astorino, T. A., Allen, R. P., Roberson, D. W., & Jurancich, M. (2012). Effect of high-intensity interval training on cardiovascular function, VO2max, and muscular force. *The Journal of Strength & Conditioning Research*, *26*(1), 138-145. doi: 10.1519/JSC.0b013e318218dd77

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise, 14*(5), 377-381.

Cooper, D. M., Weiler-Ravell., Whipp, B. J., & Wasserman, (1984). Aerobic parameters of exercise as a function of body size during growth in children. *Journal of Applied Physiology*, *56*(3), 628-634.

Cornelissen, V. A., & Fagard, R. H. (2005). Effects of endurance training on blood pressure, blood pressure–regulating mechanisms, and cardiovascular risk factors. *Hypertension*, *46*(4), 667-675. doi: 10.1161/01.HYP.0000184225.05629.51

Daussin, F. N., Zoll, J., Dufour, S. P., Ponsot, E., Lonsdorfer-Wolf, E., Doutreleau, S., ... & Richard, R. (2008). Effect of interval versus continuous training on cardiorespiratory and mitochondrial functions: relationship to aerobic performance improvements in sedentary subjects. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *295*(1), R264-R272. doi: 10.1152/ajpregu.00875.2007

Day, J. R., Rossiter, H. B., Coats, E. M., Skasick, A., & Whipp, B. J. (2003). The maximally attainable VO2 during exercise in humans: the peak vs. maximum issue. *Journal of Applied Physiology*, *95*(5), 1901-1907. doi: 10.1152/japplphysiol.00024.2003

World Health Organization Regional Office of Europe. (n.d.). Definition of cardiovascular diseases. Retrieved from http://www.euro.who.int/en/health-topics/noncommunicable-diseases/cardiovascular-diseases/cardiovascular-diseases2/definition-of-cardiovascular-diseases

Endurance Training. (n.d.). *The Free Dictionary*. Retrieved April 14, 2015, from http://medical-dictionary.thefreedictionary.com/endurance training

Gibala, M. J., Little, J. P., MacDonald, M. J., & Hawley, J. A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *The Journal of Physiology*, *590*(5), 1077-1084. doi: 10.1113/jphysiol.2011.224725

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., & Hoff, J. (2007). Aerobic high-intensity intervals improve VO2max more than moderate training. *Medicine and Science in Sports and Exercise*, *39*(4), 665-671. doi: 10.1249/mss.0b013e3180304570

Laursen, P. B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training. *Sports Medicine*, *32*(1), 53-73. doi: 10.2165/00007256-200232010-00003

McMurray, R. G., Ainsworth, B. E., Harrell, J. S., Griggs, T. R., & Williams, O. D. (1998). Is physical activity or aerobic power more influential on reducing cardiovascular disease risk factors?. *Medicine and Science in Sports and Exercise*, *30*(10), 1521-1529. doi: 10.1097/00005768-199810000-00009

Porter, M. M., Vandervoort, A. A., & Lexell, J. (1995). Aging of human muscle: structure, function and adaptability. *Scandinavian Journal of Medicine & Science in Sports*, *5*(3), 129-142. doi: 10.1111/j.1600-0838.1995.tb00026.x

Powers, S., & Howley, E. (2012). *Exercise Physiology: Theory and Application to Fitness and Performance*. (8th ed.) Toronto, ON: McGraw-Hill.

Roxburgh, B. H., Nolan, P. B., Weatherwax, R. M., & Dalleck, L. C. (2014). Is moderate intensity exercise training combined with high intensity interval training more effective at improving cardiorespiratory fitness than moderate intensity exercise training alone. *Journal of Sports Science and Medicine*, *13*(3), 702-707.

Seiler, S. (2010). What is best practice for training intensity and duration distribution in endurance athletes. *International Journal of Sports Physiology and Performance*, *5*(3), 276-291.

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi, M., & Yamamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO2max. *Medicine and Science in Sports and Exercise*, *28*(10), 1327-1330. doi: 10.1097/00005768-199610000-00018

Valim, V., Oliveira, L. M., Suda, A. L., Silva, L. E., Faro, M., Neto, T. L. B., & Natour, J. (2002). Peak oxygen uptake and ventilatory anaerobic threshold in fibromyalgia. *The Journal of Rheumatology*, *29*(2), 353-357.

Top End Sports (n.d.) VO2 max Norms. Retrieved from http://www.topendsports.com/testing/norms/vo2max.htmhttp://www.topendsports.com/testing/norms/vo2max.htm

World Heart Federation (n.d.). Cardiovascular disease risk factors. Retrieved from http://www.world-heart-federation.org/cardiovascular-health/cardiovascular-disease-risk-factors/