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# The effectiveness of high intensity interval training in improving $\text{VO}_2$ max for performance gains as compared to standard endurance training in athletes

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The effectiveness of high intensity interval training in improving  $\text{VO}_2$  max for performance gains as compared to standard endurance training in athletes

**Disciplines**

Physical Therapy

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**TITLE:** The effectiveness of high intensity interval training in improving VO<sub>2</sub> max for performance gains as compared to standard endurance training in athletes.

**CLINICAL SCENARIO:** High intensity interval training (HIIT) has become a popular form of exercise for the layman and elite athletes alike. I was introduced to HIIT by a coach who claimed that this was the best new form of endurance training to improve cardiovascular fitness. High intensity interval training has been suggested as an attractive alternative to standard endurance training due to the decreased time commitment required. I would like to determine what research has shown in regards to the effectiveness of this new trend in training as measured by maximal oxygen uptake.

**BRIEF INTRODUCTION:** High intensity interval training (HIIT) is an alternative to standard endurance training that requires a significant decrease in time commitment and argues to offer equivalent results. HIIT demands that an individual works at maximum capacity during an anaerobic exercise task for seven to eight sets of 20 seconds each. Each set is separated by a 10 second rest. This clearly offers a much shorter alternative to the standard endurance training that may consist of 20 minutes or more of continuous physical exertion.

**CLINICAL QUESTION:** Does high intensity interval training produce equivalent results, as measured by maximal oxygen consumption (VO<sub>2</sub> max), to standard endurance training in athletic populations?

**CLINICAL PICO:**

**Population:** Athletes

**Intervention:** High Intensity Interval Training

**Comparison:** Standard endurance training

**Outcome:** VO<sub>2</sub> max

**OVERALL CLINICAL BOTTOM LINE:** High intensity interval training is no better or worse than traditional endurance training according to research from Tabata et al and

Sperlich et al. Each study included developing athletes under the age of 30 years and compared the maximal oxygen uptake achieved under high intensity interval training to the maximal oxygen uptake achieved under hour long endurance protocols. Using these two studies, I do not feel comfortable saying that one method is better than the other at increasing maximal oxygen uptake, however I do feel comfortable saying that I would choose high intensity interval training for athletes that are short on time and need the same results as traditional endurance training. While HIIT did not always show increased maximal oxygen uptake as compared to the control, it never resulted in results that were less effective than the control. The decreased time requirement of HIIT makes this a more cost/time efficient option. More research into the physiological benefits or drawbacks of HIIT is necessary to define the appropriate protocol and the presence of any increased physiological benefits beyond those gained from traditional training. For example, Tabata et al also measured the anaerobic change that occurred with training, which may be a more precise or useful piece of information for athletes that depend on bursts of energy. Based on the outcomes of Tabata et al and Sperlich et al it is clear that further research is necessary for solid clinical application of high intensity interval training to athletic populations to increase maximal oxygen uptake.

**SEARCH TERMS:** interval training, high intensity,  $VO_2$  max, endurance, oxygen consumption

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## RATIONALE FOR CHOSEN ARTICLES:

Table 1. Comparison of patient population, intervention, outcome measures, and PEDro Scores

	<b>Tabata et al</b>	<b>Sperlich et al</b>	<b>Bucheit et al</b>
<b>Patient Population</b>	Young male students majoring in physical education (average age 23 years old)	Youth 13.5 years old +/- .4 years with at least 3 years of experience in soccer training and matches from the German Premier League club	Well-trained male handball players
<b>Intervention</b>	High intensity interval training vs. 60 min of continuous cycling at 70% VO <sub>2</sub> max.	High intensity interval training vs. high volume training	Speed/agility training vs. sprint interval training
<b>Outcome Measures</b>	VO <sub>2</sub> max and Anaerobic Capacity	Oxygen uptake, heart rate, sprint tests, blood lactate concentration, perceived exertion on Borg's scale, energy expenditure, fat free mass, and jump tests.	Countermovement jump, 10-m sprint, repeated sprint ability test, and a graded intermittent aerobic test
Random Allocation	0	0	0
Allocation Concealed	0	0	0
Groups Similar at Baseline	0	1	1
Blind Subjects	0	0	0
Blind Therapists	0	0	0
Blind Assessors	0	0	0
Adequate Follow-up	1	1	1
Intention-to-Treat	1	1	0
Between Group	1	1	1
Point Estimates & Variability	1	1	1
<b>Total Score</b>	<b>4/10</b>	<b>5/10</b>	<b>4/10</b>

Article 1: Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, and Yamamoto, K. Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO<sub>2</sub>max. *Medicine and Science in Sports and Exercise*. 1996; 28 (10): 1327-1330.

Article 2: Sperlich B, De Mares M, Koehler K, Linville J, Holmberg, HC, and Mester J. Effects of 5 Weeks of High-Intensity Interval Training vs. Volume Training in 14-Year-Old Soccer Players. *Journal of Strength and Conditioning Research*. 2011; 25(5): 1271-1278.

Article 3: Bucheit M, Mendez-Villanueva A, Quod M, Quesnel T, Ahmaidi S. Improving Acceleration and Repeated Sprint Ability in Well-Trained Adolescent Handball Players: Speed Versus Sprint Interval Training. *International Journal of Sports Physiology and Performance*. 2010; 5: 152-164.

For the purposes of the clinical scenario of interest, I have chosen to discuss Tabata et al and Sperlich et al. These two articles most closely fit the clinical population that I am interested in and used the desired outcome measures to determine the effects of high intensity interval training. Additionally, these two articles focused on changes in VO<sub>2</sub>max specifically, while article 3 aimed to investigate their hypothesis regarding how each type of training targets a different type of physical improvement. While interesting, this fails to address the clinical question regarding whether HIIT is a more efficient and effective means of increasing VO<sub>2</sub>max. The Sperlich et al article received the highest PEDro score of 5/10, losing points for unspecified method of allocation, lack of concealment, and lack of blinding. Tabata et al and Bucheit et al had scores of 4/10. The article we will focus on (Tabata et al) did not specify their means of allocation, concealment, or blinding. Additionally, Tabata et al failed to specify if the groups were similar at baseline. The Tabata et al article was also chosen due to its relevance to the clinical scenario in which I was first introduced to high intensity interval training as the "Tabata protocol." It appears prudent to include the article written to support said protocol in order to better understand the appropriateness of the method. Article 3 did have similar groups at baseline through artificial (nonrandom) means and they had a loss of subjects with no intention to treat performed. Thus, I have chosen the Tabata et al and Sperlich et al articles for further analysis based upon the PEDro scores, each article PICO, and the relation of the article to my clinical question and my personal training experiences.

**Article 1:** Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, and Yamamoto, K. Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO<sub>2</sub>max. *Medicine and Science in Sports and Exercise*. 1996; 28 (10): 1327-1330.

**Clinical Bottom Line:** This study indicated that moderate intensity and high intensity interval training are effective at increasing VO<sub>2</sub>max. Further, this study showed that high intensity interval training was able to increase VO<sub>2</sub>max in a statistically significant way, whereas moderate intensity training resulted in mixed outcomes. This suggests that

although it appears moderate intensity increases  $VO_2\text{max}$ , it did not do so in a statistically significant way during this six week period. The population consisted of young male students majoring in physical education and with an average age of 23. Both groups trained for six weeks on their respective protocols: moderate intensity exercise at 70%  $VO_2\text{max}$  and high intensity at 170%  $VO_2\text{max}$  with an interval format. Tables 2 and 3 present the mean differences and effect sizes that resulted from this experiment and provide the statistical implications. Both types of training provided what appeared to be an increase in  $VO_2\text{max}$ ; however the statistics performed show that the groups were not equal at baseline and the only statistically significant result was that HIIT provides a statistically significant increase in  $VO_2\text{max}$ . Complete lack of blinding and randomization pose major threats to the validity of this study. HIIT is highly feasible, does not cost more than traditional moderate intensity training, and offers the benefit of saving costs through decreased time commitment. It is necessary to examine other studies with fewer threats to validity and that evaluate the effects of HIIT on maximal oxygen uptake to determine the optimal protocol. Further investigation into the other physiological benefits of HIIT should be pursued, such as its effects on anaerobic capacity.

**Tabata et al PICO:**

**P:** Young male students majoring in physical education (average age 23 years old) were included in this study upon written consent. There was no exclusion criteria specified.

**I:** The treatment of interest was high intensity interval training (HIIT).

**C:** The intervention was compared to 60 minutes of continuous cycling at 70%  $VO_2\text{max}$

**O:** Outcome measures performed in this study were maximal oxygen uptake ( $VO_2\text{max}$ ) and anaerobic capacity.

**Blinding:** In this study, no efforts were made to blind the assessors, clinicians, and participants. The lack of assessor blinding is a major threat to the study's validity as it provides several opportunities for rater bias to occur. Due to very objective nature of measurement used ( $VO_2\text{max}$  and anaerobic capacity) and the complication of participant motivation, the inability to blind participants and clinicians to the treatment they were receiving/giving is considered a moderate threat to study results.

**Controls:** In this study there was no true control group. The individuals in the comparison group that served as a control cycled at 70% of their  $VO_2\text{max}$  for 60 minutes. These individuals followed this protocol five days a week for six weeks. These groups were not similar at baseline and thus, in order to attribute results to the intervention, we must look at relative change from baseline data rather than straight comparison of measured values.

**Randomization:** The authors of this study give no indication that individuals were randomly allocated to the two study groups and the baseline data between groups varied considerably.

**Study:** Subjects in this study included 14 young males (average age 23 years old) that were majoring in physical education and volunteered for the study. The majority of these individuals participated in athletic activities. No exclusion criteria are described by the authors. The 14 subjects were divided equally into two groups (seven per group) and it is unclear how allocation was achieved. For our purposes we will assume that it was not random, this assumption is reinforced by the inequalities between baseline data in regards to  $VO_2\text{max}$  and anaerobic capacity. Both training protocols were at a frequency and duration of five times a week for six weeks. The individuals in the first experimental group cycled for an hour at 70% of their  $VO_2\text{max}$  during each session for moderate intensity endurance training. The second experimental group performed seven to eight 20-second intervals of cycling at 170%  $VO_2\text{max}$  for 4 days of their training with 10 seconds of rest in between each interval. An individual was stopped when his pedaling fell below 85 revolutions per minute (rpm) and the intensity was increased by 11 watts (W) if they were able to complete more than nine intervals in one session without falling below 85rpm. The fifth day of their training consisted of 30 minutes cycling at 70%  $VO_2\text{max}$  and then four 20-second intervals at 170%  $VO_2\text{max}$ .

Outcome measures: The outcome measures of interest in this study are each subject's  $VO_2\text{max}$ . The individuals in the moderate intensity training group had their  $VO_2\text{max}$  measured before protocol initiation, once a week during the protocol, and after completion of the training protocol. For the HIIT group  $VO_2\text{max}$  was measured prior to training, at three weeks, at five weeks, and after completion of the training protocol. The authors of this study cite Taylor et al<sup>1</sup> as a source to indicate the reliability and validity of  $VO_2\text{max}$  as an objective form measuring the release of anaerobic energy. This is considered the "gold standard"<sup>2</sup> for measuring anaerobic energy release and because of its objectivity, provides a form of measurement that is both consistent and allows for excellent interrater reliability. The study did not cite the rater reliability or the minimal clinically significant difference (MCID) for  $VO_2\text{max}$ .

Study losses: There were no subject losses in this study, thus no intention to treat statistics were necessary.

**Summary of Internal Validity:** The internal validity of this study is fair. This study was well structured and strengthened by the use of a very objective method of measurement, had no study losses, performed adequate follow up, and provided solid statistics. The study was severely weakened by two major omissions that resulted in threats to internal validity. The first major threat is that no blinding was performed in the subjects, assessors, or clinicians. The lack of blinding in all three of these areas creates a huge risk for rater bias, patient bias, and clinician bias throughout the study. The second major threat is the lack of randomization, which in turn resulted in the inability to conceal allocation of subjects and groups that were not similar at baseline in respect to  $VO_2\text{max}$ .

**Evidence:** The outcome measure of interest in this study is the  $VO_2\text{max}$  measured before and after completing the moderate and high intensity protocols. Using this data, it is possible to determine the mean differences, effect sizes between groups, and effect sizes within groups. This allows a determination of how effective each treatment protocol was and whether one is superior to the other. Table 2 shows a comparison of



individuals from each treatment group and their corresponding VO<sub>2</sub>max before and after treatment.

Table 2: Maximal oxygen uptake of subjects before and after exercise protocol with standard deviations (SD), including mean difference with 95% confidence intervals [CI], and effect size for between group comparisons of the moderate intensity protocol and high intensity interval protocol

	VO <sub>2</sub> max Before	VO <sub>2</sub> max After
Moderate Intensity Protocol	52.9 (±4.7)	57.9 (±3)
High Intensity Interval Protocol	48.2 (±5.5)	55 (±6)
Mean Difference	4.7 [-1.1 to 10.5]	2.9 [-2.48 to 8.28]
Effect Size (Between)	.92 [0.18 to 2.02]	.61 [-0.46 to 1.68]

In this study, both the moderate intensity and high intensity protocols resulted in a significant increase of VO<sub>2</sub>max using a p-value of <.05. The confidence intervals for each mean difference and the effect size for VO<sub>2</sub>max after the protocol are negative, indicating there was no significant difference between groups. This means that if the experiment was repeated, there is more than a 5% chance that the difference would demonstrate a decrease in VO<sub>2</sub>max after completing treatment. There was only one occasion of significant difference in this study. This occurred at the measurement of maximal oxygen uptake prior to beginning the protocols, indicating the groups were not equal at baseline. Mean differences and effect sizes were calculated using the author's data, as these statistics were not included. Table 3 looks at the effectiveness of each individual protocol in increasing VO<sub>2</sub>max within the each group. Both groups have a mean difference with positive confidence intervals, indicating they were both effective at increasing VO<sub>2</sub>max. However, the confidence intervals are very wide, indicating possible bias due to an insufficient sample size.

Table 3: Maximal oxygen uptake of subjects with standard deviations (SD), mean differences, and effect sizes with 95% confidence intervals [CI] within the moderate intensity group and within the high intensity group before and after treatment

	Moderate Intensity Protocol	High Intensity Protocol
VO <sub>2</sub> max Before	52.9 (±4.7)	48.2 (±5.5)
VO <sub>2</sub> max After	57.9 (±3)	55 (±6)
Mean Difference	5 [.53 to 9.47]	6.8 [.27 to 13.33]
Effect Size (Within)	1.06 [-.08 to 2.21]	1.24 [.1 to 2.37]

The moderate intensity protocol has a within effect size with a negative confidence interval, indicating that the results are not statistically significant. The CI shows that upon repetition of the experiment the effect size could vary as much as an increase by 2.21 standard deviations to a decrease of 0.08 standard deviations from baseline. The high intensity protocol has a within effect size confidence interval that remains positive, indicating that this is a statistically significant result. For example, if the experiment were repeated we can be 95% confident that the results will be a minimum of 0.1 standard deviations greater than baseline and a maximum of 2.37 standard deviations greater than baseline, both of which are significant improvements. Both experiments resulted in large improvements in maximal oxygen uptake for the individuals participating in the study as indicated by their large effect size. However, due to the moderate intensity protocol's negative CI is an indication that the large effect is due to an insufficient sample size.

### **Applicability of Study Results:**

Benefits vs. Costs: In this study there were no adverse events due to treatment. The costs of each treatment are comparable as both treatments can be done using the same equipment, and both groups received the same duration of treatment. The real difference between the treatments becomes apparent when comparing therapist and patient time. The high intensity interval protocol requires much less time than the moderate intensity protocol, with both providing the desired outcome of increased  $VO_2\max$ . Thus, this can trickle into a financial benefit to the patient, requiring less billable units of treatment. This also benefits other patients as it provides the therapist with more time to treat an increased number of individuals.

Feasibility of Treatment: The high intensity interval protocol is simple, requires no extra equipment when compared to moderate intensity, and provides more time for the patient and therapist. The study clearly describes the different parameters surrounding the protocol of interest, making it easy to reproduce. Due to the simplicity of the protocol, it could easily be performed in any clinic equipped with a stationary bike, treadmill, or area for running. While the protocol is performed four times a week for six weeks, it is versatile enough that an individual could be performing it as part of his or her home exercise program and then returning for weekly follow up visits. Under this format of care, it would very likely be covered by insurance for such a short period of time. Additionally, significant effects were seen by week three of the treatment, indicating that the therapy program does not need to go for the full six weeks used in this experiment to start seeing benefits.

Summary of External Validity: The internal validity of this study was fair; however the results appear to be applicable to my clinical population of athletes and used  $VO_2\max$  as one of the main outcome measures. This study demonstrated that both methods of endurance training were shown to be beneficial to increasing  $VO_2\max$ ; however there is no increased benefit of one method over the other in regards to increasing maximal oxygen uptake.

**Article 2:** Sperlich B, De Marees M, Koehler K, Linville J, Holmberg, HC, and Mester J. Effects of 5 Weeks of High-Intensity Interval Training vs. Volume Training in 14-Year-Old Soccer Players. *Journal of Strength and Conditioning Research*. 2011; 25(5): 1271-1278.

**Clinical Bottom Line:** This study indicates that high velocity training and high intensity interval training are unable to significantly change  $VO_2\text{max}$ , despite claims made by the authors that state otherwise. The population of this study consisted of 19 male soccer players with the average age of 13.5 years old. Each group trained under the same soccer specific protocol and then was taken through a high volume or high intensity protocol according to their assigned study group. Tables 4 and 5 show the before and after protocol  $VO_2\text{max}$  measures and compare the mean differences and effect sizes of each group. All calculated statistics show that there was no significant difference at baseline/before protocol or after protocol within or between groups. While this is discouraging at first glance, it is important to remember that poor quality and many flaws complicated this study. Additionally, while the high intensity protocol was not statistically significantly better than the high volume group, the reverse is true as well (the high volume protocol was not statistically significantly better than high intensity). Some of the threats to validity include lack of blinding, lack of randomization, and what appears to be statistical fishing when analyzing their results. While HIIT appears to save time, especially for sport specific training where time is already limited, it cannot be concluded from this study that this is a beneficial method of training. However, if these two protocols were my only options, I would feel comfortable choosing HIIT over high volume training because it requires less time and provides equal results. Further investigation using a more strict protocol and larger sample size are necessary to draw clinically useful conclusions from this study.

**Sperlich et al PICO:**

**P:** Subjects in this study were males 13.5 years old ( $\pm 0.4$  years) with at least three years of experience in soccer training and matches. Participants were from the German Premier League club and normally trained over four times a week. Seven subjects were also part of a federal junior all-star team. There were no other specific exclusion criteria stated.

**I:** The intervention of interest is high intensity interval training.

**C:** The intervention was compared to high volume training.

**O:** Outcome measures included oxygen uptake, heart rate, sprint tests, blood lactate concentration, perceived exertion on Borg's scale, and energy expenditure, fat free mass, drop jumps, squat jumps, and countermovement jumps.

**Blinding:** This study does not describe any attempts to blind the assessors, clinicians, and subjects. It is clear that subjects and clinicians could not be blinded to the treatment being administered; however the assessors could have been blinded with the proper preparatory efforts. It is evident that the assessors were not blinded to group placement because individuals were strategically (not randomly) placed in each group according to their baseline  $VO_2\text{max}$ . The lack of assessor blinding is a major threat to the study due to the possibility of assessor bias, clinician bias, and perceived effects of

the treatment by the patient. Due to the objective nature of measuring maximal oxygen uptake and the contrasting effect of participant motivation, the lack of clinician and participant blinding is considered a moderate threat.

**Controls:** This study had no “true” control group; however the high volume training group served as the control in this study. The authors of this study hand-picked which group each participant would be a part of. However, I feel the baseline similarity of the groups allows for differences to be attributed to the treatment intervention (HIIT).

**Randomization:** Individuals in this study were not randomized into their designated groups. Instead of randomizing subjects, the authors of this study chose to form the two study groups according to each participant’s baseline  $VO_2\text{max}$ . This created artificially similar groups at baseline and presents a moderate threat to validity.

**Study:** This study consisted of 19 teenage males that played in the German Premier League for soccer, seven of which were part of the federal junior all-star team. These participants averaged 13.5 years old and were training over four times per week. The participants were divided into two experimental groups according to their  $VO_2\text{max}$ . The control group consisted of nine individuals and the intervention group had ten individuals. The two interventions were “high-intensity intervals” and “high-volume training (control).” The interventions were preceded by baseline testing of several outcome measures, including maximal oxygen uptake (our variable of interest). This was considered the pre-diagnostic phase and the study were followed by a post diagnostic phase. The period of time in which individuals participated in the intervention was called the “training period.” Interventions were focused on increasing endurance and were performed in addition to regular soccer practices. Thus, each group received the same soccer training in regards to drills, warm up, flexibility exercises, and sprints. Each week consisted of four practices that lasted 1-1.5 hours and one game. The group performing high intensity intervals performed various exercises at 90-95% their maximal heart rate and the HIIT portion of practice never exceeded 31 minutes. The intervals were separated by 1-3 minutes of jogging at intensity equal to 50-60% maximal heart rate. In contrast, the high volume group worked at 50-70% of their maximal heart rate for 45-60 minutes. Prior to measuring  $VO_2\text{max}$ , participants participated in a 20 minute warm up at 50-60% of their maximal oxygen uptake. Maximal oxygen uptake was recorded before the intervention was instituted and after the training sequence was over after five weeks of training. The procedure for measuring maximal oxygen uptake consisted of running on a treadmill at 105% of each subject’s 1,000m personal best for 5 minutes and then increasing the incline by one degree every minute after that. The test was over when the individual could no longer continue (volitional exhaustion).

**Outcome Measures:** The outcome measure of interest in this study was maximal oxygen uptake ( $VO_2\text{max}$ ). This was measured for each group before and after the five week period of intervention. No reliability or validity for this measure were given by the authors, however this is a valid measure as  $VO_2\text{max}$  via spirometry and is considered the “gold standard” for measuring maximal oxygen uptake.<sup>2</sup> The authors do not provide an MCID or information regarding inter- and intra-rater reliability.

Study Losses: There were no losses in this study, thus no intention to treat analysis was necessary.

**Summary of Internal Validity:** The internal validity of this study is poor, with three major threats and three moderate threats. The first major threat is the lack of assessor blinding, as this could have resulted in rater bias and artificial results. The second threat is the insufficient sample size, resulting in the inadequate power to extrapolate the results. Finally, the third major threat is what appears to be statistical fishing during their analysis of the data.

The moderate threats are the lack of randomization, followed by the lack of concealed assignment, and lack of therapist and subject blinding. This allows the authors of the study to bias the success of the intervention or control group by placing people according to their ability. For example, they could put all the individuals they feel will succeed in promoting their hypothesis into one group.

**Evidence:** The outcome measure of interest in this study is the  $VO_2$ max of each participant throughout the study. Using the data provided by the authors, it is possible to determine the mean differences, effect sizes between groups, and effect sizes within groups. Using these statistics, the usefulness of each treatment can be revealed. Mean differences and effect sizes were calculated using the author's data, as these statistics were not included. Table 4 shows a "before and after" comparison of the two intervention groups.

Table 4: Maximal oxygen uptake of subjects before and after training with standard deviations (SD), including mean difference with 95% confidence intervals [CI], and effect size for between group comparisons of the high volume training and high intensity interval training

	$VO_2$ max Before	$VO_2$ max After
High Volume Training	55.3 ( $\pm 4.3$ )	56.4 ( $\pm 3.7$ )
High Intensity Interval Training	55.1 ( $\pm 4.9$ )	58.9 ( $\pm 4.7$ )
Mean Difference	0.2 [-4.30 to 4.7]	2.5 [-1.65 to 6.65]
Effect Size (Between)	.04 [-0.86 to 0.94]	.59 [-0.33 to 1.51]

It is clear from the mean difference, effect size, and their corresponding confidence intervals of the "before" comparison that the groups were similar at baseline (not statistically significantly different). The "after" column shows that at the end of the study, the two groups remained statistically similar with negative confidence intervals, thus indicating that one treatment was not better than the other. The mean difference between each group before treatment was  $0.2 \text{ ml min}^{-1} \times \text{kg}^{-1}$  higher in the HVT group than the HIIT. The CI for this indicates that upon repetition of the study the HVT group could be  $4.30 \text{ ml min}^{-1} \times \text{kg}^{-1}$  lower than HIIT or as much as  $4.7 \text{ ml min}^{-1} \times \text{kg}^{-1}$  higher. After treatment, the HIIT group showed a mean difference of  $2.5 \text{ ml min}^{-1} \times \text{kg}^{-1}$  greater

than the HVT group. The CI indicates that upon retest this could be as much as 1.65 units less than HVT or as much as 6.65 units more than HVT. The effect size before treatment is essentially zero at a value of 0.04 between the two groups, demonstrating that there is no real difference between the two training groups prior to treatment. However, if the experiment was repeated the effect could result in a decrease of  $VO_{2max}$  of 0.86 standard deviations or an improvement of 0.94 standard deviations from baseline. Lastly, the effect size after treatment was a 0.59 significant difference between groups. However, this upon retest could show as much as 0.33 standard deviation decline in improvement or 1.51 standard deviation improvement from baseline. The confidence intervals indicate there is greater than a 5% chance upon retesting that these variations in results would occur.

Table 5: Maximal oxygen uptake of subjects with standard deviations (SD), mean differences, and effect sizes with 95% confidence intervals [CI] within the high volume training group and within the high intensity interval training group before and after treatment

	High Volume Training	High Intensity Training
$VO_{2max}$ Before	55.3 ( $\pm 4.3$ )	55.1 ( $\pm 4.9$ )
$VO_{2max}$ After	56.4 ( $\pm 3.7$ )	58.9 ( $\pm 4.7$ )
Mean Difference	1.1 [-2.91 to 5.11]	3.8 [-1.00 to 8.6]
Effect Size (Within)	0.26 [-0.67 to 1.18]	0.78 [-0.13 to 1.7]

The within effect sizes for each group have negative confidence intervals. This means that the results are not statistically significant and improvements could be due to chance. Neither group had statistically significant changes in  $VO_{2max}$  after training, suggesting that neither treatment is effective at changing  $VO_{2max}$ . The mean difference between the HVT group before and after treatment was an overall improvement of  $1.1 \text{ ml min}^{-1} \times \text{kg}^{-1}$ , however the CI indicates that upon retesting there is greater than a 5% chance that the mean difference would be a decrease in  $VO_{2max}$  of as much as  $2.91 \text{ ml min}^{-1} \times \text{kg}^{-1}$  to an increase of  $5.11 \text{ ml min}^{-1} \times \text{kg}^{-1}$ . The HIIT group had a mean difference of  $3.8 \text{ ml min}^{-1} \times \text{kg}^{-1}$  improvement after training, however this could vary upon retest by a decline of  $1 \text{ ml min}^{-1} \times \text{kg}^{-1}$  to an improvement of  $8.6 \text{ ml min}^{-1} \times \text{kg}^{-1}$ . The effect size within the HVT group was 0.26 and the CI shows that upon retest this could vary by 0.67 standard deviations worse than the pre treatment values or increase to 1.18 standard deviations. Finally, the HIIT group should a within effect size of 0.78 and the CI indicates that upon retest this could decline (be less effective) 0.13 standard deviations or increase 1.7 standard deviations from baseline.

### **Applicability of Study Results:**

**Benefits vs. Costs:** According to the results of this study, the only benefit of HIIT is a reduction in time commitment. In all other aspects the two treatments appear to be of equal value in regards to increasing maximal oxygen uptake. Neither intervention was

able to significantly increase VO<sub>2</sub>max, however they both have minimal cost and neither appears to have detrimental effects.

Feasibility of Treatment: This treatment is highly feasible, as the study carefully outlines each intervention and the parameters under which it was performed.

Summary of External Validity: The internal validity of this study is poor, resulting in an inability to apply the results to my clinical population. No raw data is given to further analyze the situation. Additionally, the authors were inconsistent about the size of the study, resulting in further doubt in the author's findings. The study showed that neither method increased VO<sub>2</sub>max. However, the authors claimed that the statistics showed HIIT to be significantly more beneficial. These inconsistencies discredit the usefulness of the study.

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<http://www.medicine.virginia.edu/research/cores/exercise-physiology/fitness-assessment/vo2-maximal-oxygen-consumption.html>