The Effects of High-Intensity Interval Training on VO$_2$ max in Different Groups: A Review

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ABSTRACT

Vieira EFS, Aidar FJ, de Matos DG, Santos LR, Esteva CS, de Araújo SS, Marçal AC. The Effects of High-Intensity Interval Training on VO$_2$ max in Different Groups: A Review. JEPonline 2019;4(2):142-153. The purpose of this study was to investigate whether HIIT can influence the VO$_2$ max. This review evaluated 123 articles: (a) 78 were from PubMed database; (b) 6 were in the SciELO database; (c) 29 from Periodicals Capes; and (d) 10 articles from Lilacs. Of these, 22 papers were selected and analyzed. At the end of the analysis, 11 articles met the inclusion and exclusion criteria. There is still no consensus on the duration of exercise and rest intervals in the HIIT practitioners, but most of the protocols used demonstrated efficacy for the improvement of VO$_2$ max. Further studies are needed to determine exercise and rest time that can promote the benefits of HIIT on physical condition, cardiac systolic function, and post-exercise oxygen consumption (VO$_2$) more efficiently.

Key Words: HIIT, Interval exercise adaptations, Maximum oxygen consumption (VO$_2$ max)
INTRODUCTION

Among the traditional activities aimed at improving physical activity and maintaining health, resistance exercises and low- and moderate-intensity aerobic activities are recommended. In addition to these, some activities employ primarily continuous exercises of moderate intensity (17,25,26). The success of these programs is due in part to the decrease in abdominal fat, improved metabolic parameters (e.g., cholesterol, triglycerides, and glycemia), and the lowering of high blood pressure values (36). In recent years, research has focused on high-intensity interval training (HIIT). Programs based on HIIT have recently been examined as a form of physical activity with the potential and efficiency for promoting health, with the advantage that the training can be performed within a short period of time (15).

As one of the elements of physical activity, exercise is organized and regulated so that the benefits are acquired through regular practice. These benefits include reducing the risk of cardiorespiratory and chronic metabolic diseases due to exercise having an anti-inflammatory effect. However, it is also clear from numerous studies (3,10,13,14,29,38) that there is a mixed success in achieving significant improvements as mentioned above due to the lack of agreement between HIIT protocol of intervention and the frequency, duration, and intensity of the exercise.

The HIIT uses intense loads of exercise separated by a time interval between the series. The intensity is between 80% and 100% of maximal heart rate or aerobic capacity with exercises that last between 60 and 240 sec, according to individual sub-maximal aerobic capacity (3,21,37). Lobstein and colleagues (22) indicate that HIIT promotes greater health benefits than other types of training. It is similar to continuous aerobic exercise, but with a lower volume of training. Another favorable point regarding the use of HIIT is the greater adherence of its practitioners to exercise programs, due to its efficiency, shorter execution time, and the decrease in parameters that predict obesity (16).

The stimulation of the physical capacities, specifically the aerobic capacity, has shown that the effect is a higher level of maximum oxygen consumption ($VO_2$ max). In addition, the high concentration of $VO_2$ max is associated with an improvement in quality of life (5). The HIIT is efficient in the burning of calories, and the reduced training time accelerates metabolism and prioritizes the energy expenditure for a few hours after the training has ended (6,11,34,41). These effects on caloric expenditure are also observed among practitioners of traditional resistance exercise using longer time frames (1,32,40). Another benefit of HIIT is the reduction in heart rate, blood pressure, blood sugar, and insulin resistance in several healthy, overweight, obese, and/or diabetic groups (4,39).

The practice of HIIT improves cardiorespiratory fitness in healthy individuals and in patients with cardiovascular disease. It beneficially modulates high-density lipoproteins in individuals with metabolic syndrome training with longer exercise periods (7,20,35). However, in the $VO_2$ max parameter, the literature does not have a consensus regarding the practice of HIIT. This is due in part to the sample population studied, with a population of both sexes in different age groups and with a variation in the number of weeks (24).

The American Cardiovascular and Pulmonary Rehabilitation Association and the Board of Directors of the Canadian Cardiac Rehabilitation Association in 2012 recognized that the use
of aerobic training (including HIIT) can promote beneficial outcomes during cardiovascular and pulmonary rehabilitation of individuals with related pathologies (27). This literature review is based on research from numerous resources with the purpose of clarifying how HIIT can influence the VO$_2$ max of individuals who have undergone the proposed training in a varied public between men and women in diverse age groups, and to discuss the practical implications of the training.

**Methods**

The current study refers to a systematic review that was analyzed in detail with the objective of carefully examining the databases and articles selected according to the inclusion criteria defined in this research. Articles were reviewed from the following databases: Latin America and Caribbean Center on Health Sciences (Lilacs), SciELO, Periodicals of the Coordination of Improvement of Higher Level Personnel (CAPES Periodicals), Medline, and PubMed. During the period of collecting the research, there was no restriction on language.

**Search Strategies**

The relevant descriptors for the topic were initially consulted via the Health Sciences Descriptors (DeCS), which was developed from the Medical Subject Headings of the U.S. National Library of Medicine. This was done in order to allow the use of common terminology for research in three languages after finding the relevant terms. The information that was obtained came from the following descriptors: (a) HIIT and oxygen consumption and healthy volunteers; (b) physical exercise and interval high intensity and training maximum oxygen consumption; (c) exercise and interval high intensity and training oxygen consumption; (d) physical and exercise and interval and high and intensity and training and oxygen consumption and maximum.

For the development of the present study, articles were included in which the maximum volume of oxygen had been measured to verify its effects after HIIT intervention using the different types of protocols. The studies were selected in several age groups and with both males and females. The individuals were considered healthy with normal weight, overweight, and obesity. The articles that were selected for the proposed revision used the following inclusion criteria: (a) published between December 2011 and September 2018; (b) versar on interval training of high intensity in different protocols; (c) discussion of whether the effects of HIIT may improve the maximum volume of oxygen of healthy subjects of both sexes in any age group; and (d) healthy subjects of normal weight, overweight, or obese. Articles were not included in the present study if they had individuals with any pathology, as well as texts in printed books, manuals, and editorials.

Articles from 2011 to 2018 that had a large amount of research on the subject were searched for articles that dealt with the recent findings of science about the possible benefits of VO$_2$ HIIT of healthy individuals in any age group. The researchers began screening the databases previously selected using titles, abstracts, and articles. Then, the relevant articles were analyzed. Similar articles were removed. The pertinent articles, which were within the research criteria, were organized and further analyzed using an Excel spreadsheet.
Extraction of Data

Three steps were used to evaluate the articles and extract the relevant data. In Step 1, the two reviewers began evaluating the titles found in the search engines, then, the summaries of the articles found were examined, following the criteria for inclusion. The two researchers analyzed the articles by reading them in their entirety to verify the importance of each article (i.e., in accordance with what was established in the previous stage). In Step 2, the articles that did not fit the inclusion criteria established in this review were excluded. The reviewers independently completed this step in September 2018. Where there were cases of doubt and/or disagreement, the reviewers discussed the concerns and resolved by consensus (see Figure 1).

![Figure 1](image)

As a better form of organization and structuring, the articles were organized according to authors/year of publication, target audience, duration of the intervention, and effects of the intervention, which were attached in Excel spreadsheet and organized for the year in which it was published to better discuss the data found.

RESULTS

One hundred and twenty-three articles were found: (a) 78 in the PubMed database; (b) 6 in SciELO database; (c) 29 in CAPES Periódicos website; and (d) 10 in the Lilacs database. Of these articles, 22 were read in full after observing the established exclusion and inclusion criteria; and 11 articles met the criteria and were included in the present review (Figure 2).
Studies identified in the database between the period From 2011-2017 (n = 123)
Pubmed = 78 articles Scielo = 6 articles
Lilacs = 10 articles Capes = 29 articles

Selected articles (n = 22)

Excluded articles (n = 111)
- Divergence in the target population (n = 26)
- Repeated studies (n = 9)
- After reading the titles (n = 66)
- Studies excluded after reading the full text (n = 11)
- Does not evaluate the variables of the present study

Studies analyzed and included in the review (n = 11)

Figure 2. Flowchart Representing the Stages of Preparation of the Systematic Review.

The whole process of selecting and reading the articles, in all stages of selection, was developed in pairs, following what is recommended in PRISMA 16, so that it is guaranteed that the review protocol with the inclusion and exclusion criteria were respected. The data collected are presented in Table 1.

Table 1. The Studies were Organized According to: Authors/Year of Publication; Target Audience; Duration of Intervention and Effects of Intervention (2011 to 2018).

<table>
<thead>
<tr>
<th>Author / Year</th>
<th>Target Audience</th>
<th>Duration of Intervention</th>
<th>Load / Repetition</th>
<th>Effects of Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silva et al. (33)</td>
<td>Men, 35 yrs</td>
<td>4 wks</td>
<td>Average 100% of MHR/5x of 1 min active per 1 of rest</td>
<td>No significant difference between the groups for VO₂ max (P=0.495)</td>
</tr>
<tr>
<td>Duval et al. (9)</td>
<td>Men, between 18 and 30 yrs</td>
<td>2 wks</td>
<td>Average 90% of the MHR/15 x 60 Seconds active with 60 rest</td>
<td>The trained men significantly improved their VO₂ max (P=0.03)</td>
</tr>
<tr>
<td>Huerta et al. (19)</td>
<td>Teens, 13 yrs old</td>
<td>8 wks</td>
<td>Between 95% to 115% of MHR/30x of 10 sec active with 20 rest</td>
<td>The trained adolescents significantly improved their VO₂ max (P=0.015)</td>
</tr>
<tr>
<td>Authors</td>
<td>Participants</td>
<td>Duration</td>
<td>Target Heart Rate</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------</td>
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</tr>
<tr>
<td>Ní et al.</td>
<td>Men and women, 18 to 26 yrs</td>
<td>8 wks</td>
<td>100% MHR</td>
<td>Average/between 6 and 8x of 2.5 min active. Not informing the rest</td>
</tr>
<tr>
<td>Martínez et al.</td>
<td>Boys and girls, between 7 and 9 yrs</td>
<td>12 wks</td>
<td>≥ 80% of MHR/30x of 10 sec active with 20 rest</td>
<td>The trained boys and girls significantly improved their VO₂max (P=0.01)</td>
</tr>
<tr>
<td>Hormazábal et al.</td>
<td>Women and men, between 19 and 25 yrs</td>
<td>8 wks</td>
<td>Keep 85% of MHR/60x of 8 sec active with 12 rest</td>
<td>No significant difference between the groups for VO₂max (P=0.344)</td>
</tr>
<tr>
<td>Hwang et al.</td>
<td>Men and Women, 55 to 79 yrs</td>
<td>8 wks</td>
<td>Mean of 90% of MHR/4x of 4 min active with 3 min of rest</td>
<td>Significant improvements in VO₂max (P=0.01)</td>
</tr>
<tr>
<td>Foster et al.</td>
<td>Men and women, 18 to 28 yrs</td>
<td>8 wks</td>
<td>Average of 100% MHR/13x 30 sec active with 60 sec of rest</td>
<td>Significant improvements in VO₂max (P=0.05)</td>
</tr>
<tr>
<td>Ouerghiet et al.</td>
<td>Men, 21 to 26 yrs old</td>
<td>12 wks</td>
<td>Mean of 105% of MHR/40x of 15 sec active with 15 rest</td>
<td>Significant improvements in VO₂max (P=0.05)</td>
</tr>
<tr>
<td>Oliveira et al.</td>
<td>Men, 18 to 45 yrs</td>
<td>1 session</td>
<td>Mean of 85% of MHR/6x of 1 min active with 2 rest</td>
<td>No significant difference between the groups for VO₂max (P=0.31)</td>
</tr>
<tr>
<td>Dunham (8)</td>
<td>Men and women /*</td>
<td>4 wks</td>
<td>Mean of 90% of MHR/5x of 1 min active with 3 min of rest</td>
<td>Significant improvements in VO₂max (P=0.05)</td>
</tr>
</tbody>
</table>

MHR = Mean Heart Rate
*The age group was not indicated in the article.

In a brief analysis of the 11 selected articles (Table 1), HIIT was effective in most studies to promote improvement in VO₂ among the various groups proposed. Regarding the number of weeks, some authors showed some positive adjustments on VO₂ and others without effects, suggesting that the type of protocol used may have influenced the results.

In the study by Oliveira et al. (30), no significant differences were seen between the mean percentages of VO₂ during the exercise session (HIIT: 73.3% vs. CT: 71.8%, P=0.779). The results demonstrate that one HIIT session alone was not sufficient for morphofunctional adaptations in individuals. However, Duval et al. (9) shows trained men who did HIIT for 2 wks showed a significant improvement in VO₂ max (P=0.03).
Treadmill running does not promote significant adjustments in the variable VO\textsubscript{2} max (P=0.495) (33). This same study suggests that 4 wks of HIIT improved some traditional physiological variables related to resistance performance and maximum speed on the treadmill, but did not alter overall performance during a 5-km run test. However, Dunham and Harms (8) found significant increases between the groups for VO\textsubscript{2} max (P=0.05) when using the same number of weeks proposed by Silva et al. (33) with the use of HIIT. This divergence is due, in part, to the protocol used by the researchers. Silva et al. (33) adopted the HIIT protocol of running in subjects who carried Global Positioning System (GPS), 1 min of exercise for 1 min of rest, only with active and healthy men in the age group of 35 yrs (33), while in the Dunham (8) study, cycling exercise was used, 1 min of exercise per 3 min of rest, with active and healthy men and women. This study did not record the age group of the subjects. These papers suggest that choosing the correct protocol is of fundamental importance and will result in different findings that should be analyzed with caution in each situation.

Huerta et al. (19) using the 8-wk HIIT method based on the individual intensity obtained between 95% and 115% of the mean heart rate (MHR) detected an increase in VO\textsubscript{2} max (P=0.015) at the end of the intervention. They also observed that the BMI remained unchanged throughout the intervention, and that the waist and hip ratio remained unchanged throughout the intervention. The same result occurred in the studies of Ni et al. (28) and Foster et al. (12), where the duration of 8 wks also promoted an increase in VO\textsubscript{2} in the male subjects (P=0.03) and the female subjects (P=0.05). Ni et al. (28) also observed an improvement in the time use of rowing athletes. The HIIT improved lactate output training in rowers without compromising the athletes' aerobic adaptations.

In the Hwang et al. (20) study, the healthy elderly subjects showed an improvement in VO\textsubscript{2} max (P=0.015) in the men and women who participated in the 8-wk HIIT intervention than in the group that underwent continuous training. It was also clear that this intervention was a viable and safe exercise in the sedentary elders. HIIT is more effective in improving physical condition, cardiac systolic function, and insulin resistance compared with the group that performed continuous exercises with moderate intensity. However, Hormazábal et al. (18) evaluated the effects of an 8-wk HIIT protocol on overweight and obese women and found no improvement in VO\textsubscript{2} max (P>0.05), despite the 2.67% decrease in waist circumference and improvement in other anthropometric variables as well.

On the other hand, Martinez et al. (23) reported that a 12-wk HIIT program improved VO\textsubscript{2} max (P<0.05) and excess post-exercise oxygen consumption (P<0.05) as well as significant (P<0.05) improvements in mean propulsive velocity and standing long jump in school children (7 to 9 yrs of age). Their findings indicate that a short-duration high-intensity neuromuscular exercise protocol represent an excellent approach to improving health-related physical fitness in young children.

The same outcome appears to be the case with adults as well. Ouerghi and colleagues (31) reported on the effects of short-short high-intensity intermittent training (HIIT) on aerobic capacity and plasma lipids in 24 male subjects 21 to 26 yrs of age. They were divided into three groups: (a) the Experimental Group 1 (n=8) comprising soccer players who exercised in addition to regular short-short HIIT twice a week for 12 wks; (b) the Experimental Group 2 (n=8) comprising soccer players who exercised in a regular football training program; and (c)
the Control Group (n=8) that consisted of untrained subjects who did not practice regular physical activity. Maximum oxygen consumption was significantly increased (P<0.05) in both Group 1 and Group 2, but unchanged in Group 3. Total and low-density lipoprotein cholesterol levels decreased by about 2% in Group 1 but increased in Group 3 while high-density lipoprotein cholesterol increased in Group 1 and Group 2, but decreased in Group 3.

In the study by Duval et al. (9) the results show that HIIT seems to protect much of the cardio-metabolic profile against the negative effects of a poor diet based on fast foods in the HIIT intervention group. Also, the HIIT practice is capable of promoting relevant adjustments to the peak treadmill speed and energy savings measured at 12 km·h⁻¹, but without changes in the average effort rate perceived during the 5-km run test (33). In the study by Dunham (8) both HIIT and continuous training showed improvement in VO₂ max (~8 to 10%) and time test (HIIT 6.5 ± 1.3%, resistance training 4.4 ± 1.8%) after training. Both groups increased (P<0.05) post-training maximal inspiratory pressure (resistance training ~25%, HIIT ~43%) being significantly higher values for HIT than resistance training.

CONCLUSIONS

The purpose of this review was to highlight the different studies that examined HIIT and its effectiveness in improving VO₂ max in different groups and numbers of individuals in different age groups and weeks of intervention. The studies used the HIIT on the treadmill while running, running in spaces with GPS, and on an ergometer.

The HIIT has been shown to be an effective method for improving VO₂ max according to information from 8 of the 11 articles. This review suggests that the sessions are based on the execution of maximum heart rate intensity between 90%, 100%, and 130% of maximal aerobic velocity, 2 to 3 times·wk⁻¹. Three articles did not find positive results and they have different weeks of intervention. At this point in time, it is not possible to say exactly how many weeks are needed to obtain the beneficial adjustments of HIIT necessary to influence VO₂ max. However, it is clear that HIIT improves physical condition, cardiac systolic function, insulin resistance, cholesterol values, and post-exercise oxygen consumption.

Despite these findings from different researchers, there is still no consensus regarding the duration of exercise and rest intervals in HIIT practitioners. Thus, it is still important to address addition research to identify the best protocols that can be used demonstrate its effectiveness in improving VO₂ max. As a result, more studies are needed to gain a better understanding of how much exercise time and rest time are effectively better at getting the benefits more efficiently.

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