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EFFECTS OF HIGH-INTENSITY INTERVAL TRAINING ON ANTIOXIDANT CAPACITIES

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ABSTRACT

High-intensity interval training (HIIT) is currently one of the most used methods mainly for the treatment of cardiovascular diseases, metabolic syndrome and obesity. The present study aimed to carry out an integrative review on the effect of the HIIT method on antioxidant capacities in humans. The search terms used were HIIT with the following keywords and correlates: oxidative stress, lipid peroxidation, antioxidant capacity, antioxidant enzymes and free radicals. Inclusion criteria were HIIT intervention studies on antioxidant capacity, original articles and available in full in English, Spanish and Portuguese. Studies that did not meet these criteria were excluded. A total of 27 articles were found, of which only 7 met the selection criteria. Of these, 6 studies (85%) investigated the effect of HIIT on antioxidant capacity found beneficial results in these parameters. On the other hand, in one of included studies, the damage was repaired after exercise and one (15%) did not obtain statistically significant reductions. In this review, scientific evidence points to the effects resulting from antioxidant capacity and HIIT, however, it is necessary to carry out further studies to analyze this relationship, as it is not yet well described in literature.

Key words: HIIT. Antioxidant. Reactive Oxygen Species. Humans.

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RESUMO

Efeitos do treinamento intervalado de alta intensidade nas capacidades antioxidantes

O treinamento intervalado de alta intensidade (HIIT) é atualmente um dos métodos mais utilizados principalmente para o tratamento de doenças cardiovasculares, síndrome metabólica e obesidade. O presente estudo teve como objetivo realizar uma revisão integrativa sobre o efeito do método HIIT nas capacidades antioxidantes em humanos. Os termos de busca utilizados foram HIIT com as seguintes palavras-chave e correlatos: estresse oxidativo, peroxidação lipídica, capacidade antioxidante, enzimas antioxidantes e radicais livres. Os critérios de inclusão foram estudos de intervenção do HIIT sobre capacidade antioxidante, artigos originais e disponíveis na íntegra em inglês, espanhol e português. Os estudos que não atenderam a esses critérios foram excluídos. Foram encontrados 27 artigos, dos quais apenas 7 atenderam aos critérios de seleção. Destes, 6 estudos (85%) investigaram o efeito do HIIT na capacidade antioxidante e encontraram resultados benéficos nestes parâmetros. Por outro lado, em um dos estudos incluídos o dano foi reparado após o exercício e um (15%) não obteve reduções estatisticamente significativas. Nesta revisão, as evidências científicas apontam para os efeitos decorrentes da capacidade antioxidante e do HIIT, porém, é necessária a realização de mais estudos para analisar esta relação, pois ainda não está bem descrita na literatura.

Palavras-chave: HIIT. Antioxidante. Espécies reativas de oxigênio. Humanos.

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INTRODUCTION

High-intensity interval training (HIIT) is characterized by brief bouts of vigorous exercise, followed by recovery periods (Vieira-Souza and collaborators, 2021) of low-intensity exercise or rests, which allows the restoration of metabolic system (e.g. oxygen levels and energetic substrate) (Marquezi and collaborators, 2019).

According to Silva, Galliano, Del Vecchio (2020) similarities are found in the physiological adaptations of HIIT, despite lower training volume, when compared to traditional aerobic training on aerobic capacity (e.g. mitochondria biogenesis and oxidative enzymes) (Torma and collaborators, 2019; Macinnis, Gibala, 2017).

HIIT is currently one of the most used methods, mainly for the treatment of cardiovascular diseases (Gayda and collaborators, 2016; Hussain, Macaluso, Pearson and collaborators, 2016; Morales-Palomo and collaborators, 2016; Bond and collaborators, 2015; Schjerve and collaborators, 2008; Barauna and collaborators, 2005), metabolic syndrome (Morales-Palomo and collaborators, 2016; Steckling and collaborators, 2016; Dalzill and collaborators, 2014) and obesity (Belmiro, Navarro, 2016; Denou and collaborators, 2016; Dias and collaborators, 2016; Martinez and collaborators, 2015; Pimenta and collaborators, 2015; Smith-Ryan, Melvin, Wingfield, 2015; Dalzill and collaborators, 2014; Keating and collaborators, 2014; Kuehnbaum and collaborators, 2014; Shiraev, Barclay, 2012; Schjerve and collaborators, 2008).

Several studies (Mendonça and collaborators, 2015; Srismith and collaborators, 2018) have shown that HIIT is a time-efficient strategy (e.g. low-time commitment), greater adherence and motivation in the training process that helps in an important way the reduction of body fat in subjects with obesity and factors that characterize metabolic syndromes. Moreover, HIIT has been shown an efficient method for prevention and treatment of different cardiovascular diseases due improvements of maximum oxygen consumption, respiratory capacity, cardiac muscle remodeling and blood ejection capacity (Vieira-Souza and collaborators, 2021).

The benefits of HIIT are already well described in literature (Tanaka and Matsuo, 2021; Kriel and collaborators, 2016; Steckling and collaborators, 2016; Logan and collaborators, 2014; Guillot and collaborators, 2015; Naimo and collaborators, 2015; Pugh and collaborators, 2015; Shaban, Kenno, Milne, 2014; Shiraev, Barclay, 2012).

However, the relationship between oxidative stress and antioxidant capacity has not been systematically analyzed. To date, there seems to be no integrative review being conducted with the intention of analyzing the scientific findings that associate HIIT with antioxidant capacity in humans.

The relevance of this study stands out in the sense of verifying in literature the effects of HIIT on the antioxidant capacity.

Therefore, this integrative review aimed to answer the following research question: What are the effects of HIIT on antioxidant capacity?

MATERIALS AND METHODS

The present study sought from the integrative review to gather scientific articles published in the period from 2002 to 2021 which deal with the effects of HIIT on antioxidant capacity in humans, allowing obtaining possible conclusions on the theme.

The electronic databases used in the research stages were: LILACS, Google Scholar, Scielo, Pubmed and Science Direct. The descriptors chosen were “high-intensity interval training” with the following keywords: “oxidative stress, free radicals, lipid peroxidation, antioxidant capacity, antioxidant enzymes”. The terms used in the search were combined with the Boolean operators, “high-intensity interval training” AND “oxidative stress OR antioxidant capacity OR free radicals”, another form of search was “high-intensity interval training” AND “lipid peroxidation OR antioxidant capacity”, and “high-intensity interval training” AND “antioxidant enzymes OR antioxidant capacity OR oxidative stress OR free radicals”.

Inclusion criteria were intervention studies with HIIT, complete original articles published in journals and available in full in English, Spanish and Portuguese. Studies that did not meet these criteria were excluded. The search took place between November/2021 and January/2022.

Articles identified by the initial search strategy were independently evaluated by 2 authors, according to the following inclusion criteria: (1) population (Humans), (2) intervention (HIIT), (3) outcome (antioxidant

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capacity and antioxidant enzymes) and exclusion criteria: (1) population (Animals), intervention (non-application of HIIT) and applying more than one training protocol model.

First, articles were evaluated by titles, which should inform about some of the related terms of antioxidant capacity combined with HIIT. Subsequently, by reading the abstracts, studies that met the inclusion criteria were maintained. Finally, articles that were still eligible at this stage were read in full and only those that presented at least results from the analysis of antioxidant capacities and oxidative stress, considered the main variables of interest, were kept.

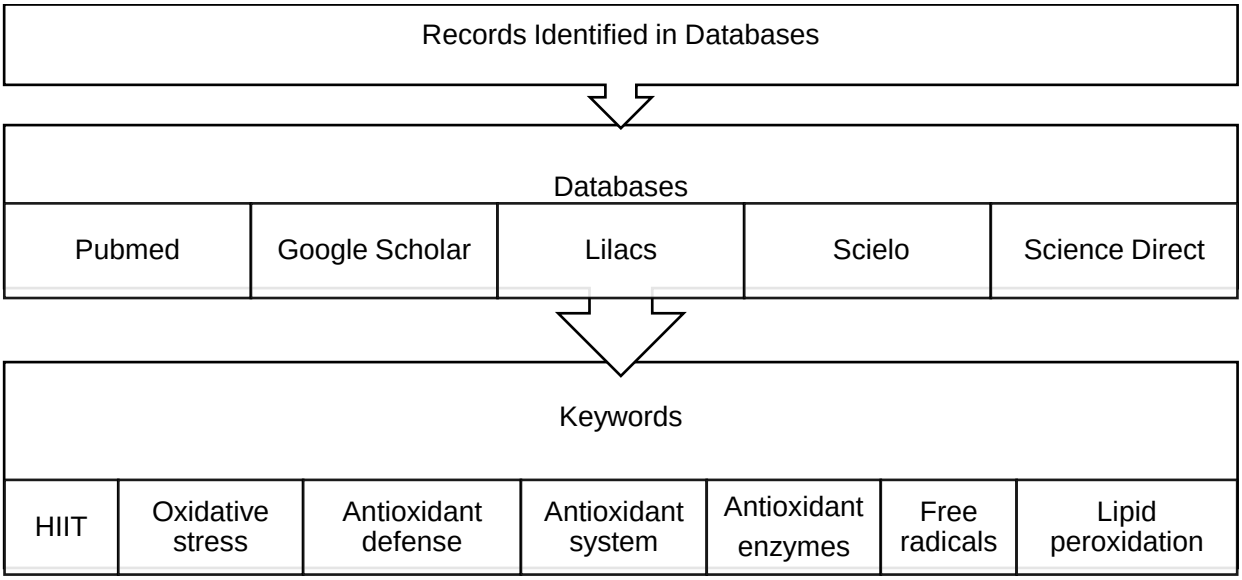

Figure 1 - Research design flowchart.

RESULTS

A total of 19,200 articles were found in databased, divided into Pubmed – 226 articles; Scielo – 6 articles; Science Direct - 2,788; LILACS – 340 articles and Google Scholar 15,840. After applying duplicity assessment filters, title and abstract reading, 19,193 articles were excluded, leaving only 26 articles. After a complete reading of eligible studies, only 7 articles met the eligibility criteria.

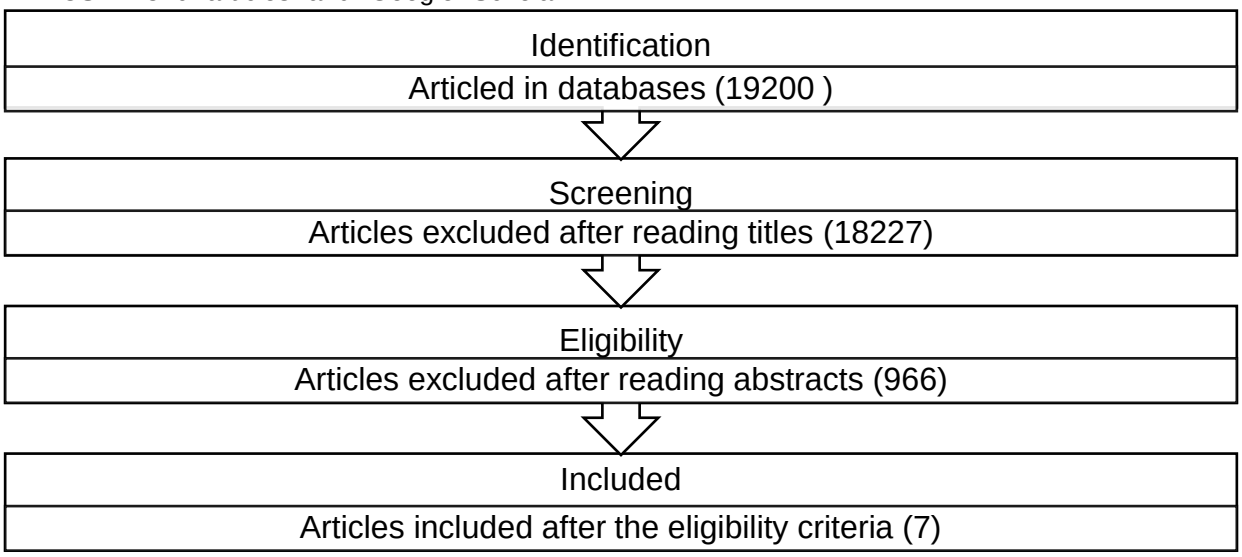

Figure 2 - Eligible articles search design flowchart.

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Table 1 - Studies characteristics included in the review.

Author and Year	Sample	Methodology	Main Outcomes
(Sarkar and collaborators, 2021)	Forty young Indian soccer and field hockey players. Participants had at least 5 years of professional training experience.	An eight-week HIIT intervention lasting 3h/day was performed 3/week (4 sets/session divided into 2 phases x 2 sets x 2 min) of total sprint training at 90-95% of HR_{max} with rest work of 1:1	HIIT increased CK; IL-6; MDA; TNF-α; GPx and cortisol and decreased SOD and GSH.
(Flensted-Jensen and collaborators, 2021)	Twelve obese individuals (6) men and (6) women, at risk of developing cardiovascular diseases and type 2 diabetes.	Six weeks of intervention, performing 3 HIIT sessions per week (five sets of 1 minute of high-intensity cycling 125% of the VO2peak with 90 seconds of recovery	Decreases the H_2O_2 emission in the mitochondria. Increased levels of antioxidant proteins in skeletal muscle. HIIT induced beneficial effects on ROS production and antioxidant status in muscle cells.
(Perween and collaborators, 2020)	20 male college football players divided into groups of repeated sprint training and interval training	The HIIT protocol consists of 4x4 minutes of training period at 90-95% of HR_{max}. All training sessions were performed on a treadmill with inclination of 5.3%. Training protocols were for a period of 4 weeks (3 times/week)	Serum levels of superoxide dismutase, catalase and glutathione, in addition to maximal oxygen uptake and maximum voluntary isometric contraction for quadriceps and hamstrings were measured before training and within 24 h after the completion of training. HIIT decreased oxidative stress and increased antioxidant capacity.
(Jamurtas and collaborators, 2018)	Twelve healthy young males.	In the HIIT single session, participants performed 4 30-second sprints on a cycle ergometer with 4 minutes of recovery against a resistance of 0.375 kg of body mass.	HIIT increased TAC immediately after exercise, uric acid and WBC. TBARS and Catalase remained unchanged.
(Parker, McGuckin, Leicht, 2014)	Fourteen male participants, healthy adults, non-smokers and sedentary.	Individuals participated in 2 exercise sessions on a cycle ergometer with electronic brake. 1st session – gradual exercise test to determine maximum power and oxygen uptake VO_2max. After the first week, they participated in 5-minute cycles at 40-55-75-85 and 100% of VO_2max with passive rest of 12 minutes between sessions phases.	HIIT increases plasma TAC; Blood lactate and perceived exertion.
(Faruk Ugras, 2013)	21 elite players (15 men and 6 women) with regular	Individuals underwent daily 3h HIIT during a brief 10-day training camp. They were	Increased MDA levels of, decreased CAT. There were

	exercise and training habits.	instructed to maintain normal dietary practices, and during the study not to take vitamin pills containing antioxidants	no changes in SOD and GPx.
(Bogdanis and collaborators, 2013)	Eight healthy young male volunteers. Participants were not athletes but were physically active.	Three HIIT sessions over 3 weeks. Each session includes 4 to 6 30-second cycles of high-intensity cycling separated by 4 minutes of recovery in the pace of 100 rpm.	Training decreased the exercise-induced increase in oxidative stress markers (PC; TBARS) and CK activity. HITT induced an increase in antioxidant status indices (TAC;CAT;GPx).

Legend: BF = Body Fat; CHOox = Oxidative Carbohydrate; CAT = Catalase; CK = Creatine Kinase; GPx = Glutathione Peroxidase Enzyme; GSH = Glutathione; HRmax = Maximum Heart Rate; H_2O_2 = Hydrogen Peroxide ; IL-6 = Interleukin-6; IPAQ = International Physical Activity Questionnaire; LAVs = Ventilatory Anaerobic Thresholds; LIPox = Lipid Determinants; MDA = Malondialdehyde; PC = protein carbonyl; SOD = Superoxide Dismutase; ROS = Reactive Oxygen Species; TAC = Total Antioxidant Capacity ; TBARS = Thiobarbituric Acid Reactive Substance; TNF-αa = Tumor necrosis factor; VJ = Vertical Jump; VO2Max = Maximum Oxygen uptake; VO2peak = Peak Oxygen uptake; Wpeak = Relative Anaerobic Peak Potential; WBC = White blood cells

DISCUSSION

The main aim of this integrative review was to analyze studies that investigated the effects of high-intensity interval training on antioxidant capacity. In the study of Flensted-Jensen and collaborators. (2021), after six weeks of high-intensity interval training, one of the main findings was related to H_2O_2 emission in the mitochondria of muscle cells, resulting in satisfactory decrease.

However, the generation of decreased ROS capacity in the mitochondria triggers a process of elevation of antioxidant properties, helping to reduce oxidative stress levels.

The effects of HIIT in this study are directly linked to the training intensity program applied in the short time of exercise, observing that the use of longer time of exercise within the protocol would generate greater beneficial effects for the antioxidant capacities.

During eight weeks of total sprint HIIT training at 90-95% of HR_{max}, Sarkar and collaborators (2021) revealed that there was an increase in muscle damage indices (LDH, CK and Cortisol), inflammatory markers (IL-6 and TNF) and antioxidant indicators. (MDA and GPx).

The antioxidants present in the analyses due to the application of HIIT exaggeratedly induced ROS production, being a mediator of cytokines produced through exercise. Puggina and collaborators (2016) showed alterations in the inflammatory responses in IL-6 and I-10 after evaluations performed after cycling competitions. The analysis of cortisol in samples revealed changes after ten weeks of training and after competition, obtaining significant increase in plasma cortisol concentration, a result of inflammatory responses and effort during the test.

Varamenti and collaborators. (2012) reported that in a competitive season with elite water polo players with four distinct phases, blood biomarkers of redox status, oxidative stress, inflammation and angiogenesis were evaluated. In phase 2 and 3, the antioxidant capacity was decreased and in phase 4, there was increase in IL-10, thus, the results indicated that oxidative stress and inflammation varied during the season.

According to Parker, McGuckin, Leicht (2014), the high-intensity exercise program of the present study indicates that the application of 70% of VO_2max resulted in increased plasma TAC (total antioxidant capacity), compared the same low-intensity training. Increased TAC after a single HIIT session did not have direct actions of changes in oxidative stress.

As reactive oxygen species (ROS) did not change in the process, the results may consider that species that react to oxygen are increased and release plasmatic antioxidants, thus, with the application of HIIT, ROS elimination occurs.

Souza and collaborators (2021) reported that high- intensity interval training with increased intensity and without recovery obtained alterations in antioxidant biomarkers,

and that adjustments of volume and intensity variables can generate different adaptive and physiological responses.

According to Jamurtas and collaborators (2018), HIIT, through a single session of 4 30-second cycling sprints, induced an increase in PC immediately after exercise.

Therefore, the intensity and duration of the exercise sessions obtain greater responses when it comes to TAC, which may be one of the main factors for the elevation of uric acid, which is known to have a marked representation in the plasmatic antioxidant capacity.

However, Santos and collaborators (2019) showed that high-intensity interval training causes tissue injury, predominantly at muscular level, and this training generated better adaptations to the antioxidant defense system.

According to Faruk Ugras (2013), during ten days of training, athletes were submitted to HIIT and the analysis of MDA levels were superior in the pre-training period, and it was observed that ROX (oxygen radicals) were produced after training, thus performing reduced actions on antioxidant activities. On the other hand, Bogdanis and collaborators (2013), during three weeks of high-intensity training applied to cyclists, obtained reduction in oxidative stress markers and increase in antioxidant capacities, however, short-term high-intensity interval training generates some adaptations in the oxidant and antioxidant system, showing beneficial responses complementary to the type of exercise applied.

Souza and collaborators (2021) observed no effect on animals after short-term high-intensity interval training, causing neither muscle damage nor oxidative stress.

Applying the HIIT protocol on an incline treadmill with football players, Perween and collaborators (2020) showed improvement in the antioxidant system, an important factor, as it controls the defense system related to free radicals, thus requiring the participation of both to balance the process, enabling the removal of oxidative stress in organelles.

CONCLUSION

Based on this review, the scientific evidence found points to the physiological effects resulting from HIIT on antioxidant capacity. However, it is necessary to carry out further studies to analyze the relationship between HIIT and the improvement of antioxidant capacities and oxidative stress response in different groups and individuals, comparing volume and intensity, as it is not yet well described in literature.

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