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Update

High-intensity interval training: a brief review on the concept and different applications

Treinamento intervalado de alta intensidade: uma breve revisão sobre o conceito e diferentes aplicações

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ABSTRACT

Introduction: Due to its highly dynamic characteristic and the time efficiency generated in relation to other training methods, High Intensity Interval Training (HIIT) has become a strategy used in different contexts. HIIT is understood as a training method that intersperses periods of effort performed at high intensity with periods of active (when an activity is performed at low intensity) or passive (when no activity is performed) recovery. Based on this concept that does not discriminate types of exercises, different HIIT models can be found in the literature, such as classic HIIT, Sprint Interval Training (SIT), HIIT with bodyweight, High Intensity Functional Training (HIFT), High Intensity Circuit Training (HICT), and High Intensity Resistance Training (HIRT), expanding the possibilities of applying HIIT to different purposes and audiences. **Aim:** a) to revisit, through a brief update, the concept of HIIT and its different aspects; b) present, from a scientific perspective, different protocols that can be applied based on the concept of HIIT and its effects. **Conclusion:** Based on the exposed concept and on the HIIT intensity control variables, this approach can be applied to different training modalities. In addition, it can be used as a strategy to provide safe and efficient training across different populations.

Keywords: physical exercise; performance; healthy; physical fitness; high intensity interval training.

RESUMO

Introdução: Devido à sua característica altamente dinâmica e à eficiência do tempo gerado em relação a outros métodos de treinamento, o Treinamento Intervalo de Alta Intensidade (HIIT) tem se tornado uma estratégia utilizada em diferentes contextos. O HIIT é entendido como um método de treinamento que intercala períodos de esforço realizados em alta intensidade com períodos de recuperação ativa (quando uma atividade é realizada em baixa intensidade) ou passiva (quando nenhuma atividade é realizada). Partindo desse conceito que não discrimina tipos de exercícios, diferentes modelos de HIIT podem ser encontrados na literatura, como o HIIT clássico, *Sprint Interval Training* (SIT), HIIT com peso corporal, Treinamento Funcional de Alta Intensidade (HIFT), Treinamento em Circuito de Alta Intensidade (HICT), e Treinamento Resistido de Alta Intensidade (HIRT), ampliando as possibilidades de aplicação do HIIT para diferentes finalidades e públicos. **Objetivo:** a) revisitar, através de uma breve atualização, o conceito de HIIT e seus diferentes aspectos; b) apresentar, do ponto de vista científico, diferentes protocolos que podem ser aplicados com base no conceito de HIIT e seus efeitos. **Conclusão:** Com base no conceito exposto e nas variáveis de controle de intensidade HIIT, esta abordagem pode ser aplicada a diferentes modalidades de treinamento. Além disso, pode ser usado como uma estratégia para fornecer treinamento seguro e eficiente para diferentes populações.

Palavras-chave: exercício físico; desempenho; saúde; aptidão física, treinamento intervalado de alta intensidade.

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Introduction

The regular practice of physical exercise is associated with numerous benefits that positively impact the quality of life and maintenance of functional capacity of its practitioners [1]. The American College of Sports Medicine [2] recommends that all adults engage in cardiorespiratory training, accumulating a minimum of 75 to 150 minutes per week of vigorous or moderate activity, respectively. If the goal is weight loss and/or control, at least twice the weekly volume of moderate-intensity physical activity (> 300 minutes) is suggested. Associated with this, the collegiate also postulates that strength training should be carried out around 2 to 3 times a week.

However, in Brazil, the percentage of adults who reach the minimum volume recommended for the weekly practice of physical activity is still a minority. In the 27 capitals, the frequency of reported physical activity equivalent to 150 minutes of moderate activity per week in free time was only 39% [3]. The main reasons for this, according to a study by Pinheiro *et al.* [4] include excessive working hours and family commitments, in addition to a lack of company and interest in practicing more traditional activities, such as weight training.

Thus, more dynamic strategies and efficient training time may be attractive to many people, which could help to increase not only the level of physical activity, but also the adherence of practitioners in the long term [5,6]. Among these strategies, high intensity interval training (HIIT) has been gaining popularity, occupying a prominent position in the lists of current market trends in Brazil [7] and worldwide [8]. The growth in the number of adepts is associated with the possibility of training with few or no material resources [9], training sessions with short duration [10], and a modality can be performed outside the gym environment [11], offering advantages for individuals who do not have much time to train [12].

Since it was first proposed, HIIT has enabled athletes and different clinical populations to enjoy the benefits caused by the accumulation of high intensity exercise, a principle that guides HIIT, for long periods [13]. In this sense, due to its high versatility and application possibilities, HIIT is used in multifaceted ways [14], which can generate a conflict of concepts and difficulty in controlling variables, both in research and in practice. Therefore, the objectives of this study were: a) to revisit, through a brief update, the concept of HIIT and its different applications; b) present, from a scientific perspective, different HIIT protocols that can be applied based on the concept, in addition to the effects related to each modality.

Definition of high intensity interval training

High-intensity interval training, by definition, is a method in which a high--intensity stimulus (effort) period is interspersed with an active or passive recovery period [13]. This training proposal has been applied for many decades in different populations and its use is justified, above all, by two facts: 1) the possibility of simulating every day and/or sporting situations in which intermittent effort is present

(e.g., application of HIIT based on reduced games, used in different types of team sports); 2) an increase in the time (volume) of stimuli at higher intensities through the partial recovery of the metabolic pathways, provided by the recovery intervals between each effort period and between sets (series) of stimuli [13,15].

The high intensity in this method is characterized by a level of effort that leads different physiological systems to operate above some pre-established thresholds [13], which have a submaximal, maximal, or supramaximal character. Table I describes the prescription measures, intensity, and characteristic rates by which popular protocols based on the HIIT concept are prescribed.

In fact, intensity is a fundamental parameter for the prescription of HIIT, as it is an important principle of the method [13]. However, this is not the only dose control variable in HIIT. Buccheit and Laursen [16] describe nine variables related to stimulus and recovery intervals in HIIT sessions: 1) intensity of effort; 2) duration of effort; 3) intensity of recovery; 4) duration of recovery; 5) total duration of the training session; 6) number of series; 7) type of exercise used; 8) duration of series; and 9) interval between series, as well as environmental factors, which are capable of altering acute and chronic responses [17,18].

Although there are numerous manipulable parameters, in the fitness context, the exercise modality in which HIIT is applied has been significantly modified in different protocols [17,19-21]. Although it is not a consensus, to our understanding, what characterizes HIIT is the magnitude of effort in the stimulus intervals and not the modality (or type of exercise). Considering this same perspective, different types of training and exercises have been used to apply this proposal, which could expand the range of options for training variation, as long as there is full knowledge of the characteristics of each model.

Table I - Parameters used in the prescription of interval training and characteristics associated with the intensity rate

Prescription measure	Intensity	Characteristic
Maximum heart rate	80 to 95%	Submaximal
	100%	Maximal
Heart rate reserve	85%	Submaximal
Perception of effort (6 to 20)	17 to 19	Submaximal
	20	Maximal
Perception of effort (0 to 10)	8 to 9	Submaximal
	10	Maximal
Maximum aerobic intensity (iVO_{2max})	85 to 95%	Submaximal
	100%	Maximal
	>100%	Supramaximal
Maximum oxygen consumption (VO_{2max})	75 to 90%	Submaximal
	100%	Maximal
All-out	Maximum capacity to perform a given activity	Supramaximal (not parameterized)

Table II - Main HIIT application models

Authors	Type of HIIT	Objectives	Type of exercise	Effort parameter	Examples of most common applications
Helgerud *et al.*, 2007 [57]	Classic HIIT*	Aerobic fitness	Cyclic exercises performed on ergometers (bicycle, treadmill)	Percentage of heart rate and maximum oxygen consumption	4 x 4-minute bouts with a 3-minute recovery
Gibala *et al.*, 2012 [21]	SIT*	Aerobic and anaerobic fitness	Cyclic exercises, performed on ergometers or in the field	*All-out*	4 to 6 30 second sprints with 4,5 minutes of passive recovery
Machado *et al.*, 2018 [22]	HIIT with bodyweight*	Aerobic fitness, muscle endurance	Exercises using bodyweight	Subjective perception of effort, all-out	30 seconds of stimulus for 30 seconds of recovery
Feito *et al.*, 2018[a] [20]	HIFT*	Multisystemic adaptations	Functional exercises using bodyweight, free weights and accessories	Subjective perception of effort, all-out	Several protocols. The most common include AMRAP (As Many Reps as Possible, which means: as many repetitions or rounds as possible within a given period) and the EMONS (Every Minute On the Minute)
Batrakoulis *et al.*, 2018 [52]	HICT*	Multisystemic adaptations	Resistance and functional exercises using bodyweight, free weights and accessories	Maximum number of movements possible	20 to 40 seconds of stimulus for 20 to 40 seconds of recovery
Paoli *et al.*, 2012 [23]	HIRT*	Maximum strength and hypertrophy	Resistance exercises using free weights and weight machines	Percentage of maximum load	6 sets with loads around 80-85% of 1RM followed by 20" intervals of passive recovery and resumption of execution until new concentric failure. This procedure of pausing and resuming execution is repeated 2 or 3 times

HIIT = High-Intensity Interval Training; SIT = Sprint Interval Training; HIFT = High-Intensity Functional Training; HICT = High-Intensity Circuit Training; HIRT = High-Intensity Resistance Training

Based on these parameters, HIIT has been performed through cyclic exercises (pedaling, rowing, and running) [16], using calisthenics [22], strength [23], and functional [20] exercises. When modifications are made in the modalities used to perform HIIT, the way in which the intensity is monitored also changes, since certain measures are inadequate for some exercises, which are often performed in an "all out" manner on account due to the greater practicality and adequacy in controlling the intensity [19]. However, perceived exertion is also a strategy used to prescribe HIIT in different exercise modalities [13], and these models appear frequently in the scientific literature, as described in table II.

Over the years, HIIT has been shown to be an important training strategy to improve performance, both for competitive athletes and for non-athletes, and it is very effective in stimulating physiological adaptations, allowing for the improvement of different components of physical fitness [24-26]. Although the risk of musculoskeletal injury and cardiovascular events increases with higher intensity exercise, HIIT performed as a component of sports training has historically been associated with minimal risk [27]. Furthermore, this method has been extensively studied in different specific groups, showing ample safety, even in populations with different disorders [28] and during cardiac rehabilitation [29].

Dun *et al.* [30], in subjects who had suffered a myocardial infarction, suggested that, when well supervised, HIIT may offer even more benefits than continuous training of moderate intensity. In addition, although researchers continue to assess the safety of HIIT, it appears that this training method can be performed by people with a variety of health challenges. An HIIT prescription model has also been suggested for populations with certain comorbidities, based on different stimulus intervals and care that professionals should take before, during, and after the session [31]. Therefore, application of this method is recommended, as long as guidance and supervision (monitoring) are appropriate [32-34].

Classic HIIT

Classic HIIT is characterized by cyclical stimuli that can be performed through activities such as running, cycling, swimming, or paddling. Regardless of the modality in which it is performed, there are 2 traditional formats applied to HIIT sessions [13]:

• Long intervals HIIT: characterized by the performance of series of stimuli longer than 1 minute in duration (usually between 2 and 5 minutes) with intensity between 90% and 100% of vVO_{2max} (or higher) and passive (around 1 to 3 minutes duration) or active recovery intervals (2 to 4 minutes of low intensity running [< 65% vVO_{2max}]).

• Short intervals HIIT: characterized by the performance of series of stimuli between 10 and 60 seconds in duration with intensity >100% of vVO_{2max} and passive recovery intervals that obey the proportion varying between a shorter recovery time in relation to work (1:0.5) and a longer recovery time in relation to work (1:4) according to the intensity used.

Different adaptations to HIIT have been demonstrated, including improvements in VO_{2max} parameters, anaerobic capacity, and physical performance [35]. These long-term improvements are associated with central and peripheral readjustments resulting from the high intensity provided by HIIT, improving cardiac output, and peripheral vascular structure and function, including acceleration in peripheral oxygen utilization, among other mechanisms that allow for increased cardiometabolic health [36]. In addition, benefits also include decreased insulin resistance [37], decreased body fat percentage [38], and reduced blood pressure, with concomitant increases in strength in older adults [39].

Sprint interval training

Sprint interval training (SIT) is a method often used to improve sports activities in different individual modalities [13]. The session consists of short stimuli of supramaximal intensity that are not parameterized (all-out), which require a great contribution from the anaerobic metabolism for energy supply [40]. Generally, the duration of each stimulus varies between 30 and 45 seconds, with long recovery intervals (around 3 to 5 minutes or longer), performed passively [16,21]. Stimuli with "all-out" intensity are understood as the maximum capacity to perform a task of running, rowing, or pedaling on a non-motorized treadmill or over ground [16].

SIT has been applied in different populations with promising results related to health indicators, such as increased cardiorespiratory fitness [24]. Although not parameterized, these protocols can reach very high intensity values, which are closely related to the increased activity of cell signaling pathways related to mitochondrial biogenesis (increase in the number of mitochondria per cell) [33,41]. As a result of this process, there is an increase in the lactate threshold, thus allowing individuals to exercise for longer and at higher VO_{2max} percentages [41,42].

The high intensity and non-parametrization of the stimuli are complicating factors that can lead Physical Education professionals to insecurity about the use of SIT in clinical populations. Because of this, it is suggested that further studies be conducted to evidence safety and to establish recommendations on the conduction and monitoring of complicating signals during the execution of protocols with these characteristics in populations whose objective is to improve general health.

HIIT with bodyweight

Like traditional HIIT, HIIT with bodyweight is also characterized by training sessions with high intensity stimuli, followed by recovery periods that can be passive or active, in which only bodyweight is used as resistance [11].

HIIT studies using bodyweight adopt different nomenclatures, namely: whole-body training [10], high-intensity intermittent calisthenic training [9], whole-body High-intensity Interval Training [43], and HIIT body work [19,44].

The relationship between stimulation time and session recovery can present three characteristics, being they: 1) the load ratio between the stimulus time and the

recovery time and 2) the exercises selected in the session. Didactically, it is suggested that the exercises can be classified as simple, those that have a single movement pattern (e.g., jumping jack), or complex, those with a combined movement pattern (e.g., Burpee) [11].

The session load ratio can present three distinct characteristics, namely: a) stimulus time less than recovery time (2:1), b) stimulus time equal to recovery time (1:1), and c) stimulus time greater than recovery time (2:1) [11].

Session duration varies from ~4 to ~30 minutes [44] and intensity control is based on the use of PSE, however the practitioner must be instructed to perform the maximum number of repetitions of each exercise possible at the high interval intensity, obeying previously established intensity criteria (RPE) [11].

In one study [22], a significant reduction in body mass was observed in a group of individuals who participated in an HIIT with bodyweight program of four weeks duration, a weekly frequency of training of three times a week, and a 30 min training session duration. These results are in line with those observed in the previously proposed experiment [9], demonstrating that 6 weeks of training, with a frequency of three times a week, and a session duration of 20 minutes, did not induce improvements in parameters of general physical fitness and in muscle thickness. However, limitations regarding progression and organization of the training session were indicated as possible parameters that can be manipulated to optimize the session, with the objective of improving physical fitness and also promoting changes in body composition.

Two other studies [10,43], based on the application of extremely short models of HIIT with bodyweight (8 sets of 20 seconds of "all-out" stimulus interspersed with 10 seconds of passive recovery), showed interesting results on different variables of general physical fitness, highlighting cardiorespiratory fitness. However, in both works, dumbbells (~3kg) were used for the execution of one of the proposed exercises, which mischaracterizes the exclusive use of bodyweight. Despite this, as it presents interesting results, this HIIT model must be considered, particularly given the opportunity to use few implements.

High Intensity Functional Training

High-intensity functional training (HIFT) is a model in which the concepts of HIIT (exercise at high intensity) are emphasized, with the application of multisegmental, multiplanar, and integrated tasks performed at a high intensity of effort. For this, exercises that use movement patterns such as squatting, pushing, pulling, and carrying are selected to compose the HIFT training session. Control of the high intensity of effort in this modality can be carried out through the PSE or it can be performed in an all-out way. These stimuli are also interspersed with recovery periods, which may or may not follow a specific duration, and are generally passive, as observed in other HIIT models [45-49].

In many contexts, HIFT sessions can be divided into three blocks: 1) move-

ment preparation, 2) neuromuscular conditioning, and 3) cardiometabolic conditioning [50]. In the scientific literature, HIFT has often been associated with "cross" modalities (Cross Training, Mix Modalities Training – MMT, and Functional Fitness), methods that are capable of promoting multisystem adaptations, through the concomitant improvement of different parameters of physical fitness [45]. Based on this, studies have shown that HIFT is able to promote positive benefits to both body composition [20] and improved performance in different biomotor abilities [48].

Ratifying the above, Sperlich *et al.* [49] verified the effects of nine weeks of HIFT compared to training associated with high-volume, low-intensity exercise. After the intervention period, the authors found significant improvement in body mass, percentage of fat-free mass, fat mass, body mass index, and muscle strength in both training methods. However, the HIFT showed greater improvements when the maximum oxygen consumption was analyzed. In the same vein, Kliszczewicz *et al.* [48] observed an increase in aerobic and anaerobic capacity in trained individuals submitted to four weeks of HIFT.

Although there are different pre-established HIFT models in the scientific literature (AMRAP and EMONS), the prescription of this type of protocol can be targeted and specific, based on work, sports, or daily life activities. This makes it possible to apply HIFT in different populations, enabling an increase in functional capacity, in addition to promoting an improvement in physiological parameters, arising from the accumulation of time spent at high intensity, the main proposal of HIIT.

High-Intensity Circuit Training

According to Clayton *et al.* [51], high-intensity circuit training (HICT) is a model generally based on the application of exercises that mimic the movements used in activities of daily living (squatting, pulling, pushing), which provide benefits to the physical fitness components related to functionality. HICT is usually applied with stimuli performed at a high intensity, for about 20 to 40 seconds, followed by pauses, with a work:recovery ratio ranging from 1:2 to 2:1 [52].

As the name suggests, the organization of the session follows the traditional circuit model (all sessions based on circuit) or blocks (minicircuits), covering between 6 and 12 exercises [53]. In both situations (blocks or circuit) it is possible to use more than one round, being common the use of 2 to 3 rounds. The average duration of training sessions is usually between 20 and 40 minutes [52]. Overall, the benefits of HICT mainly involve the improvement in cardiorespiratory fitness and strength and changes in body composition [52,54].

High-Intensity Resistance Training

High Intensity Resistance Training (HIRT) has been used, based on advanced methods of strength training, with the aim of inducing levels of stress/stimuli beyond those provided by maximum sets or those conducted up to concentric failure [55]. As the models use high intensity stimuli interspersed with brief intervals of

passive recovery, the concept of HIIT is present.

The most popular HIRT protocol was proposed by Paoli *et al.* [23] and is based on the rest-pause model. In this protocol, multi-joint exercises are applied, in which maximal sets are performed (concentric failure) with high loads (80-85% of 1RM), followed by 20" intervals of passive recovery and resumption of execution until a new concentric failure. This procedure of pausing and resuming performance is repeated 2 or 3 times after the first set, characterizing the rest-pause. Although the study by Paoli *et al.* [23] only assessed issues related to energy expenditure, a study by Prestes *et al.* [56] analyzed the effects of 6 weeks of training with a similar protocol and observed an increase in muscle strength and endurance in the upper and lower limbs, as well as muscle hypertrophy in the thigh of trained men.

Conclusion

The concept of HIIT is based on the alternation between periods of stimulus (performed at high intensity) and recovery. From this point on, it is possible to state that, based on the main objective of HIIT (accumulation of maximum exercise time at high intensity), using high intensity as a guiding principle, several exercise models with different neuromuscular stimuli can be applied. Obviously, the impacts of HIIT and the adaptations in physiological systems in the medium and long term may vary between the protocols used, however, it seems to be a consensus that the different models can promote different benefits to health and physical fitness in general. In addition, the versatility of HIIT allows it to be performed in different conditions and populations, enabling broad benefits and minimal complications arising from the practice of this training method, provided that the information on the application and monitoring of the variables is observed, making this approach extremely attractive in the current context of society. Nevertheless, it is suggested that further studies be conducted in order to increase knowledge about the application of different protocols based on the HIIT concepts mentioned throughout this manuscript. In addition, it is recommended that studies are conducted with the aim of observing possible differences in the acute response and chronic effects that the different forms of application of HIIT provide to different populations.

Potential conflict of interest
No conflicts of interest have been reported for this article.

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Authors' contributions
Conception and design of the research: Evangelista AL, La Scala Teixeira CV, Da Silva-Grigoletto ME; **Writing of the manuscript:** Evangelista AL, La Scala Teixeira CV, Brandão LHA, Machado AF, Bocalini DS, Santos LM, Da Silva-Grigoletto ME; **Critical review of the manuscript for important intellectual content:** Evangelista AL, La Scala Teixeira CV, Brandão LHA, Da Silva-Grigoletto ME.

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