SSE #249

Sports Science Exchange (2024) Vol. 37, No. 249, 1- 5

GATORADE SPORTS SCIENCE INSTITUTE

AN UPDATE ON INTERVAL TRAINING FOR PERFORMANCE AND HEALTH

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KEY POINTS

- Interval training is a simple concept that refers to repeated bouts of relatively hard work interspersed with recovery periods of easier work or rest.
- There is no common definition of the term "high-intensity interval training" (HIIT) but it can generally be characterized as intermittent work bouts performed above the heavy-intensity domain in a performance context or above moderate-intensity in a health context from the standpoint of physical activity or exercise prescription.
- High-level endurance athletes typically practice an intensity distribution that involves ~80% of training sessions completed at lower intensities and ~20% performed at higher intensities, including interval training.
- There is debate over the best method to structure the portion of training time spent at high-intensity, including whether a polarized, pyramidal or threshold approach to intensity distribution is optimal to enhance endurance performance.
- A key focus of interval training for health has been on cardiorespiratory fitness as objectively measured by maximal oxygen uptake (VO_2max), given the strong association between this clinical marker and risk for mortality and many chronic diseases.
- Simple, practical and relatively time-efficient applications of interval training can increase VO_2max, including activities such as brief vigorous stair climbing, bodyweight style exercise and "exercise snacks" in which short (≤ 1 min) bouts of vigorous activity are performed periodically throughout the day.

INTRODUCTION

Interval training is a simple concept that refers to repeated bouts of relatively hard work interspersed with recovery periods of easier work or rest (Fox et al., 1973). It is historically rooted in the training of high-level athletes for performance and particularly those engaged in sport and events that demand a high capacity for aerobic energy provision such as middle- and long-distance running (Billat et al., 2001). Interval training is broadly applicable and has also been advocated for decades as a strategy to enhance health in a wide range of individuals. This includes the physical conditioning of previously inactive individuals and application in a rehabilitative context in people with chronic diseases (Smodlava, 1973).

The last decade has seen a resurgence of interest and an exponential increase in research on interval training responses, including basic mechanisms of physiological remodeling and applications for performance and health (Gibala, 2021; Gibala & Little, 2020). This work has been a reminder of the tremendous versatility and generalizability of interval training. It has coincided with increased attention amongst fitness professionals and the public, particularly regarding the potential for brief, intense exercise to elicit responses in a time-efficient manner (Thompson et al., 2022). The awareness is reminiscent of the interest spurred by the seminal research of Professor Izumi Tabata in the mid-1990s (Tabata et al., 1996) and in some ways the topic of interval training is "rediscovered" every decade or two. The purpose of this Sports Science Exchange (SSE) article is to consider the application of interval training for athletic performance and health. It is based on concepts discussed in a more detailed review published elsewhere (Coates et al., 2023).

CLASSIFYING INTENSITY: WHAT IS "HIGH-INTENSITY" INTERVAL TRAINING?

While simple in concept, the application of interval training can be complicated owing to its infinite variety and non-standardized taxonomy. Interval training prescription involves the manipulation of up to nine variables, including the work interval intensity and duration, relief interval intensity and duration, exercise modality, number of repetitions, number of series, as well as the between-series recovery duration and intensity (Buchheit & Laursen, 2013). Regarding the key variable of intensity, terminology varies widely across stakeholders including coaches and athletes, exercise scientists, clinicians, fitness professionals and practitioners. A fundamental three-domain model is common in a performance context, with indicators related to blood lactate, ventilation or work rate commonly marking the transitions between moderate, heavy and severe domains (Poole et al., 2016; Seiler, 2010). Many other models have been proposed for endurance training beyond the basic three-domain framework, and these typically involve additional zones that are similarly demarcated by metrics including those related to work rate, cardiorespiratory stress, blood lactate or perceived effort (Casado et al., 2023; Jamnick et al., 2020). In a health context, the three fundamental intensity classifications for aerobic physical activity are light, moderate and vigorous, based on indicators related to perceived effort or metabolic equivalents. Exercise testing and prescription guidelines typically incorporate additional categories or levels, with boundaries anchored to indicators related to heart rate or oxygen uptake, in addition to perceived effort or metabolic equivalents (ACSM, 2022; Garber et al. 2011).

There is no common definition of the term "high-intensity interval training" (HIIT) despite its widespread use. In a performance context, HIIT can be characterized as intermittent bouts performed above the heavy-intensity domain. This categorization principally encompasses the severe-intensity domain and is demarcated by indicators that principally include the critical power or critical speed, or other indices including the second lactate threshold, maximal lactate steady state or lactate turnpoint (Ianetta et al., 2022; Poole et al., 2016). In a health context, HIIT can be characterized as intermittent bouts performed above moderate-intensity. This characterization principally encompasses the classification of vigorous-intensity and is demarcated by indicators related to perceived exertion, oxygen uptake or heart rate as defined in authoritative public health and exercise prescription guidelines (ACSM, 2022; Bull et al., 2020; Garber et al., 2011). "Sprint" interval training" (SIT) can be considered a particularly intense version of HIIT and distinguished as bouts performed with near-maximal to "all out" effort. This characterization coincides with the highest intensity classification included in some training zone models, including the extreme-intensity domain (Jamnick et al., 2020) or anaerobic speed reserve, which constitutes work rates between maximal aerobic speed or power and maximal sprint speed/power (Buchheit & Laursen, 2013), or near-maximal to maximal-intensity classification in exercise prescription guidelines (ACSM, 2022; Garber et al., 2011).

INTERVAL TRAINING FOR PERFORMANCE

A key tenet of interval training in an athletic context is to accumulate a greater volume of work at a higher intensity than could be achieved through continuous work at a fixed intensity (Billat, 2001). This is believed to enable superior training responses that facilitate the capacity to maintain a higher work rate or race pace, and enhance fatigue-resistance (Laursen & Jenkins, 2002). While widely accepted as an essential component to optimize performance, high-level endurance athletes typically practice an intensity distribution that involves ~80% of training sessions completed at low to moderate intensities and ~20% performed at higher intensities including interval training (Laursen et al., 2010; Seiler, 2010). These individuals also typically engage in a high overall volume of training, and limiting the time spent at high-intensity is believed necessary to reduce the risk of overreaching, injury and illness (Foster et al., 2022). There is debate over the best method to structure the portion of training time spent at high-intensity (i.e. polarized, pyramidal, threshold), including the organization and amount of time spent in the heavy and severe intensity domains (Burnley et al., 2022; Casado et al., 2022; Foster et al., 2022). Determination of the optimal sport- or event-specific periodization strategy may be more important than identifying the single best training intensity distribution that is broadly applicable to all endurance athletes.

Numerous short-term studies have demonstrated that replacing a portion of traditional aerobic "base" training with interval training for a few weeks or months improves endurance performance in already highly trained individuals (Acevedo & Goldfarb, 1989; Lindsay et al., 1996). A wide range of protocols have been applied in terms of interval bout duration and intensity that would broadly constitute both HIIT and SIT interventions (Stepto et al., 1999). The best type of interval training to optimize performance in already highly trained individuals is unclear. A limitation is that interventional studies that explicitly compare protocols in highly trained athletes are limited, and often involve relatively small numbers of participants. Interval training with work bouts close to race pace as well as shorter bouts at much higher intensities can improve performance, although the mechanisms may be different (Stepto et al., 1999). Recent work has highlighted the potential for effort-matched shorter intervals to induce superior training adaptations compared with longer intervals in very highly trained individuals (Ronnestad et al., 2015; 2020). This includes work in elite male cyclists that showed when training programs were matched for total volume and intensity, three weeks of thrice weekly training with short SIT-type intervals (3 sets of 13 x 30-s bouts at maximal-sustainable intensity, with 15 s recovery and 3 min between sets) improved 20-min cycling power, maximal aerobic power and maximal oxygen uptake (VO_2max) as compared to longer, HIIT intervals (4 series of 5-min work intervals with 2.5 min recovery between series) (Ronnestad et al., 2020). In contrast, other recent work in highly trained but non-elite men (Hov et al., 2023) and female endurance athletes (Helgerud et al., 2023) have concluded that HIIT elicits greater improvements in VO_2max compared to SIT. Relatively few studies have included elite females and research is warranted to clarify the potential impact of biological sex on various outcomes given physiological differences that could impact responses to interval training (Ansdell et al., 2020).

INTERVAL TRAINING FOR HEALTH

A key focus of interval training for health has been cardiorespiratory fitness as objectively measured by VO_2max. VO_2max reflects the peak integrative capacity of primarily the cardiovascular, pulmonary and skeletal muscular systems to transport and utilize oxygen during heavy exercise and thus provides a broad index of the functioning of many physiological processes. The clinical correlate, cardiorespiratory fitness, is a critical health marker and a recent meta-analysis based on over two million adults found the relative risk for all-cause mortality was reduced by 11% for every 1-metabolic equivalent increase in this marker (i.e. 3.5 ml/kg/min, which equates to a ~10% increase in fitness for a typical untrained adult), independent of age and biological sex (Laukkanen et al., 2022). Leading agencies have called for cardiorespiratory fitness to be included as a clinical vital sign, as it is a stronger predictor of mortality than established risk factors such as smoking, hypertension, high cholesterol and type 2 diabetes (Ross et al., 2016). Randomized controlled trials employing continuous exercise interventions that considered the interaction between exercise intensity and exercise amount have suggested that intensity is the strongest driver of the increase in cardiorespiratory fitness (Ross et al. 2015). Many studies have compared the effect of continuous and interval training on VO_2max, employing both work- and non-work-matched approaches, typically based on some measure of total energy expenditure or exercise volume, and usually lasting up to 12 weeks. Systematic reviews and meta-analyses based on this work in healthy adults reported that interval training elicited increases in VO_2max like traditional moderate-intensity

continuous training despite a lower total exercise amount, and superior increases in VO_2max after interval training compared to continuous training when the exercise "dose" is matched (Gist et al., 2014; Poon et al., 2021). However, this is not a universal finding (Wen et al., 2019), and the interested reader is referred to a considerate review by Bonafiglia et al. (2021) that addresses methodological concerns related to research design and an unclear risk of bias owing to poor reporting quality in many studies comparing interval and continuous training. As emphasized by the authors (Bonafiglia et al., 2021), the methodological and reporting principles highlighted in their review are applicable to all disciplines within exercise and sports medicine research.

Recent research has shown the potential for simple, practical and relatively time-efficient applications of interval training to increase VO_2max and other health-related markers. This includes activities such as brief vigorous stair climbing (Allison et al., 2017), bodyweight style exercise (Archila et al., 2021; Scott et al., 2019) and "exercise snacks" in which very short (≤ 1 min) bouts of activity are performed periodically throughout the day (Islam et al., 2022; Jenkins et al., 2019). Another novel approach that has recently been advanced is "vigorous intermittent lifestyle physical activity" (VILPA). This refers to brief intermittent bursts of vigorous-intensity physical activity embedded incidentally or secondary to regular activities of daily living, such as stair climbing or carrying children or groceries for short distances (Stamatakis et al., 2021). Stamatakis et al. (2022) examined the association of VILPA with mortality in over 25,000 individuals who identified as non-exercisers (mean age 62 years) in the UK Biobank. This work showed that as few as two or three short bouts or approximately 3-4 min of VILPA per day were associated with substantially lower all-cause, cardiovascular disease and cancer mortality risk as compared with participants who engaged in no VILPA. This work collectively highlights the potential for small amounts of vigorous physical activity to improve health. Larger interventional studies including randomized controlled trials that incorporate best practice approaches are needed to advance the field.

PRACTICAL APPLICATIONS

- Interval training is widely considered an essential component of training programs designed to optimize performance in endurance sport and events that require a high rate of aerobic energy metabolism.
- High-level endurance athletes typically practice an intensity distribution that involves an ~80:20 split of training sessions completed at low to moderate intensities and higher intensities including interval training, but the best way to structure the latter is unclear.
- Elite athletes who already practice traditional "high-intensity interval training" (e.g. repeated 5-min efforts at close to race pace) might consider using "effort-matched" shorter intervals (e.g. repeated 30-s efforts at a higher work rate) as a strategy to potentially augment training responses and enhance performance.
- Short-term interval training for at least several weeks can lead to measurable improvements in cardiorespiratory fitness, the clinical correlate of maximal oxygen uptake that is strongly associated with risk for all-cause mortality and many chronic diseases.
- Simple, practical and relatively time-efficient applications of interval training include "exercise snacks" or short (≤ 1 min) bouts performed periodically throughout the day, and "vigorous intermittent lifestyle physical activity", which refers to short bursts of vigorous effort embedded incidentally or secondary to regular activities of daily living.

SUMMARY

Interval training is a simple concept that refers to repeated bouts of relatively hard work interspersed with periods of easier effort or rest for recovery. While historically rooted in the training of high-level athletes for performance, interval training has been advocated for decades as a strategy to improve the physical conditioning of a wide range of individuals including people with chronic diseases. The method is widely accepted as an essential component to optimize performance, and high-level endurance athletes typically practice an intensity distribution that involves ~80% of training sessions completed at low to moderate intensities and ~20% performed at higher intensities including interval training. Systematic reviews and meta-analyses based on healthy adults have found that interval training can elicit increases in VO_2max like traditional moderate-intensity continuous training despite a lower total exercise amount, and superior increases in VO_2max after interval compared to continuous training when the exercise "dose" is matched, although this is not a universal finding. Recent research has shown the potential for simple, practical and relatively time-efficient applications of interval training to increase VO_2max and other health-related markers. This includes include "exercise snacks" or short (≤ 1 min) bouts performed periodically throughout the day, and "vigorous intermittent lifestyle physical activity", which refers to short bursts of vigorous effort embedded incidentally or secondary to regular activities of daily living.

The author thanks Dr. Alexandra M. Coates, Dr. Michael J. Joyner, Dr. Jonathan Little and Dr. Andrew Jones for insightful discussions that informed the writing of the present work.

The views expressed are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Inc.

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