SPEED-BASED HIGH-INTENSITY INTERVAL APPROACH AS AN ALTERNATIVE TO HEART RATE TRAINING: SIMILAR GAIN WITH LESS PAIN

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Abstract:

The aims of this study were to: 1) compare the effects of speed-based versus heart-rate-based high-intensity interval training (HIIT) on changes in high-intensity intermittent running performance, and 2) examine the between-group differences in heart rate (HR) and rating of perceived exertion (RPE) responses during the training sessions. Sixteen female students were divided into the HR-based (n=8, M±SD, age 17.3±0.2 years, body mass, 59.2±5.7 kg, and body height, 167.8±2.2 cm) and speed-based (n=8, age 17.2±0.3 years, body mass, 57.7±6.4 kg, and body height, 171.0±5.1 cm) groups before commencing the HIIT intervention. After completing five weeks of HIIT, both the HR-based and speed-based groups showed most likely moderate enhancement in high-intensity intermittent running performance (+9%, 90% confidence limits [CL] [6.4; 11.7]; standardized change [ES] +1.04 [0.75; 1.33]) and (+9.2%, [6.0; 12.5]; +1.09 [0.73; 1.46]), respectively. However, the difference between the experimental groups with regard to changes in high-intensity running performance was trivial. Between-group differences of weekly average HR and RPE responses showed trivial to moderate (ES range; -0.95; 0.15) and moderate to very large (ES: -0.63; -2.88) values, respectively. Although it seems that both the speed-based and HR-based HIIT approaches have some limitations when implementing for HIIT individualization, using the speed reached at the end of the 30-15 Intermittent Fitness test (V_{IFT}) seems to elicit the same performance enhancement, but with lower psychophysiological responses during short-term interventions.

Key words: *rating of perceived exertion (RPE), 30-15 Intermittent Fitness Test (30-15$_{IFT}$), V_{IFT}, physiological response, high-intensity running performance, young women*

Introduction

High-intensity interval training (HIIT) encompasses high-intensity bursts of intense exercises ranging from short to long work durations interspersed with recovery periods (Billat, 2001; Laursen & Jenkins, 2002). Due to the short time course of athletes' preparation and limited time available for conditioning in each training session, both sports scientists and practitioners try to implement more efficient methods to improve athletic performance (Buchheit & Laursen, 2013a, 2013b). Subsequently, HIIT has been receiving a growing interest as a time-efficient training method for improving high-intensity intermittent running performance (Buchheit & Laursen, 2013a; Buchheit & Rabbani, 2014; Buchheit, Rabbani, & Beigi, 2014; Rabbani & Buchheit, 2015).

Although designing appropriate HIIT programs requires consideration of multiple variables (e.g., work and relief duration, intensity and ratio, series duration, etc.), work intensity plays a major role when monitoring adaptations of cardiopulmonary and metabolic functions (Buchheit & Laursen, 2013a). There are two common ways for individualizing the intensity of HIIT: the HR-based and speed-based approaches, which use percentages of maximal heart rate (HR_{max}) (Buchheit & Rabbani, 2014; Impellizzeri, et al., 2006) and the maximal test's final speed (Buchheit & Laursen, 2013a; Rabbani & Buchheit, 2015), respectively, as references.

Heart-rate feedback, as a well-known index of physiological response during exercise, is still broadly used by practitioners to adjust training intensity (Achten & Jeukendrup, 2003; Buchheit, 2014). However, there seems to be some inherent limitations when using HR_{max} to individualize HIIT. One such limitation is the difficulty practitioners have in controlling running intensity during training. Another limitation is the possible dissociation between HR and actual metabolic demands, particularly during short time intervals (Buchheit & Laursen, 2013a).

Furthermore, the velocity associated with the maximal oxygen uptake ($VO2_{max}$), known as maximal aerobic speed (MAS), is mainly targeted in HR-based HIIT using percentages of HR_{max} to individualize interventions (Buchheit & Laursen, 2013a). However, athletes with similar MASs may have different anaerobic, inter-effort recovery, or change of direction (COD) profiles, leading to fewer standard individualizations at supramaximal intensities (i.e., intensities > MAS threshold) (Buchheit, 2012).

When individualizing interval training using a running speed, the maximum speed reached in the 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$, V_{IFT}) is a well-respected reference value, particularly in short and supramaximal bouts of exercises involving changes in direction (Buchheit, 2008). V_{IFT} is 2-5 $km{\cdot}h^{-1}$ faster than MAS (15-25%), and the anaerobic contribution to the $30\text{-}15_{IFT}$ is greater than during a continuous straight-line running test aiming to measure $VO2_{max}$ (Buchheit & Laursen, 2013a). Due to the nature of $30\text{-}15_{IFT}$, which demands that athletes run faster than MAS in the final stages, V_{IFT} not only represents aerobic power, but is also associated with anaerobic speed reserve, inter-effort recovery capacity, acceleration, deceleration, and COD abilities (Buchheit, 2008, 2012). Therefore, V_{IFT} can be used as a valid reference to individualize speed-based HIIT, especially for supramaximal formats (Buchheit, 2008, 2012; Rabbani & Buchheit, 2015).

Whereas different aspects of HIIT, in terms of cardiopulmonary and metabolic functions as well as performance improvement, have been extensively studied (Buchheit & Laursen, 2013a, 2013b), only one study has investigated the performance effects of speed-based versus HR-based HIIT approaches in young male athletes (Rabbani & Buchheit, 2015). However, there were some limitations in this study including different time frames for training of the experimental groups (i.e., different pre-season preparation periods) and a lack of recording acute HR responses throughout the entire intervention for the speed-based group.

Investigating the performance outcomes of different HIIT individualization methods provides important information for practitioners aiming to improve athletes' high-intensity intermittent fitness with a better approach. Therefore, it has not yet been determined whether different performance gains exist between methods in a strictly controlled experiment (i.e., an experiment in which acute HR and rating of perceived exertion [RPE] responses are monitored during training sessions). Comparing the differences in HR and RPE responses between groups during interventions would also provide important practical information and help coaches to highly standardize their periodization of speed-based methods. However, differences between HR and RPE responses during speed-based and HR-based approaches to HIIT sessions have not been investigated yet. Accordingly, the aims of this study were to: 1) compare the effects of speed-based versus HR-based high-intensity interval training (HIIT) on changes of high-intensity intermittent running performance, and 2) examine the between-group differences in HR and RPE responses during a training intervention in young female athletes.

Methods

Participants

Before commencing the training interventions, subjects were deliberately allocated into two homogenous groups of HR-based HIIT (n=8, M±SD, V_{IFT} 13.7±1.0 $km{\cdot}h^{-1}$, age 17.3±0.2 years, body mass 59.2±5.7 kg, and body height 167.8±2.2 cm) and speed-based (n=8, V_{IFT} 13.6±0.9 $km{\cdot}h^{-1}$, age 17.2±.3 years, body mass 57.7±6.4 kg, and body height, 171.0±5.1 cm) according to the baseline V_{IFT} and their anthropometric characteristics. Before the study, all subjects had a background of two months of regular physical activity (three sessions per week) in their school. During the intervention, however, the participants were instructed to refrain from taking part in any extra training outside of school to diminish any possible interfering influence on the experimental training-induced outcome. All participants became familiarized with the testing and training protocols before the experimental phase. The familiarization period (three sessions) was designed to conduct a pilot study to ensure both groups would receive the same physiological load in terms of HR response during the training sessions. In fact, the experiment was aimed to be conducted on an indoor track in 20-metre shuttle runs. However, there was not any exact information available in the literature regarding the percentage of V_{IFT} eliciting the 85-90% of HR_{max} in 20-metre shuttle runs. Therefore, in the pilot study, several trials were conducted to monitor the HR responses of speed-based group running with different percentages of V_{IFT}; the 90% of V_{IFT} was observed to elicit the 85-90% of HR_{max} for the 15"-15" HIIT formats.

Female athletes and their parents were informed of the experimental risks and signed an informed consent document before commencing the investigation. A local research ethics committee approved the protocol and the study conformed to the Declaration of Helsinki.

Data collection

Testing

All participants performed $30\text{-}15_{IFT}$ (Buchheit, 2008) before and after the training intervention.

Pre- and post-tests were separated from the HIIT sessions by periods of 72 hours. 30-15$_{IFT}$ was used as a field-based incremental high-intensity running performance test to examine the maximal performance, providing a reference value (i.e., V_{IFT}) to individualize speed-based HIIT (Buchheit, 2012). Both pre- and post-tests were performed on the indoor track at the same time of the day (starting at 10:00 a.m.) with similar temperature and humidity ranges of 26-28°C and 10-15%, respectively.

Training

The experimental period lasted five weeks (14 training sessions in total) (Table 1). Training sessions were conducted in the morning between 10:00 a.m. and 12:00 a.m. Before commencing the study, all participants were familiarized with the methods that would be used for controlling and adjusting running speeds according to a signal (HR on the smartphone application for the HR-based group and beeps for the V_{IFT}-based group). During the five weeks of the experiment, eleven HIIT sessions were completed. In the remaining three sessions, only a warm-up workout was performed by all athletes; this was due to the average worsened self-reported wellness measures collected before training sessions (Table 1). Training sessions were preceded by a standardized warm-up which included two sets of four-minute running intervals – the first at 75% of HR_{max} and the second at 85% of HR_{max} interspersed with two minutes of recovery time. During training sessions, all R-R intervals, which were sent from Bluetooth HR sensors (Polar H7, Finland) (Giles, Draper, & Neil, 2016) to a smartphone heart rate application (Elite HRV™), were recorded and then analyzed by Kubios HRV software in order to calculate accurate average HR responses for each individual (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014).

HR-based HIT

The intensity in the HR-based group was individualized according to the athletes' HR_{max} derived from the pre-test (i.e., 30-15$_{IFT}$); the intensity was similar to the predicted value, which followed the formula of Tanaka, Monahan, and Seals (2001). All participants were instructed to check their smartphone HR monitors on a regular basis while they were running to ensure that they were exercising within the prescribed zone. Athletes were running back and forth on an indoor track, at a self-controlled pace adjusted to HR responses, between two cones which were 20 meters apart from one another. Subjects in the HR-based group checked their HR on their smartphones after finishing each 15" trial to adjust, if needed, for the upcoming running velocity. Two investigators were also responsible for randomly checking athletes' smartphone monitors to ensure the athletes were running within the planned HR zones.

V_{IFT}-based HIT

The number of training sessions for the V_{IFT}-based group was similar to the number of training sessions for the HR-based group, and all athletes trained during the same time of the day on the same indoor track. Also, time series, their duration and the work/rest ratio were similar in both experimental groups (Table1). The only difference between the HR-based and the V_{IFT}-based training

Table 1. Five weeks of HIIT protocol

Week number	Session	HIIT sets/reps	Work/rest duration (seconds)	HR-based % of HR_{max}	Speed-based % of V_{IFT}
One	1	3/6	15/15	85-90%	90%
	2	3/6	15/15	85-90%	90%
	3	3/6	15/15	85-90%	90%
Two	4	2/6 – 1/8	15/15	85-90%	90%
	5	1/6 – 2/8	15/15	85-90%	90%
Three	6	3/6 – 1/2	15/15	90-95%	92.5 %
	7	0	(15 min jogging)		
	8	3/6 – 1/4	15/15	90-95%	92.5 %
Four	9	3/6	15/15	90-95%	95%
	10	0	(15 min jogging)		
	11	3/6	15/15	90-95%	95%
Five	12	3/6	15/15	90-95%	95%
	13	3/6	15/15	90-95%	95%
	14	0	(15 min jogging)		

Note. In all HIIT sessions, work periods were interspersed with three minutes of passive recovery; HIIT: high-intensity interval training. HR_{max}: maximal heart rate, V_{IFT}: maximal speed reached during the last stage of 30-15 Intermittent Fitness Test.

protocols was the way of prescribing and controlling the intensity. Running pace, according to 90 to 95% of V_{IFT}, was individualized for every athlete. All the V_{IFT}-based athletes were guided to set their running pace according to an audio signal. For the athletes in the V_{IFT}-based group, the distances between the front and back cones were adjusted to the individualized running pace detailed previously (Rabbani & Buchheit, 2015).

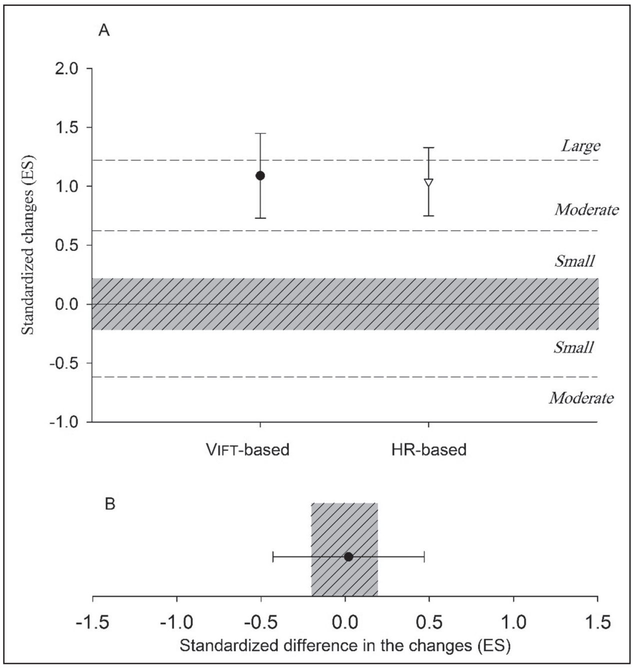
Statistical analyses

Data in the text and figures are presented as means with standard deviations (SD), or 90% confidence limits (CL) in the case of standardized change/differences when needed. All data were first log-transformed to reduce bias arising from non-uniformity error. Within-group changes and between-groups differences of V_{IFT} changes were analyzed. The between-group differences in weekly HR and RPE responses during HIIT sessions were also calculated. All results were expressed as percentage changes and as standardized differences or effect sizes (ES) with 90% CL (Hopkins, Marshall, Batterham, & Hanin, 2009). The Hopkins scale was used for standardized differences interpretation: <0.2: trivial; 0.2-0.6: small; 0.6-1.2: moderate; >1.2: large. A magnitude-based inference approach was used to analyze the chance that the true changes were clear or trivial (Batterham & Hopkins, 2006). The comparison of the changes was adjusted for the baseline V_{IFT} values. Probabilities were also calculated to establish whether the true changes/differences were lower than, similar to, or higher than the smallest worthwhile changes/differences (SWC, 0.2 × between-subjects SD) (Hopkins, et al., 2009).

Results

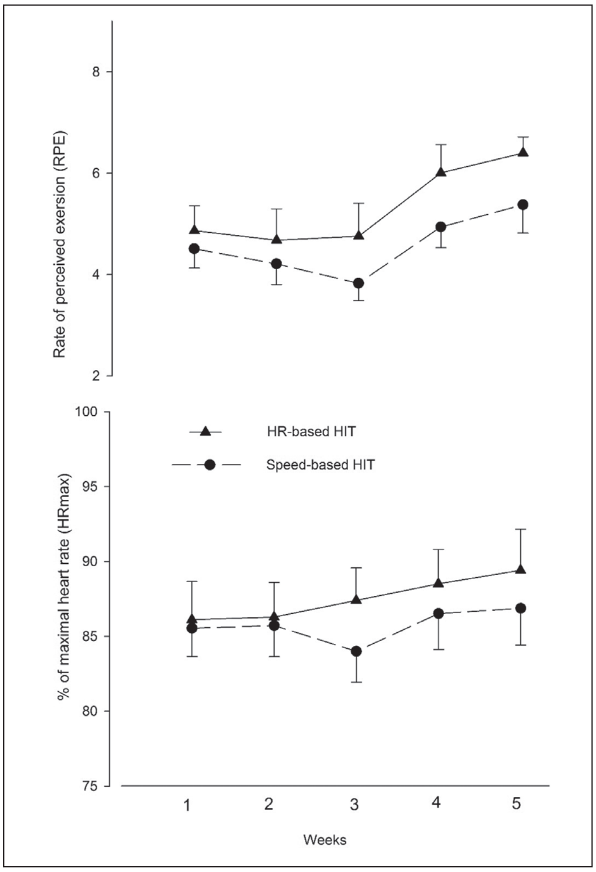
V_{IFT} was changed from 13.75 (1.04) to 15.00 (1.22) and from 13.63 (0.99) to 14.88 (1.03) in HR-based and speed-based HIIT groups, respectively. Within-group analyses in both the HR-based and speed-based HIIT groups showed most likely moderate improvement in high-intensity intermittent running performance (+9%, 90% CL [6.4; 11.7]; standardized change: +1.04 [0.75; 1.33]) and (+9.2%, [6.0; 12.5]; +1.09 [0.73; 1.46]), respectively (Figure 1/A). However, there was an unclear trivial difference between the experimental groups in changes of high-intensity running performance (+0.1%, [-3.4; 3.8]; .0 [-0.43; -0.47]) (Figure 1/B).

The between-group differences of weekly average HR and RPE responses were trivial to moderate (ES range; -0.95 to 0.16) and moderate to very large (ES; -0.63 to -2.88) values, respectively (Figure 2 and Table 2).



Note. The shaded area represents trivial change/differences; V_{IFT}: maximal speed reached in the final stage of 30-15 Intermittent Fitness Test, HR: heart rate, ES: effect size.

Figure 1. Within-group changes (A) and between-group differences of changes (B) (90% confidence intervals) in the performance of 30-15 Intermittent Fitness Test (30-15$_{IFT}$).



Note. HIIT: high-intensity interval training, HR: heart rate, RPE: rating of perceived exertion.

Figure 2. Weekly average acute HR and RPE responses in speed- and HR-based HIIT.

Table 2. Weekly differences between the groups in HR and RPE responses

Week number	Variable	% difference (90% CI)	Standardized difference (90% CI)	Interpretation	% greater/similar/ lower	Values
One	HR	0.5 (-2; 3.1)	0.15 (-0.56; 0.85)	Trivial	45/35/20	Unclear
	RPE	-7.2 (-14.9; 1.2)	-0.63 (-1.35; 0.10)	Moderate	3/13/84	Likely
Two	HR	0.5 (-1.9; 3.0)	0.16 (-0.60; 0.92)	Trivial	47/33/21	Unclear
	RPE	-9.7 (-18.9; 0.6)	-0.67 (-1.37; 0.04)	Moderate	1/11/87	Likely
Three	HR	-2.8 (-5.1; -0.5)	-0.95 (-1.7; -0.16)	Moderate	1/5/94	Likely
	RPE	-19.3 (-27.2; -10.5)	-1.40 (-2.08; -0.73)	Large	0/0/100	Most likely
Four	HR	-1.1 (-3.6; 1.6)	-0.34 (-1.10; -0.49)	Small	14/25/61	Unclear
	RPE	-17.8 (-24.4; -10.7)	-1.75 (-2.49; -1.01)	Large	0/0/100	Most likely
Five	HR	-1.6 (-4.4; 1.2)	-0.44 (-1.20; -0.33)	Small	8/21/70	Unclear
	RPE	-16.3 (-22.8; -9.3)	-2.88 (-4.18; -1.58)	Very large	0/0/100	Most likely

Note. Values are mean ± CI; CI: confidence interval, %: percentage, HR: heart rate, RPE: rating of perceived exertion.

Discussion and conclusions

The aims of this study were to: 1) compare the effects of speed- vs. HR-based high-intensity interval training (HIIT) on changes of high-intensity intermittent running performance, and 2) examine the between-group differences in HR and RPE responses during the training intervention. The main findings of the present study were that: 1) almost the same level of improvement (most likely moderate) was seen in V_{IFT} following the HIIT intervention using either the speed-based or HR-based approach, and 2) trivial to very large differences were observed between both HIIT interventions in weekly HR and RPE responses. The trivial difference observed between the groups in changes of V_{IFT} showed that the speed-based approach can be implemented as a practical way of conducting supramaximal training within a short time span. Trivial to very large differences were observed between both methods, suggesting that overloading a V_{IFT}-based approach needs careful consideration.

In the analyses of the within-group changes, the results showed 9.0 and 9.2% performance enhancements in the HR-based and V_{IFT}-based groups, respectively. In the present study, both groups experienced a moderate change after the training intervention (Figure 1/A). It has been previously reported that low-fit athletes may experience larger improvements in their maximal performance than their fitter counterparts following training interventions (Mann, Lamberts, & Lambert, 2014). However, moderate changes observed in the present study for both groups with a lower fitness profile were not in agreement with the large improvement in the recent study of the speed-based HIIT intervention (Rabbani & Buchheit, 2015). A higher total training load, which was tolerated by the team sport athletes in the recent study, could be, at least in part, responsible for this disagreement. The results of our study, however, support previous evidence of similar HIIT-induced adaptations for both males and females (Astorino, et al., 2011). The difference between groups in terms of V_{IFT} changes was trivial in our study (Figure 1/B) and could not confirm the superiority of the V_{IFT}-based approach which had been reported in the study by Rabbani and Buchheit (2015). It seems that some limitations in the aforementioned study – namely, the differing time schedules for training of the experimental groups and the lack of HR monitoring during V_{IFT}-based HIIT sessions – might be responsible, to some extent, for this disagreement.

Analyses of the between-group differences in weekly HR responses showed trivial effects in the first two weeks (Table 2 and Figure 2), demonstrating the similar physiological load of 90% of V_{IFT} and 85-90% of HR_{max} (Table 1). There was, however, a moderate reduction in HR responses in the speed-based group in the third week (Table 2 and Figure 2). This reduction was observed when the intensity increased further to 92.5 and 90-95% for the speed- and HR-based HIIT groups, respectively. This HR response difference, however, attenuated in the fourth and fifth weeks with a small effect (Table 2 and Figure 2) when the intensity was increased even further to 95% of V_{IFT} for the speed-based group (Table 1). Likewise, the differences between groups in RPE response during the training weeks ranged from moderate to very large effects (Table 2 and Figure 2), which suggested that less psychological strain was experienced among the athletes when using V_{IFT}-based approach. The change from a moderate to a large effect from the first and second weeks to the third week is likely associated with the implementation of the first overload approach in the third week (90 to 92.5%, Table 2). A very large difference observed in RPE responses in the fifth week (Table 2) might be associated with the speed-based HIIT limitation when increasing intensity according to the baseline values of V_{IFT}.

Although in the HR-based approach HR responses changes according to athletes' adaptation throughout the intervention period (Gibala & McGee, 2008), there would not be an exact estimation of athletes' physiological progress in the speed-based HIIT approach if HR responses are not monitored. Nevertheless, there seems to be the same physiological load at least in the first two weeks, when using both HIIT approaches. Reduced HR responses and the difference in RPE with a higher magnitude in the third week, which was observed in the speed-based group, are consistent with previous evidence of increased skeletal muscle oxidative capacity and improved endurance performance following only two weeks of HIIT intervention (Gibala & McGee, 2008). The results seem to illustrate that, while the intensity was increased in the third week from 90 to 92.5% in the V_{IFT}-based group, such a level might not overload the athletes enough parallel to their adaptation. The higher average RPE reported by the HR-based group during the entire experiment in the present study can only be speculated. In the HR-based group, the possible higher cognitive involvement due to the regular checking of HR monitors during training – and, likely, its subsequently higher mental fatigue (Boksem & Tops, 2008) – have probably played an important role. Self-obligated controlling of running pace in the HR-based group probably increased the rating of perceived exertion (Borg, 1982). The HR-based group also recived higher cardiovascular loads in the final weeks of training intervention (Figure 2), which possibly increased their perceptual training intensity.

There were, however, some limitations of the present study, like slightly hot weather during testing sessions (26-28°C), the fact that subjects were not randomly allocated into experimental groups, and the use of individual smartphone applications for monitoring HR responses during training sessions. These limitations suggest that conducting more controlled investigations are required in the future to describe the differences, if any, between the physiological responses and fitness outcomes of these HIIT approaches (i.e., speed-based vs. HR-based). In practice, athletes usually train more at high intensities with a speed-based approach, whereas lower intensities during HIIT are usually monitored by HR, so the HR-based approach for very high intensities is artificial and not practical.

In conclusion, although it seems that both the V_{IFT}- and HR-based approaches have some limitations for HIIT individualization, the V_{IFT} may elicit the same performance improvement, albeit with a possibly lower RPE experienced among athletes during the training sessions. Therefore, it seems that the V_{IFT}-based approach is a more suitable method of developing high-intensity running performance than the HR-based approach. Special attention, however, needs to be paid to the magnitude of athletes' physiological progression in the speed-based approach and monitoring athletes' fitness changes using HR measures on a weekly basis is recommended (Buchheit, 2014).

References

Achten, J., & Jeukendrup, A. E. (2003). Heart rate monitoring. *Sports Medicine*, *33*(7), 517-538.

Astorino, T. A., Allen, R. P., Roberson, D.W., Jurancich, M., Lewis, R., McCarthy, K., et al. (2011). Adaptations to high-intensity training are independent of gender. *European Journal of Applied Physiology*, *111*(7), 1279-1286.

Batterham, A.M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50-57.

Billat, L. V. (2001). Interval training for performance: A scientific and empirical practice. *Sports Medicine*, *31*(1), 13-31.

Boksem, M.A., & Tops, M. (2008). Mental fatigue: Costs and benefits. *Brain Research Reviews*, *59*(1), 125-139.

Borg, G.A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sport and Exercise*, *14*(5), 377-381.

Buchheit, M. (2008). The 30-15 Intermittent Fitness Test: Accuracy for individualizing interval training of young intermittent sport players. *Journal of Strength and Conditioning Research*, *22*(2), 365-374.

Buchheit, M. (2012). Individualizing high-intensity interval training in intermittent sport athletes with the 30-15 Intermittent Fitness Test. *NSCA-Hot Topic Series*, Retrieved February 15, 2017, from: http://www.nsca.com/Education/Articles/Hot-TopicIndividualizing-HIIT-in-Intermittent-Athletes

Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? *Frontiers in Physiology*, *27*(5), 73.

Buchheit, M., & Laursen, P.B. (2013a). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. *Sports Medicine*, *43*(5), 313-338.

Buchheit, M., & Laursen, P.B. (2013b). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine*, *43*(10), 927-954.

Buchheit, M., & Rabbani, A. (2014). The 30–15 Intermittent Fitness Test versus the Yo-Yo Intermittent Recovery Test level 1: Relationship and sensitivity to training. *International Journal of Sports Physiology and Performance*, *9*(3), 522-524.

Buchheit, M., Rabbani, A., & Beigi, H.T. (2014). Predicting changes in high-intensity intermittent running performance with acute responses to short jump rope workouts in children. *Journal of Sports Science and Medicine*, *13*(3), 476.

Gibala, M.J., & McGee, S.L. (2008). Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exercise and Sport Sciences Reviews*, *36*(2), 58-63.

Giles, D., Draper, N., & Neil, W. (2016). Validity of the Polar V800 heart rate monitor to measure RR intervals at rest. *European Journal of Applied Physiology*, *116*(3), 563-571.

Hopkins, W., Marshall, S., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sport and Exercise*, *41*(1), 3-13.

Impellizzeri, F.M., Marcora, S.M., Castagna, C., Reilly, T., Sassi, A., Iaia, F.M., et al. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. *International Journal of Sports Medicine*, *27*(06), 483-492.

Laursen, P.B., & Jenkins, D.G. (2002). The scientific basis for high-intensity interval training. *Sports Medicine*, *32*(1), 53-73.

Mann, T.N., Lamberts, R.P., & Lambert, M.I. (2014). High responders and low responders: Factors associated with individual variation in response to standardized training. *Sports Medicine*, *44*(8), 1113-1124.

Rabbani, A., & Buchheit, M. (2015). Heart rate-based versus speed-based high-intensity interval training in young soccer players. In T. Favero, B. Dawson & B. Drust (Eds.), *Proceedings Book of the 4td World Conference on Science and Soccer, Portland, 2014* (pp. 119-130). University of Portland Oregon.

Tanaka, H., Monahan, K.D., & Seals, D.R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153-156.

Tarvainen, M.P., Niskanen, J.P., Lipponen, J.A., Ranta-Aho, P.O., & Karjalainen, P.A. (2014). Kubios HRV – heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, *113*(1), 210-220.

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