High-intensity interval training using whole-body exercises: training recommendations and methodological overview

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REVIEW ARTICLE

High-intensity interval training using whole-body exercises: training recommendations and methodological overview

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Summary

HIIT whole body (HWB)-based exercise is a new calisthenics exercise programme approach that can be considered an effective and safe method to improve physical fitness and body composition. HWB is a method that can be applied to different populations and ages. The purpose of this study was to describe possible methodologies for performing physical training based on whole-body exercise in healthy subjects. The HWB sessions consist of a repeated stimulus based on high-intensity exercise that also include monitoring time to effort, time to recuperation and session time. The exercise intensity is related to the maximal number of movements possible in a given time; therefore, the exercise sessions can be characterized as maximal. The intensity can be recorded using ratings of perceived exertion. Weekly training frequency and exercise selection should be structured according to individual subject functional fitness. Using this simple method, there is potential for greater adherence to physical activity which can promote health benefits to all members of society.

Introduction

The performance of physical exercise utilizing body weight was practice by the ancient Romans, as a form of military preparation. However, the use of an individual's whole-body exercise while performing physical activity was not integrated into physical education until 1785.

In 1829, the Swiss physical trainer Clias published a book entitled Kallisthenie – Exercises for Beauty and Strength, which featured calisthenics as rhythmically practiced exercises with the use of body weight (Alijas & Torre, 2015). Later, the Swedes generated a table with groups of organized exercises according to specific objectives, and they suggested the use of daily training sessions (Alijas & Torre, 2015).

Regarding the use of an individual's body weight as the training load, some researchers (McRae *et al.*, 2012; Gist *et al.*, 2014, 2015) reintroduced the concept of training with body weight using a high-intensity interval training (HIIT) method in their experiments, and they characterized this method as whole-body training (McRae *et al.*, 2012). This method is also known as whole-body calisthenics (Gist *et al.*, 2014, 2015).

In this newly proposed form of calisthenics (McRae *et al.*, 2012; Gist *et al.*, 2014, 2015), training with body weight was performed in professional practice using simple conventional variables available in the literature. These included intensity, modality and duration of work, intensity and duration of relief, number and duration of sets, time and number of intervals between sets, recovery intensity and duration which are used for HIIT prescription (Buchheit & Laursen, 2013a,b). According to Buchheit & Laursen (2013a,b), the manipulation of each variable in isolation has a direct impact on metabolic, cardiopulmonary and neuromuscular adaptations observed. In contrast, the manipulation of more than one parameter results in greater difficulty to predict outcomes due to complex interaction of inter-related parameters. These factors include the use of high-intensity supramaximal stimuli (Germano *et al.*, 2015), a stimulation time between 10 s and 1 min (McRae *et al.*, 2012), and a recovery interval of 10 s to 2 min (Buchheit & Laursen, 2013a,b), resulting in a total session time of between 4 and 30 min (Gibala *et al.*, 2014).

HIIT became known as an effective and safe tool for increased conditioning in both athletes and non-athletes (Gibala & Little, 2010; Gibala *et al.*, 2014; Osawa *et al.*, 2014; Rozenek *et al.*, 2016). The sessions consist of repeated high-intensity stimuli followed by a short recovery time, which can be performed using ergometers, such as a static bike or treadmill (Gibala et al., 2014; Rozenek et al., 2016) or using individual body weight (McRae et al., 2012; Gist et al., 2014, 2015).

According to Gray et al. (2016), HIIT using the whole body as the resistive force could be considered as practical and low cost compared to traditional HIIT that utilizes specialized equipment that is frequently used in a laboratory or gym-based situation. Additionally, whole-body exercise may be performed indoor or outdoor, an important characteristic when we consider individual preferences related to gymnasium membership, the costs involved and the training environment. However, the efficient application of HIIT requires a considerable theoretical and practical approach by the professional during the preparation of the training programme, especially monitoring the variable load during the training session (Tucker et al., 2015).

No previous reports have described a safe strategy for controlling the training load in this form of exercise. However, variables such as the stimulus time, recovery time and total session time can be manipulated so that the individual can perform the greatest number of stimuli at the requested intensity, regardless of fitness level (Buchheit & Laursen, 2013a).

From this perspective, it is possible that the load used during the all-out method, which is characterized as the maximum possible intensity during the stimulus period as proposed by the published protocol (Gibala & McGee, 2008), can easily be manipulated. This can be accomplished by increasing or decreasing the stimulus or recovery times during the training cycles according to different practitioner profiles (beginner, intermediate, and advanced). In addition, other variables, such as the total time and selection of exercises to be performed during the training session, are important for the success of properly prescribed HIIT whole-body training (McRae et al., 2012; Buchheit & Laursen, 2013a,b).

A consensus does not exist in the literature regarding how to handle the training loads during the HIIT whole-body session; further, sufficient evidence to guide the implementation of an adequate training programme is lacking. Thus, the purpose of this document was to present possible strategies for prescribing the training load variables based on the HIIT whole-body training exercise.

Methods

An extensive literature search was performed using PubMed and MEDLINE. Searches were performed for 'HIIT', 'whole-body training', 'resistance training', 'exercise', 'whole-body calisthenics', 'calisthenics exercise', 'high-intensity interval training' and combinations of the aforementioned keywords. The publications obtained were screened for studies that included healthy humans. Studies on HIIT whole body were preferentially included. In their absence, HIIT studies focusing on body fat loss or fitness were used. Due to a lack of studies found specifically on natural HIIT whole body during manuscript preparation, and the relative broad nature of this review, a narrative style was chosen (Helms et al., 2015).

Time and training load variables

An increasing body of evidence suggests that HIIT induces physiological adaptations that are superior (Buchheit & Laursen, 2013a; Germano et al., 2015; Rozenek et al., 2016) or similar to conventional continuous training (De Feop et al., 2013; Gillen et al., 2016; Keating et al., 2014).

The majority of studies in the literature (Tabata et al., 1997; Gibala & McGee, 2008; Osawa et al., 2014; Tucker et al., 2015; Rozenek et al., 2016) that employed the traditional HIIT method traditionally used treadmills, or cycle ergometers, and incorporated stimulus and recovery times ranging from 10 s to 4 min. Exercise session times were recorded to be between 4 and 28 min duration.

According to previous studies (Tabata et al., 1997; Gibala & McGee, 2008; Tucker et al., 2015; Gray et al., 2016; Rozenek et al., 2016), the overall duration of the HIIT training session can vary between 4 and 32 min. In addition, this time-frame has been established in the literature to be sufficient for promoting favourable adaptations to weight loss and increased physical fitness quickly and efficiently (Gibala & Little, 2010; McRae et al., 2012; Buchheit & Laursen, 2013a; Gibala et al., 2014; Rozenek et al., 2016). However, exercise protocols applied to HIIT whole-body training are still sparse in the literature, limiting the applicability of this modality.

Another important component of physical training programmes is the training load (Pinho et al., 2016). Conceptually, the training load consists of the stimuli that make up the training session; moreover, this parameter is considered an important variable for controlling the exercise, and it may be monitored internally and externally (Borin et al., 2007, 2008; Mazurek et al., 2016).

The external load is considered the work performed during training (Borin et al., 2008; Mazurek et al., 2016; Pinho et al., 2016) and is directly related to the volume and intensity of the exercise variables during HIIT. The training load can be characterized as follows: the number of stimuli and total training time (volume) and the intensity of the stimulus and recovery time (intensity). However, the internal training load corresponds to the acute physiological responses induced by the exercise (Pinho et al., 2016). The adaptation to the training stimulus will be greater as the internal load is increased (Impellizzeri et al., 2006).

The main variables of adaptation are heart rate during exercise, recovery heart rate and blood lactate concentrations postexercise (Impellizzeri et al., 2006; Borin et al., 2007, 2008; Pinho et al., 2016).

In conventional HITT protocols, the main internal load parameters used in the literature (Impellizzeri et al., 2006; Borin et al., 2007, 2008) correspond to effort perception, heart rate and VO2max. With regard to monitoring the external load, conventional HITT protocols have traditionally considered the stimulation time and recovery time as the training load indicators (Tabata et al., 1997).

In addition, the proportion of the recovery time relative to the time effort and the total length of the training session have been widely used for monitoring (Buchheit & Laursen, 2013a,b; Tucker et al., 2015). In this type of monitoring, the following loads have been applied: 1:1, in which the stimulus and recovery times are similar (Osawa et al., 2014; Rozenek et al., 2016); 1:1/2, in which the recovery time is half the time of the stimulus (Tabata et al., 1997), resulting in a training session with greater intensity but shorter duration; and 1:2, where the recovery time is twice the stimulus time, which allows for greater recovery during the training session.

Another important point to consider is that recovery time following a HIIT session could have active or passive component (Dourado et al., 2004; Fujita et al., 2009; Abderrahman et al., 2013). Fujita et al. (2009) found no differences in power between sprint sessions when active and passive recovery sessions were used. However, differences were found in VO2 max and heart rate when active recovery was used when compared with a passive recovery protocol. In addition, the active recovery sessions were more efficient than passive recovery in promoting maintenance of heart rate, oxygen consumption and removal of blood lactate (Abderrahman et al., 2013).

Although the training load control for HIIT whole body has not yet been fully clarified, we recommend that the applied load be characterized as all out, where the scores of effort perception of the adapted Borg scale (Tiggemann et al., 2010) are between 9 and 10 for each stimulus during all training cycles. The cycles are equal to the product of the sum of the stimulation time with the time of recovery, as described in Fig. 1; this method was previously used in conventional HIIT training (Buchheit & Laursen, 2013a,b).

Only three studies (McRae et al., 2012; Gist et al., 2014, 2015) relating to HIIT whole body have been published, and these studies suggest that this method produces positive changes including improved fitness, decreased body fat and increased muscle strength and endurance. Using the protocol proposed by Tabata et al. (1997), McRae et al. (2012) reported

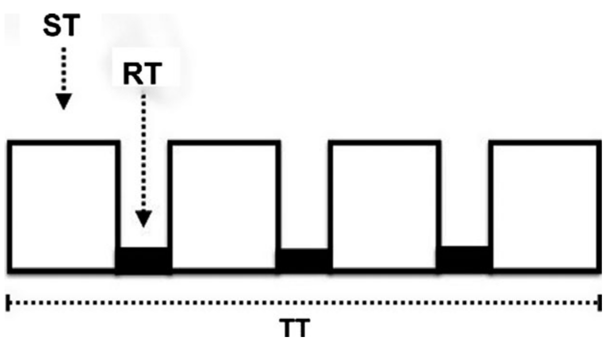

Figure 1 Distribution of loads of time on HIIT. ST, stimulation time; RT, recovery time; TT, Total training time in the session.

improvement in both the VO2peak at the time of fatigue and body weight. Gist et al. (2014, 2015) used a methodological proposal of 4–7 cycles of 30 s of exercise with 4 min of recovery, and both studies showed an improvement in VO2peak.

Given the observations with the training load control in conventional HIIT, we can consider that manipulating the stimulus time (ST), recovery time (RT) and total training time (TT) variables (Fig. 1) is also crucial for the physiological adaptations during the session of HIIT whole body. However, we have found no published studies with suggested guidelines for the training load ratio or how this load ratio should be managed in the training programme, for HIIT whole body, according to the profile of the practitioner.

Exercise selection and weekly frequency

The exercise selection used on whole-body exercise traditionally is based on callisthenic sessions; recently, Anthony & Brown (2016) proposed the following exercise classification: power stabilization (CORE) and support. In this proposal for training, the importance of the selection of exercises in the developmental phase of conditioning was essential because it allowed coaches to maximize performance and reduce sports-related injuries (Anthony & Brown, 2016). Rozenek et al. (2016) also proposed a system of training in which a positive overall result was achieved in the performance of individuals using the training programme. McRae et al. (2012) used four free exercises in his study (burpee, jumping jack, mountain climber and squat thrust); however, the criteria for choosing both the exercises and the order of the selected exercises were not described.

Considering the criteria for selecting and order of the exercises, we recommend that the adjustments used for strength training be considered. Numerous previous studies (Pauletto, 1986; Simão et al., 2005, 2007; Janning et al., 2009; Santos et al., 2009; Gil et al., 2011) have shown that exercise selection should be considered as a critical parameter in neuromuscular adaptations; therefore, it is arguable that the choice of exercises can significantly affect the dynamic training session.

While no guidelines exist for the criteria for selecting the exercises in HIIT whole body, we suggest that the complexity of the motor task be considered a viable strategy when organizing the training session. According to the motor control point of view (Semenick Douglas & Adams Kela, 1987), we can classify the exercises into two distinct groups:

1 With a unique movement pattern, jumping Jack (Fig. 2a).
2 With a unique movement combined, burpee (Fig. 2b)

Performing exercises that are more complex requires greater energy expenditure (Pauletto, 1986; Simão et al., 2007) and increases metabolic demand (De Aguiar et al., 2013; Fernandez-Fernandez et al., 2015) and can therefore affect the dynamics of the training session, from the quality of movements, associated with greater or lesser fatigability and to the

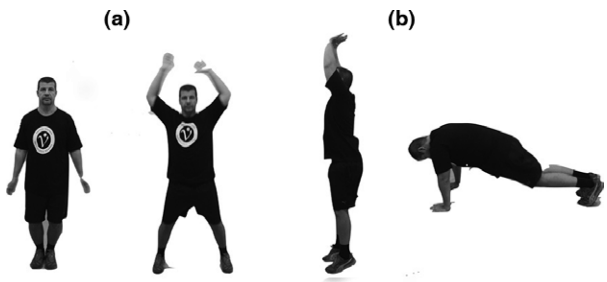

Figure 2 Classification according to the complexity of the motor gesture exercises. (a) Exercise jump jack; (b) burpee exercise.

total energy expenditure during the exercise (Amorin & Faria, 2012; De Aguiar et al., 2013; Garcia et al., 2013; Fernandez-Fernandez et al., 2015).

Despite the performance of numerous studies on the physiological impact of HIIT, gaps in scientific evidence still exist regarding the practical application of HIIT whole body. These gaps include the cost effectiveness for fitness programmes, as suggested by Gray et al. (2016), as well as guidelines for handling exercise session variables such as load control, session length, weekly frequency and exercise selection.

In relation to weekly frequency, to the best of our knowledge, there are few studies (Dalleck et al., 2010; Hatle et al., 2014) that have investigated the impact of weekly HIIT frequency on training parameters. Dalleck et al. (2010) demonstrated improvements in lactate threshold; however, a dose–response relationship between frequency of interval training and the magnitude of lactate threshold improvement occurred at a sprint training frequency of only 1–2 days week^{-1}. Hatle et al. (2014) comparing a moderate (4× week^{-1}) and high (8× week^{-1}) frequency using treadmill training found improvements in VO2 max in both protocols. However, a delay in adaptation was noted in the high-frequency group, which may have been related to recovery, or exercise and rest ratio during the activity. Further studies are required to investigate this finding.

Therefore, based on the published data, we propose a basic guideline for the preparation of a HIIT whole-body programme, using a maximal system (Table 1). This system is based on control of the external training loads through the stimulus, time recovery cycles, overall training time in the session and selection of exercises. The internal load is monitored through perceived exertion, with scores ranging from 9 to 10 on the scale adapted to the level of physical fitness and the motor experience of the practitioner.

Our proposal is based on a total fixed training time (30 min) for different practitioner profiles and on the effort time for each fixed cycle (30 s), but with total time of stimuli during session for different profiles (beginners = 10 min, intermediate = 15 min and advanced = 20 min). The intensity of each stimulus is maximal, regardless of the practitioner profile, but the recovery time varies according to the HIIT whole-body practitioner profile, which takes into account the relationship of the training load. Therefore, beginners have a ratio with lower physiological impact (1:2), intermediates have a greater load pattern (1:1) and advanced practitioners have a load ratio that is much more intense (1:1/2), as shown in Fig. 3. In addition, another important point in our proposal is the alternation between exercises characterized as simple (less fatigue) and complex (greater fatigue) to better develop the training programme for intermediate profile training.

Table 1 Proposal for HIIT whole body, with different levels of fitness.

Parameters	Beginner	Intermediate	Advanced
Exercise selection	Pattern	Pattern and combined	Combined
Frequency (days week^{-1})	2–3	3–4	5
External load			
Effort time (s)	30″	30″	30″
Recovery time (s)	60″	30″	15″
Session time (min)	20–30′	20–30′	20–30′
Movement amount[a]	Maximal	Maximal	Maximal
Internal load			
RPE (score)	9–10	9–10	9–10

RPE, rating of perceived exertion scale (0–10).
[a]Maximal number of movements during efforts time.

Recommendations

HIIT is an effective training method for enhancing fitness and weight loss. Given these known adaptations due to HIIT whole-body training, we recommend the use of training load by manipulating the stimulus time variables, recovery time and choice of exercises according to the practitioner profile. We also recommend monitoring intensity using perceived exertion with scores ranging from 9 to 10. Regarding quantification of load, as shown in Table 1, we recommend three

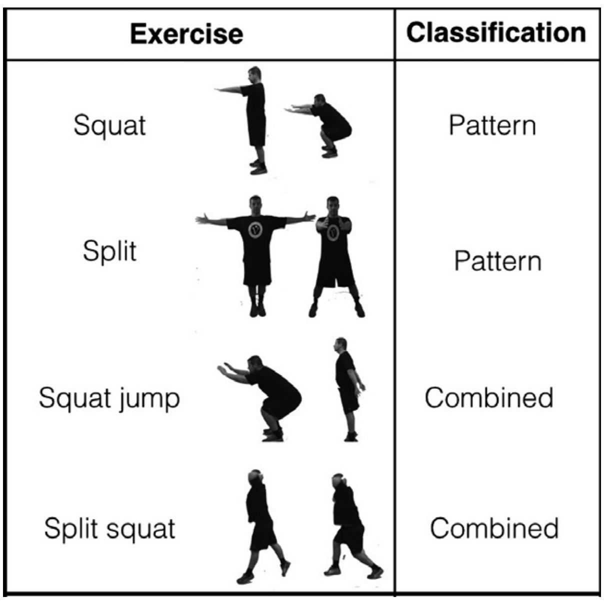

Figure 3 Classification according to the complexity of the motor gesture exercises.

cycles per week for beginners and four to five cycles per week for intermediate and advanced practitioners. In intermediate individuals, exercises characterized as simple and complex can be applied, and we recommend switching between a simple exercise and a complex exercise during training; other exercises that can be incorporated in the training session are shown in Fig. 3.

The HIIT whole body is an effective and safe method to improve conditioning and also for those seeking weight loss. The work methodology allows it to be carried out in any environment that is specific for training or not, such as gyms, clubs, parks, studios and even at home. Finally, we believe that the proposed methodology is simple and can generate greater adherence to physical activity to promote health in all types of individuals from a variety of backgrounds and abilities.

Conclusion

Considering the evidence available in the literature, we suggest that HIIT whole-body training is an alternative strategy that needs consideration for use to improve parameters that are used to measure adaptations to physical training. These parameters include, time to exhaustion, time to recuperation and session time. All subjects engaging in HIIT should be encouraged to perform a maximal number of movements possible, in the prescribed time period, and the effort needs to be characterized as maximal. The intensity of the efforts can be controlled by monitoring the rating of perceived exertion. Finally, the weekly frequency and exercise selection should be related to the functional fitness of the individuals, and should also be subject specific.

References

Abderrahman AB, Zouhal H, Chamari K, *et al.* Effects of recovery mode (active vs. passive) on performance during a short high-intensity interval training program: a longitudinal study. *Eur J Appl Physiol* (2013); **113**: 1373–1383.

Alijas RDR, Torre AHD. Calisthenics: Volviendo a los Origenes. *Emásf Digit J Educ Phys* (2015); **33**: 87–96.

Amorin PRS, Faria FR. Energy expenditure of human activities and their impact on health. *Motricity* (2012); **8**(S2): 295.

Anthony CC, Brown LE. Resistance training considerations for female surfers. *Natl Strength Cond Assoc* (2016); **2**: 64–69.

Borin JP, Prestes J, Moura NF. Characterization, control and evaluation: limitations and possibilities within the sports training. *Rev Treinamento Desportivo* (2007); **8**: 6–11.

Borin JP, Gomes AC, Dos Santos Leite G. Sports preparation: control aspects of training load in team sports. *Rev Educ Física/UEM* (2008); **18**: 97–105.

Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle. *Sports Med* (2013a); **43**: 313–338.

Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. *Sports Med* (2013b); **43**: 927–954.

Dalleck L, Bushman TT, Crain RD, *et al.* Dose response relationship between interval training frequency and magnitude of improvement in lactate threshold. *Int J Sports Med* (2010); **31**: 567–571.

De Aguiar RA, *et al.* Effect of intensity intermittent running 30s exercise: 15s maintenance time on or near the VO2max. *Motriz Rev Educ Fís* (2013); **19**: 207–216.

Dourado C, Moysi-Sanchis J, Calbet JAL. Effects of recovery mode on performance O2 uptake, and O2 deficit during high-intensity intermittent exercise. *Can J Appl Physiol* (2004); **29**: 227–244.

Feop D, *et al.* Is high-intensity exercise better than moderate-intensity exercise for weight loss? *Nutr Metab Cardiovasc Dis* (2013); **23**: 1037–1042.

Fernandez-Fernandez J, *et al.* Acute physiological responses during crossfit® workouts. *Eur J Human Mov* (2015); **35**: 1–25.

Fujita Y, Koizumi K, Sukeno S, *et al.* Active recovery effects by previously inactive muscles on 40-s exhaustive cicling. *J Sports Sci* (2009); **27**: 1145–1151.

Garcia NM, *et al.* Acquisition of multiple physiological parameters during physical exercise. *Digit Adv Med E-Health Commun Technol* (2013);DOI: 10.4018/978-1-4666-2794-9.ch006.

Germano MD, *et al.* High intensity interval training: cardiorespiratory adaptations, metabolic and performance. *Int J Sports Sci* (2015); **5**: 240–247.

Gibala MJ, Little JP. Just HIT it! A time -efficient exercise strategy to improve muscle insulin sensitivity. *J Physiol* (2010); **588**: 3341–3342.

Gibala MJ, McGee SL. Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? *Exerc Sport Sci Rev* (2008); **36**: 58–63.

Gibala MJ, Gillen JB, Percival ME. Physiological and health-related adaptations to low-volume interval training: influences of nutrition and sex. *Sports Med* (2014); **44**: 127–137.

Gil S, *et al.* The effect of the exercises order on number of repetitions and rate of perceived effort in resistance trained men. *Rev Bras Educ F_ıs Esporte* (2011); **25**: 127–135.

Gillen JB, *et al.* Twelve weeks of sprint interval training improves indices of cardio metabolic health similar to traditional endurance training despite a five-fold lower exercise volume and time commitment. *PLoS One* (2016); **11**: e0154075.

Gist NH, Freese EC, Cureton KJ. Comparison of responses to two high-intensity intermittent exercise protocols. *J Strength Cond Res* (2014); **28**: 3033–3040.

Gist NH, *et al.* Effects of low-volume, high-intensity whole-body calisthenics on army ROTC cadets. *Mil Med* (2015); **180**: 492–498.

Gray SR, *et al.* High-intensity interval training: key data needed to bridge the gap from laboratory to public health policy. *Br J Sports Med* (2016); **50**: 1231–1232. doi: 10.1136/bjsports-2015-095705

Hatle H, Stobakk PK, Molmen HE, *et al.* Effect of 24 sessions of high intensity aerobic interval training carried out at either high or moderate frequency, a randomized trial. *PLoS One* (2014); **9**: e88375.

Helms E, Fitschen JP, Aragon A, *et al.* Recommendations for natural bodybuilding contest preparation: resistance and cardiovascular training. *J Sports Med Phys Fitness* (2015); **55**: 164–178.

Impellizzeri FM, *et al.* Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int J Sports Med* (2006); **27**: 483–492.

Janning PR, *et al.* Influence of resistance exercises order performance on postexercise hypotension in hypertensive elderly. *Rev Bras Med Esporte* (2009); **15**: 338–341.

Keating SE, Machan EA, O'Connor HT, *et al.* Continuous exercise but not high intensity interval training improves fat distribution in overweight adults. *J Obes* (2014); 834865. doi: 10.1155/2014/834865

Mazurek K, Zmijewski P, Krawczyk K, *et al.* High intensity interval exercise and moderate continuous cycle training in a physical education program me improves health-related fitness in young females. *Biol Sport* (2016); **33**: 139–144.

McRae G, *et al.* Extremely low volume, whole-body aerobic–resistance training improves aerobic fitness and muscular endurance in females. *Appl Physiol Nutr Metab* (2012); **37**: 1124–1131.

Osawa Y, *et al.* Effects of 16-week high-intensity interval training using upper and lower body ergometers on aerobic fitness and morphological changes in healthy men: a preliminary study. *Open Access J Sports Med* (2014); **5**: 257.

Pauletto B. Choice and order of exercises. *Strength Cond J* (1986); **8**: 71–74.

Pinho RWS, Braz TV, Cruz WA, *et al.* Effect of internal training load on VO2max of adult women. *Rev Bras Ci e Mov* (2016); **24**: 43–51.

Rozenek R, *et al.* Acute cardiopulmonary and metabolic responses to high-intensity interval training protocols using 60s of work and 60s recovery. *J Strength Cond Res* (2016); **30**: 3014–3023.

Santos D, *et al.* Analysis of the order of the exercises of the inferior members on the number of repetitions. *Rev Bras Presc Fisiol Exerc* (2009); **3**: 349–354.

Semenick Douglas M, Adams Kela O. Sports performance series: the vertical jump: a kinesiological analysis with recommendations for strength and conditioning programming. *Strength Cond J* (1987); **9**: 5–11.

Simão R, Farinatti PTV, Polito MD, *et al.* Influence of exercise order on the number of repetitions performed and perceived during resistive exercises. *J Strength Cond Res* (2005); **19**: 84–88.

Simão R, *et al.* Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercise in women. *J Strength Cond Res* (2007); **21**: 23–28.

Tabata I, *et al.* Metabolic profile of high intensity intermittent exercises. *Med Sci Sports Exerc* (1997); **29**: 390–395.

Tiggemann CL, Pinto RS, Kruel LFM. Perceived exertion in strength training. *Rev Bras Med ESporte* (2010); **16**: 301–309.

Tucker WJ, *et al.* Physiological responses to high-intensity interval exercise differing in interval duration. *J Strength Cond Res* (2015); **29**: 3326–3335.