

Different recovery types do not affect training parameters in high-intensity interval training based on whole body exercise

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Published online: August 31, 2023

(Accepted for publication August 15, 2023)

DOI:10.7752/jpes.2023.08256

Abstract:

The purpose of the study was to evaluate the effects of two recovery types on the training parameters in high intensity interval training (HIIT) sessions using body weight training, the recovery included active and passive. Participating in this study, twenty male voluntaries performed two acute single sessions with a break between sessions of 7 days, each training session, was composed by (20-min duration sessions of a HIIT whole body training, consisting of 20 sets of 30 seconds at stimulus all-out of intensities of high-intensity interval training using different types of recovery, the time of duration by recovery was 30 seconds. Each cycle of exercise consisted of 30 seconds of "maximum intensity" stimulation followed by 30 seconds of recovery (active or passive). The following parameters were evaluated: heart rate, perceived exertion, perceived recovery, lactate concentration, feeling scale and number of movements in total. In the present study no differences were found in relative heart rates, perceived exertion, and lactate concentrations between protocols. No differences ($p>0.05$) were found on number total movements (Active: 695 ± 52 , Passive: 723 ± 56) between protocols. Additionally, significant reductions ($p<0.0001$) on feeling scale were found after the exercise session using Active (Before: 4.35 ± 0.58 , After: 0.85 ± 1.22) and Passive (Before: 4.30 ± 0.80 , After: 1.00 ± 1.45) recovery type, no differences were found between protocols. There were no differences ($p<0.05$) found for the respective area under the curve for rate of perceived recovery between protocols (Active: 59.70 ± 18.69 , Passive: 64.58 ± 14.89).

Keywords: bodyweight; exercise; performance; rest types; training, HIIT

Introduction

High intensity interval training (HIIT) is considered as a reliable method to increase parameters of general physical fitness (Gist et al., 2015; Machado et al., 2018) due to its time-efficient nature. Differently from traditional methods using ergometers (Gray et al., 2016), HIIT using body weight can be considered a facilitative method due to its easy application and low cost encouraging more people to participate in regular physical exercises useful to increment physical fitness (McRae et al., 2012; Machado et al., 2017; Bossmann et al. 2023).

According to a traditional study by Buchheit e Laursen (2103), there are at least nine parameters that can be used in the prescription of HIIT, these include: the intensity, stimulus duration, modality/type of exercise, duration of recovery intervals and the types of recovery. Among these parameters, the type of recovery can influence adaptive processes such as better resynthesis of PCr (Spencer et al., 2006), reduction of intramuscular pH (Spencer et al., 2006), lactate removal, oxidative phosphorylation (Tokmakidis et al., 2011), provide greater potential to achieve high percentages and spend greater time in high percentages of $\dot{V}O_{2\max}^2$ (Thevenet et al., 2007), influence the energy demand, muscle fatigue etiology and voluntary time to exhaustion (Zafeiridis et al., 2010). Influences that can change the characteristics and objective of the training session and that can also influence the results achieved.

Smilios et al. (2018) demonstrated that active recovery intervals present a better potential to reach and remain at a high percentage of $\dot{V}O_{2\max}^2$ and maximal heart rate and a shorter time to return to these maximum parameters. Connolly et al. (2003) showed that $\dot{V}O_{2\max}^2$ kinetics is faster during sprints preceded by active compared to passive recovery. Passive recovery may also induce greater restoration of intramuscular pH. This will facilitate longer exercise time (Edge et al., 2013) and, consequently, a higher volume of O_2 consumed (Spencer et al., 2006) with greater resynthesis of PCr (Buchheit et al., 2009) maintaining or improving exercise performance. In contrast, Dourado et al. (2004) investigating active recovery intervals, observed an improvement in sprint performance mediated by a significant increase in muscle and blood lactate removal due to increased

blood flow. However, others (Spencer et al., 2006; McAinch et al, 2004) have shown that passive recoveries allow maintenance or improvement of performance without any direct relationship with lactate kinetics.

Additionally, active recovery may enhance lactate and H^+ elimination and potassium clearance (Signorile et al., 1993; Bangsbo et la., 1994), and promote the resynthesis of PCr (Yoshida et al., 1996) and H^+ transport from the muscle to the extracellular space (Bangsbo et la., 1994). Specifically, active recovery induces acceleration in the restoration of ionic balance across the sarcolemma of fatigued fibers due to K^+ and Na^{2+} accumulation progressively in the external and internal side of the sarcolemma induced by repeated muscle contractions at high intensity reducing muscle excitability and altering the propagation of the action potentials (Bangsbo et la., 1992; Saltin et al., 1992). Active recovery could potentiate the activity of the Na^{2+}/K^+ pump, leading to a faster recovery of hydro electrolytic balance across the sarcolemma (Sjøgaard et al., 1990).

Although many studies have investigated the effects of active and passive recovery on the performance of interval sprints (Edge et al., 2013), there are few studies (Buchheit et la., 2009; Germano et la., 2022) that compared passive and active recoveries on intermittent exercises. However, of all the studies investigating the influence of recovery type on traditional HIIT (cyclic exercise), to our knowledge there are no reports in the literature about the influence of the interval type during HIIT exercise sessions using body weight. Therefore, the purpose of the study was to evaluate the effects of the type of recovery following the training parameters during HIIT sessions using body weight training parameters.

Material and methods

Participants

Following approval from the research ethics committee of the Federal University of Espírito Santo (Nº3.733.252/2019), 20 cross fit practitioner men active for at least 2 years (Age: 24 ± 2 years old, body mass: 74.13 ± 12.48 kg; height: 1.71 ± 0.07 m and body mass index: 25.10 ± 3.04 kg/m²) voluntarily participated in the study. The following parameters were used as exclusion criteria: positive clinical diagnosis of diabetes mellitus, smoking, musculoskeletal complications, or cardiovascular alterations confirmed by medical evaluation and lower than 150 min of physical active per week. All participants were assigned to an exercise condition routine using a computerized random number generator. The randomization process was completed with six subjects being assigned to different exercise sessions. Each session resulted in the allocation of three subjects to each protocol, ensuring a recruitment balance of 1:1 throughout the study. Sample size was calculated by a priori analysis G * Power software (v. 3.1.9.4).

Procedures

Two acute single sessions of high-intensity interval training using two different types of recovery (active and passive) were evaluated based on full body exercises performed. Randomly, for active recovery, all subjects were instructed to perform a stationary march at an intensity corresponding to 1 or 2 perceived exertion rate (0-10 scale) and for the passive recovery the subjects were instructed to remain motionless. The training session was performed according to previous publications (Machado et al. 2018; Machado et al., 2019), consisted of 20 sets with 30 s of activity (TE) using “all-out” effort, followed by 30 s of passive recovery (TR). Five cycles were performed for each of the four exercises and were performed in different orders. The exercises used included jumping jack, burpee, mountain climber and squat jump. All participants underwent two sessions of HIIT (active and passive recovery) at random with an interval of 7 days between sessions. The participants were instructed to abstain from physical exercise for 48 h before all procedures and from consumption of caffeine and alcohol for 24 h before the session. In addition, the subjects were instructed to maintain their usual meals for the 24 h prior to the interventions and to arrive at the laboratory well-fed in the afternoon and to consume 500 ml of water every hour in the 2 h prior to the exercise sessions.

Parameter evaluated

Anthropometrics

Height was measured by a Cardiomed (WCS model) stadiometer, with an accuracy of 115/220 cm. The measurements were performed with the cursor at an angle of 90° with the subject in a standing position, and feet together in contact with the Stadiometer, arms loose along the body and the measurement was performed at the end of a maximum inspiration. Total body mass was measured by a calibrated Filizola electronic scale (Personal Line Model 150) with a 100g scale and a maximum capacity of 150 kg. The volunteers all male, were wearing only shorts for the body mass measurement. Body mass index (BMI, kg/m²) was calculated using the equation $BMI = \text{weight}/\text{height}^2$.

Number of movements

The total number of movements of the training session was obtained from the sum of the movements of each exercise cycle proposed in the protocol, the total number of movements was used as an external load (Machado et al., (2018).

Heart rate

Heart rate (HR) was continuously monitored throughout the training session using HR monitors (Polar Electro Oy S810i, Kempele, Finland). The HR data were recorded by an assessor at the end of each stimulus period and at the end of each recovery period. To reduce HR recording error during training, all subjects were asked to check their HR monitors before the session and after each set (~3 and 10 min). The maximal heart rate was estimated using the Tanaka et al., (2004) equation.

Blood lactate concentration

The assessment of blood lactate concentration was evaluated before and immediately after the HIIT sessions using body weight. Capillary blood samples were taken from a sterile fingertip using a sterile lancet. The first drop of blood was discarded, and free flowing blood was collected in glass capillary tubes. All blood samples for lactate analysis were evaluated using an Accutrend® (Roche – Basel, Switzerland) as outlined in a previous study (Machado et al., 2018).

Rate of perceived exertion and recovery

Perceived exertion (RPE, scale 1-10) was recorded at the end of each stimulus cycle throughout the training session proposed in the present study, following the guidelines by Machado et al., (2017). The perception of recovery (RPR, scale 1-10) was recorded at the end of each recovery cycle after the stimulus cycle (Machado et al., 2017).

Affective response

The feeling scale (FS) is an 11-point bipolar scale ranging from +5 to -5, commonly used to measure the affective response (pleasure/displeasure) during exercise. This scale presents the following verbal anchors: -5 = very bad; -3 = bad; -1 = fairly bad; 0 = neutral; +1 fairly good; +3 = good; and +5 = very good. Previous studies have used this scale to measure affective responses during exercise (Evangelista et al., 2017). The subjects received standard instructions regarding the use of the FS in the initial screening and immediately before both protocols. The subjects received standardized instructions regarding the use of the feeling scale in the initial screening regarding the scale response procedure. The volunteers answered the feeling scale at two different time points in each of the HIIT sessions using their body weight. The first measure was before starting the warm-up and in the second measure was immediately at the end of the training session.

Statistical analysis

The D'Agostino–Pearson test was applied for Gaussian distribution analysis. Paired Student's t-test and ANOVA repeated measurements followed by Kruskal–Wallis posthoc test were performed to compare differences during the exercise sessions. An alpha of 0.05 was used to determine statistical significance. All data were expressed as mean $\pm$ standard deviation. All analyses were performed using GraphPad Prism version 6.00 for Windows (GraphPad Software, La Jolla California, United States).

Results

The participants did not present any injuries because of the workout neither before nor after the sessions. The values for heart rate, lactate concentration and perceived exertion are shown in figure 1. No differences were found for HR between the sets (data not shown), however, statistical increases ($p < 0.0001$; $F = 869.7$) were found in heart rate in active (Before: 81.90 ± 14.13 , After: 198 ± 11.74 ; bpm) and passive (Before: 76.95 ± 9.63 , After: 187 ± 12.48 ; bpm) rest intervention after exercise sessions. However, no differences were found between rest protocols and % of heart rate (Active: 90 ± 3 , Passive: 91 ± 3 ; $p = 0.1461$; $t = 1.516$; $95\%IC = -0.2522$ to 1.576). Similar responses ($p < 0.0001$; $F = 318.1$) were found for lactate concentrations for both active (Before: 1.15 ± 0.34 , After: 13.14 ± 2.47 ; mMol/L) and passive (Before: 1.41 ± 0.66 , After: 14.54 ± 2.88 ; mMol/L). No difference ($p = 0.8154$; $t = 0.236$; $95\%IC = -0.4921$ to 0.3921) was found between rest intervention (Active: 9.35 ± 0.74 , Passive: 9.30 ± 0.73) for rate of perceived exertion.

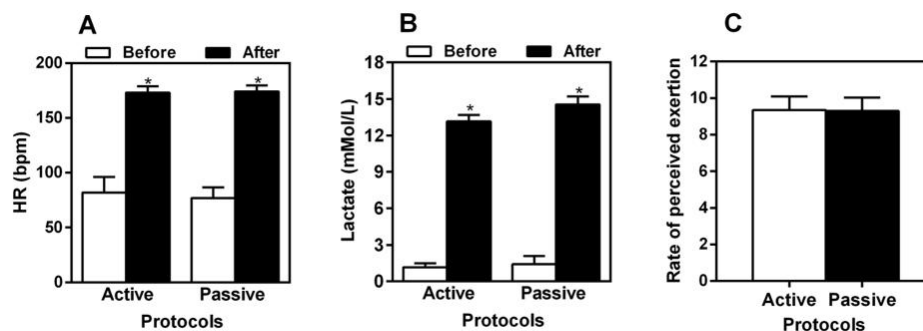


Figure 1. Heart rate (Panel A), lactate concentrations (Panel B) and rate of perceived exertion (Panel C). Values expressed in mean $\pm$ SD. * $p < 0.05$ vs before.

As presented in figure 2A, no differences were found for total movements (Active: 695 ± 52 n, Passive: 723 ± 56 ; $p = 0.1355$; $t = 1.559$; $95\%CI = -9.313$ to 63.71) between recovery type. Additionally, significant statistical reductions ($p < 0.0001$; $F = 80.62$) on feeling scale (Figure 2B) were found after the exercise session for Active (Before: 4.35 ± 0.58 , After: 0.85 ± 1.22) and Passive (Before: 4.30 ± 0.80 , After: 1.00 ± 1.45) recovery type without any differences ($p > 0.05$) between recovery protocols.

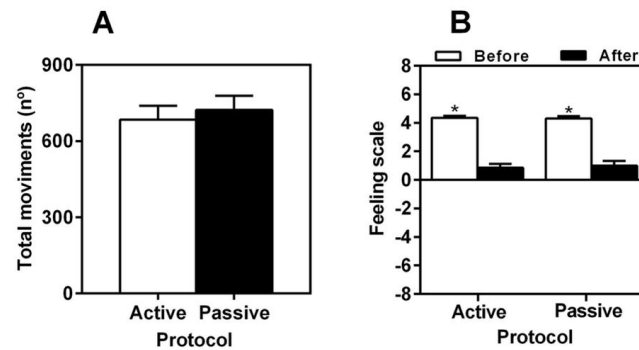


Figure 2. Total movements (Panel A) and affective response (Panel B). Values expressed in mean $\pm$ SD. * $p < 0.05$ vs after.

The rate of perceived recovery (Figure 3) was lower ($p < 0.05$) from the third set compared to the first and second sets. No differences were found on rate of perceived recovery (Panel A) and its respective area under curve (Panel B) between protocols (Active: 59.70 ± 18.69 , Passive: 64.58 ± 14.89 ; $p = 0.1162$; $t = 1.646$; 95%IC = -1.325 to 11.07).

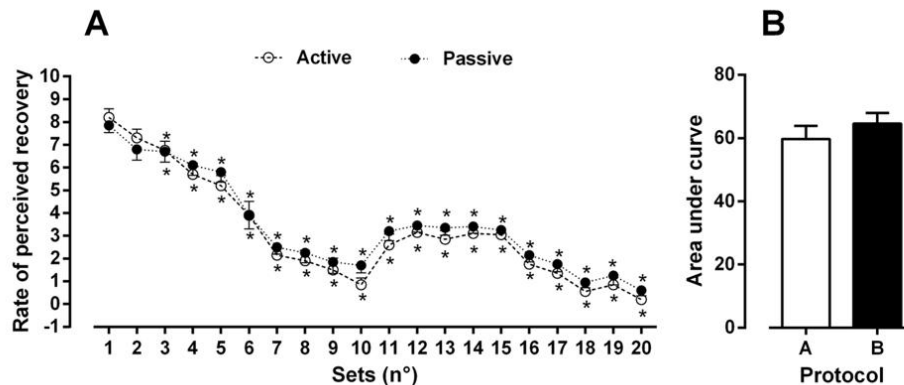


Figure 3. Rate of perceived recovery around sets (Panel A) and area under curve (Panel B). Values expressed in mean $\pm$ SD. * $p < 0.05$ vs set 1.

Discussion

In the present study, we evaluated the influence of different types of intervals during HIIT sessions using body weight. Furthermore, it was demonstrated that the type of interval did not promote alterations in internal and external load parameters.

Recently, other studies have proposed to investigate acute responses to HIIT sessions using traditional modalities (Gibala et al., 2012) as well as using bodyweight (Gist et al., 2015). There are studies in the literature proposing to investigate changes in the rate of sweating (Machado et al., 2018a), heart rate response and lactate concentration (Machado et al., 2018; Machado et al., 2018a), perception of exertion (Machado et al., 2018; Rica et al., 2018), perception of body image (Rica et al., 2018) and mood (Evangelista et al., 2017).

The values presented in this study, regarding parameters such as percentage of heart rate, lactate concentration, perception of effort and recovery, total movements (shown in figures 1, 2 and 3), were like other studies reported by our group using HIIT and bodyweight (Machado et al., 2018; Machado et al., 2018a; Rica et al., 2018). When comparing the results of lactate concentration after the training sessions in the present study, the protocol with passive recovery (14.54 ± 2.88 mMol/L) and the protocol with active recovery (13.14 ± 2.47 mMol/L) compared to those obtained by Machado et al., (2018), who used the same protocol of the present study with passive recovery (14.10 ± 1.66 mMol/L) provided similar results. It was also observed that the lactate concentration variation, which was recorded as the difference of the post training session measurement with the pre training session measurement, was similar to the study by Machado et al., (2018), with a variation of 13.12 mMol/L with the results obtained in the present study, protocol with passive recovery (13.13 mMol/L) and protocol with passive recovery, respectively (11.99 mMol/L).

This indicates reproducibility between studies regardless of the type of study. However, it should be noted that the sample in the studies was essentially composed of young men, preventing generalizations to other populations. Many studies have investigated the effects of active and passive recovery on the performance of interval sprints (Spencer et al., 2006; Driller et al., 2009; Edge et al., 2013; Smilios et al., 2018). However, to

the best of our knowledge, there are few studies (Connolly et al., 2003; Buchheit et al., 2009; Germano et al., 2022) that compared passive and active recoveries using intermittent exercises. Moreover, considering body weight, to our knowledge, even using "all out" intensity, all studies available in the literature have used passive intervals (Evangelista et al., 2017; Machado et al., 2018; Machado et al., 2018a; Schaun et al., 2018; Moghaddam et al., 2020).

The similarities in the percentage of heart rate, lactate concentration, effort perception, and recovery between the different types of intervals in this study, suggests that the metabolic contribution may have been similar, as suggested by Germano et al., (2022). This is particularly true when evaluating lactate concentrations that indicate similarity in the contribution of anaerobic glycolysis regardless of recovery.

A further important point related to performance in the session was the equality between the values of the total number of movements between the different sessions. Connolly et al., (2003) observed improved performance with protocols using active recovery. However, it is important to highlight that both studies used a cycle ergometer and recovery periods longer than the stimulus time (1:5). Therefore, based on this information, it is possible to consider that relationships between stimulation time and recovery as well as type/modality may induce different responses in the training session.

Dourado et al., (2004) also using a cycle ergometer, showed greater performance during high-intensity intermittent exercise using active recovery at 20% of $\dot{V}O_{2\max}$ than with resting recovery or just performing stretching exercises. The improvement in performance with active recovery was achieved by an increase in aerobic energy yield combined with a higher fractional contribution of aerobic metabolism to total energy turnover with similar anaerobic energy production. Buchheit & Laursen (2013) showed a decrease in running velocity and in the frequency of steps, when active recovery was applied in sports players to 6x4 seconds on a non-motorized treadmill, with an active recovery of over 21 seconds of 45% corresponding to $\dot{V}O_{2\max}$. Thevenet et al., (2007) analyzing the effects of recovery mode on time spent at a high percentage of maximal oxygen uptake in endurance-trained male adolescents, suggested that active recovery allows a shorter time with proportionally longer $t_{90\dot{V}O_{2\max}}$ and $t_{95\dot{V}O_{2\max}}$; whereas passive rest allows a longer running time for similar $t_{90\dot{V}O_{2\max}}$ and $t_{95\dot{V}O_{2\max}}$, with both efficient to solicit the aerobic system during an intermittent exercise. The results suggest that the choice of recovery could be associated with exercise objectives. In this way, if the training session aims to improve $\dot{V}O_{2\max}$, active recovery (at 50% of MAV) should be chosen. Conversely, a passive recovery should be chosen to improve $\dot{V}O_{2\max}$ and induce muscular adaptations.

Like the results in this study, Germano et al., (2022) investigated the type (passive and active) and duration (short and long) of recovery between maximum sprints in healthy male subjects demonstrating no significant differences in blood lactate concentration between any of the recoveries during the exercise period. However, the long duration associated with active recovery presented significantly lower blood lactate for the post-exercise period compared to a long period and passive recovery. Additionally, although the long period and passive recovery had shown higher O_2 volume consumed in detriment to the active protocol, the passive recoveries showed a significantly higher effort time compared with the active recoveries. Thus, as well as the suggestion of Germano et al., (2022), in this study, it is also possible to assume that active recoveries have no superiority to the removal of blood lactate during exercise compared to passive recoveries. Additionally, our data agree with previous studies that verified the effect of different recoveries on performance and blood lactate (Toubekis et al., 2006; Kostoulas et al., 2018).

Considering that that interval had been considered an important strategy to organization on HIIT whole body design session our data indicate that passive or active interval recovery do not promote influence. Thus, the choice of subjects may be an alternative way to promote autonomy during exercise sessions compared to other organization models. The findings of the present study are useful for fitness professionals, allowing the development of different training strategies, by alternating the type of recovery during exercise session design. This will allow professionals who work with high-intensity interval training using body weight to plan efficiently and safely with variations of their training sessions.

Additionally, some important limitations are present in this study. The sample was limited to healthy individuals who had no experience with HIIT whole body sessions. The findings reported here cannot be generalized for other individuals. The maximal test should also be applied to confirm the % HR kinetics during the exercise session. In the present study, it was not possible to measure the kinetics of O_2 , an important parameter used to determine metabolic parameters during exertion and during the recovery period. Additionally, there is a large variety of HIIT applications on programs and exercise regimes, and the results from this study cannot be applied to other forms of exercise or session designs, so in combination these points limit the generalization of the results.

In summary, even if some studies (Thevenet et al., 2007; Germano et al., 2022) point to the superiority of passive recovery compared to active following traditional HIIT, our findings using body weight suggest no causality between all parameters and types of recovery, which indicates that the type of recovery in HIIT sessions with body weight does not promote changes in training parameters.

Acknowledgments: The authors would like to thank to Fundação de Amparo à Pesquisa do Espírito Santo (FAPES, grants numbers 637/2022; 1007/2022) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) to scientific assistance. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Conflicts of Interest: The authors would like to disclose a conflict of interest in this publication as the AFM and ALE sells clinics and workshops associated with the manuscript topic. Other authors do not declare a conflict of interest.

References

- Bangsbo, J., Graham, T., Johansen, L., & Saltin, B. (1994). Muscle lactate metabolism in recovery from intense exhaustive exercise: impact of light exercise. *Journal of Applied Physiology*, 77(4), 1890-1895. <http://www.ncbi.nlm.nih.gov/pubmed/7836214>
- Bangsbo, J., Graham, T., Johansen, L., Strange, S., Christensen, C., & Saltin, B. (1992). Elevated muscle acidity and energy production during exhaustive exercise in humans. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 263(4), R891-R899. <http://www.ncbi.nlm.nih.gov/pubmed/1415803>
- Bossmann, T., Bickmeyer, M., Woll, A., Wagner, I. (2023). Effects of whole-body high-intensity interval training and different runningbased high-intensity interval training protocols on aerobic capacity and strength endurance in young physical education students. *Journal of Physical Education and Sport*, 23(2): 360 – 371.
- Buchheit, M., Cormie, P., Abbiss, C. R., Ahmaidi, S., Nosaka, K. K., & Laursen, P. B. (2009). Muscle deoxygenation during repeated sprint running: Effect of active vs. passive recovery. *International journal of sports medicine*, 418-425. <http://www.ncbi.nlm.nih.gov/pubmed/19437381>
- Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports medicine*, 43(5), 313-338. <http://www.ncbi.nlm.nih.gov/pubmed/23539308>
- Buchheit, M., Laursen, P. B., Kuhnle, J., Ruch, D., Renaud, C., & Ahmaidi, S. (2009). Game-based training in young elite handball players. *International journal of sports medicine*, 251-258. <http://www.ncbi.nlm.nih.gov/pubmed/19199207>
- Connolly, D. A., Brennan, K. M., & Lauzon, C. D. (2003). Effects of active versus passive recovery on power output during repeated bouts of short term, high intensity exercise. *Journal of sports science & medicine*, 2(2), 47. <http://www.ncbi.nlm.nih.gov/pubmed/24616610>
- Dorado, C., Sanchis-Moysi, J., & Calbet, J. A. (2004). Effects of recovery mode on performance, O₂ uptake, and O₂ deficit during high-intensity intermittent exercise. *Canadian journal of applied physiology*, 29(3), 227-244. <http://www.ncbi.nlm.nih.gov/pubmed/15199225>
- Driller, M. W., Fell, J. W., Gregory, J. R., Shing, C. M., & Williams, A. D. (2009). The effects of high-intensity interval training in well-trained rowers. *International journal of sports physiology and performance*, 4(1), 110-121. <http://www.ncbi.nlm.nih.gov/pubmed/19417232>
- Edge, J., Eynon, N., McKenna, M. J., Goodman, C. A., Harris, R. C., & Bishop, D. J. (2013). Altering the rest interval during high-intensity interval training does not affect muscle or performance adaptations. *Experimental physiology*, 98(2), 481-490. <http://www.ncbi.nlm.nih.gov/pubmed/22923232>
- Evangelista, A. L., Evangelista, R. A. G. T., Machado, A. F., Miranda, J. M. Q., Teixeira, C. V. L. S., Lopes, C. R., & Bocalini, D. S. (2017). Effects of high-intensity calisthenic training on mood and affective responses. *J Exerc Physiol Online*, 20(6), 15-23.
- Germano, M. D., Sindorf, M. A., Crisp, A. H., Braz, T. V., Brigatto, F. A., Nunes, A. G., ... & Lopes, C. R. (2022). Effect of different recoveries during HIIT sessions on metabolic and cardiorespiratory responses and sprint performance in healthy men. *Journal of Strength and Conditioning Research*, 36(1), 121-129. <http://www.ncbi.nlm.nih.gov/pubmed/31895286>
- Gibala, M. J., Little, J. P., MacDonald, M. J., & Hawley, J. A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *The Journal of physiology*, 590(5), 1077-1084. <http://www.ncbi.nlm.nih.gov/pubmed/22289907>
- Gist, N. H., Freese, E. C., Ryan, T. E., & Cureton, K. J. (2015). Effects of low-volume, high-intensity whole-body calisthenics on army ROTC cadets. *Military medicine*, 180(5), 492-498. <http://www.ncbi.nlm.nih.gov/pubmed/25939101>
- Gray, S. R., Ferguson, C., Birch, K., Forrest, L. J., & Gill, J. M. (2016). High-intensity interval training: key data needed to bridge the gap from laboratory to public health policy. *British Journal of Sports Medicine*, 50(20), 1231-1232. from: <http://www.ncbi.nlm.nih.gov/pubmed/26994125>
- Kostoulas, I. D., Toubekis, A. G., Paxinos, T., Volaklis, K., & Tokmakidis, S. P. (2018). Active recovery intervals restore initial performance after repeated sprints in swimming. *European Journal of Sport Science*, 18(3), 323-331. <http://www.ncbi.nlm.nih.gov/pubmed/29249177>
- Machado, A. F., Baker, J. S., Figueira Junior, A. J., & Bocalini, D. S. (2019). High-intensity interval training using whole-body exercises: training recommendations and methodological overview. *Clinical physiology and functional imaging*, 39(6), 378-383. <http://www.ncbi.nlm.nih.gov/pubmed/28471050>

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- Machado, A. F., Evangelista, A. L., Miranda, J. M. Q., Teixeira, C. V., Rica, R. L., Lopes, C. R., ... & Bocalini, D. S. (2018). Description of training loads using whole-body exercise during high-intensity interval training. *Clinics*, 73 (e516): 1-6.
- Machado, A. F., Evangelista, A. L., Miranda, J. M. D. Q., Teixeira, C. V. L. S., Leite, G. D. S., Rica, R. L., ... & Bocalini, D. S. (2018). Sweat rate measurements after high intensity interval training using body weight. *Revista Brasileira de Medicina do Esporte*, 24, 197-201.
- McAinch, A. J., Febbraio, M. A., Parkin, J. M., Zhao, S., Tantalakis, K., Stojanovska, L., & Carey, M. F. (2004). Effect of active versus passive recovery on metabolism and performance during subsequent exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 14(2), 185-196. <http://www.ncbi.nlm.nih.gov/pubmed/15118192>
- McRae, G., Payne, A., Zelt, J. G., Scribbans, T. D., Jung, M. E., Little, J. P., & Gurd, B. J. (2012). Extremely low volume, whole-body aerobic-resistance training improves aerobic fitness and muscular endurance in females. *Applied Physiology, Nutrition, and Metabolism*, 37(6), 1124-1131. <http://www.ncbi.nlm.nih.gov/pubmed/22994393>
- Moghaddam, M., Estrada, C. A., Baghurst, T., & Jacobson, B. H. (2020). Muscular morphological adaptations of two whole-body high intensity interval training configurations. *The Journal of Sports Medicine and Physical Fitness*, 60(7), 985-991. <http://www.ncbi.nlm.nih.gov/pubmed/32343081>
- Rica, R. L., Miranda, J. M., Machado, A. F., Evangelista, A. L., Teixeira, C. L. S., Gama, E. F., ... & Bocalini, D. S. (2018). Body-image and-size perception after a single session of HIIT body work in healthy adult men. *Motricidade*, 14(4), 66-73.
- Saltin, B., Bangsbo, J., Graham, T. E., & Johansen, L. (1992). Metabolism and Performance in Exhaustive Intense Exercise; Different Effects of Muscle Glycogen Availability, Previous Exercise and Muscle Acidity. In *Muscle fatigue mechanisms in exercise and training* (Vol. 34, pp. 87-114). Karger Publishers. <https://www.karger.com/Article/FullText/420984>
- Schaun, G. Z., Pinto, S. S., Silva, M. R., Dolinski, D. B., & Alberton, C. L. (2018). Whole-body high-intensity interval training induce similar cardiorespiratory adaptations compared with traditional high-intensity interval training and moderate-intensity continuous training in healthy men. *The Journal of Strength & Conditioning Research*, 32(10), 2730-2742. <http://www.ncbi.nlm.nih.gov/pubmed/29746386>
- Signorile, J. F., Tremblay, L. M., & Ingalls, C. (1993). The effects of active and passive recovery on short-term, high intensity power output. *Canadian Journal of Applied Physiology*, 18(1), 31-42. <http://www.ncbi.nlm.nih.gov/pubmed/8471992>
- Sjøgaard, G. (1990). Exercise-induced muscle fatigue: the significance of potassium. *Acta physiologica scandinavica. Supplementum*, 140(593), 1-63. <http://www.ncbi.nlm.nih.gov/pubmed/2239345>
- Smilios, I., Myrkos, A., Zafeiridis, A., Toubekis, A., Spassis, A., & Tokmakidis, S. P. (2018). The effects of recovery duration during high-intensity interval exercise on time spent at high rates of oxygen consumption, oxygen kinetics, and blood lactate. *The Journal of Strength & Conditioning Research*, 32(8), 2183-2189. <http://www.ncbi.nlm.nih.gov/pubmed/28301436>
- Spencer, M., Bishop, D., Dawson, B., Goodman, C., & Duffield, R. (2006). Metabolism and performance in repeated cycle sprints: active versus passive recovery. *Medicine and science in sports and exercise*, 38(8), 1492. <http://www.ncbi.nlm.nih.gov/pubmed/16888464>
- Spencer, M., Dawson, B., Goodman, C., Dascombe, B., & Bishop, D. (2008). Performance and metabolism in repeated sprint exercise: effect of recovery intensity. *European journal of applied physiology*, 103(5), 545-552. <http://www.ncbi.nlm.nih.gov/pubmed/18443815>
- 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. <http://www.ncbi.nlm.nih.gov/pubmed/11153730>
- Thevenet, D., Tardieu-Berger, M., Berthoin, S., & Prioux, J. (2007). Influence of recovery mode (passive vs. active) on time spent at maximal oxygen uptake during an intermittent session in young and endurance-trained athletes. *European journal of applied physiology*, 99(2), 133-142. <http://www.ncbi.nlm.nih.gov/pubmed/17115178>
- Tokmakidis, S. P., Toubekis, A. G., & Smilios, I. (2011). Active versus passive recovery: metabolic limitations and performance outcome. *MA Powell, Physical Fitness Training, Effect and Maintaining*, 1-43.
- Toubekis, A. G., Smilios, I., Bogdanis, G. C., Mavridis, G., & Tokmakidis, S. P. (2006). Effect of different intensities of active recovery on sprint swimming performance. *Applied Physiology, Nutrition, and Metabolism*, 31(6), 709-716. <http://www.ncbi.nlm.nih.gov/pubmed/17213885>
- Yoshida, T., Watari, H., & Tagawa, K. (1996). Effects of active and passive recoveries on splitting of the inorganic phosphate peak determined by ³¹P-nuclear magnetic resonance spectroscopy. *NMR in Biomedicine: An International Journal Devoted to the Development and Application of Magnetic Resonance In Vivo*, 9(1), 13-19. <http://www.ncbi.nlm.nih.gov/pubmed/8842028>
- Zafeiridis, A., Sarivasilou, H., Dipla, K., & Vrabas, I. S. (2010). The effects of heavy continuous versus long and short intermittent aerobic exercise protocols on oxygen consumption, heart rate, and lactate responses in adolescents. *European journal of applied physiology*, 110, 17-26. <http://www.ncbi.nlm.nih.gov/pubmed/20383773>
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