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Article

IS PERCEIVED EXERTION AN USEFUL INDICATOR OF METABOLIC AND CARDIOVASCULAR RESPONSE TO METABOLIC CONDITIONING OF FUNCTIONAL-FITNESS SESSION? A RANDOMIZED CONTROLLED TRIAL.

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Abstract: The purpose of this study was to assess if self-regulation of intensity based on rating of perceived exertion (RPE) is a reliable method to control the intensity of metabolic conditioning of functional-fitness session. In addition, the relationship between RPE and changes in heart rate and lactate responses was also analyzed. Eight male participants (age 28.1 ± 5.4 years; body mass 77.2 ± 4.4kg; VO_2max: 52.6 ± 4.6 mL·(kg·min)$^{-1}$) completed three randomly sessions (5 to 7 days apart) under different conditions: (1) all-out (ALL); (2) self-regulation of intensity based on a RPE of 6 (hard) on the Borg CR-10 scale (RPE6); and (3) a control session. Rate of perceived exertion, LAC and HR response were measured pre, during and immediately after the sessions. The RPE and LAC during the ALL-OUT sessions were higher ($p \leq 0.05$) than the RPE6 and control sessions for all the analyzed time points during the sessions. Regarding HR, the 22 min area under the curve of HR during ALL-OUT and RPE6 sessions were significantly higher ($p \leq 0.05$) than the control session. The average number of repetitions was lower ($p \leq 0.05$) for the RPE6 session (190.5 ± 12.5 repetitions) when compared to the ALL session (214.4 ± 18.6 repetitions). There was a significant correlation between RPE and LAC ($p = 0.001$; $r = 0.76$; very large) and number of repetitions during the session ($p = 0.026$; $r = 0.55$; large). No correlation was observed between RPE and HR ($p = 0.147$; $r = 0.380$). These results indicate that self-regulation of intensity of effort based on RPE may be a useful tool to control exercise intensity during a metabolic conditioning session of functional-fitness.

Keywords: CrossFit; High-intensity functional training; Extreme conditioning programs;

1. Introduction

Functional-Fitness (FFT), also known as CrossFit, high-intensity functional training (HIFT), or extreme conditioning programs (ECP), is an exercise modality that contemplates a variety of training

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methods. Sessions are often classified as weightlifting (W), metabolic (M), or gymnastics (G), and utilize weightlifting/powerlifting (e.g. clean and jerk, snatch, squat, deadlift, push press, bench press, and power clean), calisthenic bodyweight exercises (e.g. pull-ups, dips, push-ups, handstands, presses to handstands, pirouettes, kips, cartwheels, muscle-ups), cardiovascular exercises (e.g. row, bike, run), sprints, and flexibility exercises, depending on the goal of the session and the fitness components that are to be targeted [1,2]. Metabolic training sessions are often performed either as a single mode of exercise focusing on a cardiovascular exercise or utilizing a combination of exercise methods in order to maximize physiological stress and the purported training adaptations [3].

Previous research has shown that a metabolic conditioning session of functional-fitness resulted in increased acute oxidative stress [4], high metabolic, inflammatory [5], and cardiovascular responses, elevated perceived exertion [6] and increased sympathetic nervous system markers (i.e., plasma Epinephrine and Norepinephrine) [7]. However, due to increases in oxidative and inflammatory markers [4,5] and the extreme effort associated with FFT, some studies have raised concerns about a tendency for the development of symptoms of overtraining in functional fitness practitioners [8,9]. For example, Drake, et al. [8] found that four weeks of FFT, led to a state of functional overreaching in some participants, and that non-functional overreaching could be developed if the high intensity associated with FFT was maintained after the four weeks of study. Similarly, Drum, et al. [9] demonstrated a high presence of severe post-exercise symptoms during a CrossFit program, such as excessive fatigue, muscle soreness, muscle swelling, and limited muscle movement during workouts due to the extreme intensity of the workout. Thus, despite evidence that finds extreme metabolic conditioning leads to severe post exercise symptoms of fatigue, the current literature regarding methods of monitoring and controlling training intensity during these sessions in functional-fitness is limited.

In this context, a correct control and prescription of training intensity can minimize the deleterious effects that have been shown to occur following metabolic sessions or periods of intense training. Considering the wide variety of exercises used during such sessions (strength/power, gymnastics, and endurance), controlling training intensity is a challenge. The Borg CR-10 scale, called the rate of perceived exertion (RPE) scale [10] has been widely used to determine the intensity during different modalities of exercise, including resistance training [11], high-intensity interval exercise [12] and swimming [13]. The use of RPE has been shown to be related to physiological markers, such as maximal oxygen consumption (VO_2max), lactate and ventilatory thresholds, and can be used as a surrogate of heart rate to understand the heart rate response to a specific exercise intensity. However, the validity and utility of RPE for prescribing and self-regulating training intensity during the metabolic conditioning of FFT has not been studied. Furthermore, the relationship between metabolic and cardiovascular responses and RPE to metabolic conditioning of FFT have not been established.

Thus, the aim of the present study was to examine whether RPE could be used as a method to prescribe exercise intensity during extreme type metabolic conditioning. Secondly, we aimed to assess and compare the physiological responses of the RPE-prescribed session to that of the typical all out conditioning and what the difference in total work performed. It was hypothesized that participants would be able to self-regulate intensity when a target RPE was prescribed and that the metabolic and cardiovascular response as well as total work done would be lower when intensity is regulated via RPE.

2. Materials and Methods

2.1. Participants

Eight members of the functional fitness community (age 28.1 ± 5.4 years; body mass 77.2 ± 4.4kg; VO_2max: 52.6 ± 4.6 mL·(kg·min)$^{-1}$) were recruited through advertisements. All subjects were free of injury and known illness, were not using drugs to enhance performance, and had a minimum of six months of FFT experience. The subjects were advised to sleep between six and eight hours the night before each experimental session, to maintain their regular hydration and food consumption habits, to avoid any exercise in the 48 h before the experimental sessions, and to avoid smoking, alcohol and caffeine consumption 24 h before the experimental session. All subjects signed an informed consent document and the study was approved by the University Research Ethics Committee for Human Use (2.698.225/Universidade Estácio de Sá/ UNESA/RJ) and conformed to the Helsinki Declaration on the use of human participants for research.

2.2. Experimental Design

Subjects completed a metabolic conditioning session (5 to 7 days apart) in randomized fashion under two different conditions: (1) all-out (ALL); (2) self-regulation of intensity based on a RPE of 6 (hard) on the Borg CR-10 scale (RPE6). A control session (CONT) consisting of 22 minutes in the sitting position without any type of exercise was also performed. The all-out and RPE-based autoregulation sessions were as follows: 4 min of as many rounds as possible (AMRAP) of 5 thrusters (60 kg) and 10 box jump over (round 1); 2 min of rest; 4 min of AMRAP of 10 power clean (60 kg) and 20 pull-ups (round 2); 2 min of rest; 4 min of AMRAP of 15 shoulder to overhead (60 kg) and 30 toes to bar (round 3); 2 min of rest; 4 min of AMRAP of 20 calories of row and 40 wall ball (9 kg) (round 4). During the all-out workout, subjects were instructed to complete the maximum number of repetitions possible for each round. The RPE-based autoregulation session consisted of performing the same activity, but with participants told to self-regulate the intensity of their session based on a perception of effort of 6 (hard) on the Borg CR-10 scale. During the session, the subjects were instructed to take more breaks if needed or just “slow down” the execution of their exercises to keep the perception of effort of 6 (hard). No changes of the weights were performed during the sessions. The Borg CR-10 scale was printed and available to the participants as a visual reminder of the prescribed target intensity.

2.3. Blood Lactate

Capillary blood samples were collected through transcutaneous puncture on the medial side of the tip of the middle finger using a disposable hypodermic lancet. Blood lactate (LAC) concentrations were measured before and immediately after 4, 10, 16, and 22 minutes in each protocol of exercise and control session. LAC was determined by photometric reflectance on a validated Portable Accutrend Plus system (Roche, Sao Paulo, Brazil).

2.4. Heart Rate (HR)

The continuous monitoring of HR during the experimental sessions was done with the use of a Polar H10 HR-monitor (Polar Electro Oy, Kemple, Finland), with a recording interval of 1 s. Maximal heart rate was obtained in the 2 km row test that was used for indirect assessment of maximal oxygen uptake [14] of the subjects. The 2 km row test consisted in rowing 2 km with the maximal effort (power) as possible. During the test, continuous monitoring of HR was done and the maximum HR during the test was used as the maximum HR of the subject. The values of HR obtained during the protocols of the present study were normalized as percentual values using the maximum HR obtained during the 2 km row test.

2.5. Rating of Perceived Exertion (RPE)

Data were collected as previously described by Tibana, et al. [15]. The RPE was measured before, during and immediately after exercise by the RPE CR10 Borg scale adapted from Foster, et al. [16], an instrument composed by a Likert type scale of 11 points, varying from 0 to 10, initiated with “very, very light“ and terminated with “very, very hard “. The following instructions were used to ensure each participant clearly understood what the RPE scale was and how it was to be used to regulate their exercise intensity. First, RPE was explained to the subjects individually according to the recommendations from Foster, et al. [16]. Secondly, the following information was verbally provided: “The perceived exertion is defined as the effort intensity, stress, discomfort, and fatigue

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felt during exercise. Utilize the numbers of this scale to report how your body feels during exercise. The number zero in the scale describes "minimal effort" and represents your lowest imaginable effort. The number 10 described "maximum effort" and represents the highest imaginable effort. If you feel an exertion between extremely easy and maximum effort indicate a number between 0 and 10. There are no right or wrong numbers. The verbal descriptors may help you to choose a number" [16].

During the sessions, a printed version of the RPE scale (large scale) was fixed in a wall so that the subjects could visualize at all time the scale. During the anchoring procedure, the subject was instructed by another evaluator that was presented in the testing room to describe their effort using the RPE scale. Subjects also received a copy of the scale with the respective instructions for anchorage. This was provided for subjects to read during the general warm-up for each session [16].

2.6. Statistical analysis

Data are expressed as mean ± standard deviation (SD). Shapiro–Wilk test was used to check for normal distribution of study variables (all variables presented normal distribution). A two-way repeated measures ANOVA (sessions x time) was used to compare the LAC, HR and RPE between REP6, ALL-OUT and CONT sessions. Sphericity assumption was verified by Mauchly's test. When the assumption of sphericity was not met, a Greenhouse-Geiser adjustment was used to determine the significance of the ANOVA tests. Tukey's post-hoc test with Bonferroni correction was applied in the event of significance. One-way repeated measures ANOVA was used to compare the area under the curve of LAC, HR and RPE generated during the 22 min of the RPE6, ALL-OUT and CONT functional fitness sessions. The Pearson product moment correlation was used to evaluate the relationship between RPE and LAC and RPE and HR. Instead of a fixed time point of the study variables, it was used the area under the curve for all correlations (RPE, LAC and HR) during the ALL-OUT and RPE6 sessions. The magnitude of the correlations was classified as: $r \leq 0,1$ trivial; $0,1 < r \leq 0,3$ small; $0,3 < r \leq 0,5$ moderate; $0,5 < r \leq 0,7$ large; $0,7 < r \leq 0,9$ very large; $> 0,9$ almost perfect (Hopkins, 1996). The achieved power of the sample size was calculated based on the interaction of RPE between ALL-OUT, RPE6 and CONT sessions. The effect size f was 0.312 and the achieved power was 0.810. The level of significance was $p \leq 0.05$ and all analyses were performed using SPSS version 20.0 (Somers, NY, USA).

3. Results

3.1. Number of repetitions performed

The average number of repetitions was significantly lower ($p \leq 0.05$) for the RPE6 session (190.5 ± 12.5 repetitions) than for ALL-OUT session (214.4 ± 18.6 repetitions) however as shown in Table 1 the differences in work completed in each set varied. Specifically, as shown in Table 1 more reps were completed in the ALL-OUT condition for R1 and R2 however in R3 the RPE6 condition had more reps completed compared and in R4 the average difference was less than 2 reps. Table 1 presents the results of the functional-fitness sessions each round as well as the percentage change in work done between sets overall and the frequency of participants whom completed more reps in the ALL-OUT condition compared to the RPE6 condition.

3.2. Rating of perceived exertion

A significant two-way interaction between functional fitness sessions and time on RPE ($p < 0.005$; Figure 2) was found. The RPE during the ALL-OUT session was significantly higher ($p \leq 0.05$) than the RPE6 and CONT sessions at each time point. The RPE during the RPE6 session was also significantly higher ($p \leq 0.05$) than the CONT session. There was a significant increase in RPE from rest to R1, R2 and R3 in the ALL-OUT condition (Figure 2) and from rest to R1 and R2 during the RPE6 session (Figure 2). There were no differences in RPE between R1, R2, R3 and R4 for either ALL-OUT or RPE6 conditions. However, the global RPE as determined via the 22 min area under the

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curve for RPE during ALL-OUT was significantly higher ($p \leq 0.05$) than during RPE6 and CONT sessions and RPE6 was greater than CONT.

3.3. Blood lactate concentration

There was a statistically significant two-way interaction between session and time on LAC ($p < 0.0005$; Figure 3). The LAC during the ALL-OUT session was significantly higher ($p \leq 0.05$) than the RPE6 and CONT sessions at each time point (R1, R2, R3 and R4). The LAC during the RPE6 session was also significantly higher ($p \leq 0.05$) than the CONT session. LAC increased until R3 during the ALL-OUT and RPE6 sessions, where R1 was different than Rest, R2 was greater than R1 and R3 was greater than R2 for both ALL-OUT and RPE6. The LAC area under the curve during ALL-OUT and RPE6 sessions were significantly higher ($p \leq 0.05$) than CONT sessions and ALL-OUT significantly higher ($p \leq 0.05$) than during RPE6.

3.4. Heart rate

Figure 4 shows the % of HRmax during the functional fitness sessions. There was a significant interaction between functional fitness sessions and time for % of HRmax ($p = 0.048$). The % of HRmax during the ALL-OUT and RPE6 sessions were significantly higher ($p \leq 0.05$) than during the CONT session for all time points. However, there was no difference in % of HRmax at any time point for ALL-OUT compared to RPE6 ($p > 0.05$). Within condition time point comparisons found that % of HRmax at R4 was greater than R1 and R3 for RPE6 ($p \leq 0.05$). During the ALL-OUT the % of HRmax was greatest at R1 ($p \leq 0.05$) compared to R2, R3 and R4. Area under the curve for % of HRmax during ALL-OUT and RPE6 sessions were significantly higher ($p \leq 0.05$) than CON sessions. No statistically significantly differences ($p > 0.05$) were observed between ALL-OUT and RPE6 sessions (Figure 4).

3.5. Correlations between RPE and physiological variables

Figure 5 shows the correlations between the area under the curve of RPE and LAC, HR and number of repetitions. It was observed a statistically significant correlation between RPE and LAC ($p = 0.001$; $r = 0.757$; very large) and number of repetitions during the session ($p = 0.026$; $r = 0.555$; large). No correlation was observed between RPE and HR ($p = 0.147$; $r = 0.380$).

Table 1 – Mean ± SD of number of repetitions for ALL-OUT and RPE6 sessions

	ALL-OUT	**RPE6**	**Δ (%)**	**p-value**	**ES**
Set 1	63.9 ± 4.4	46.6 ± 5.8*	27.1%	≤ 0.0005	3.36
Set 2	58.0 ± 7.7	46.4 ± 7.0*	20%	0.006	1.58
Set 3	41.9 ± 6.6	48.0 ± 1.9*	14.5%	0.049	1.26
Set 4	50.6 ± 6.5	49.5 ± 4.0	2.2%	0.663	0.20
Total	214.4 ± 18.6	190.5 ± 12.5*	11.1%	0.020	1.51

ES, effect size. *$p \leq 0.05$ for ALL-OUT session

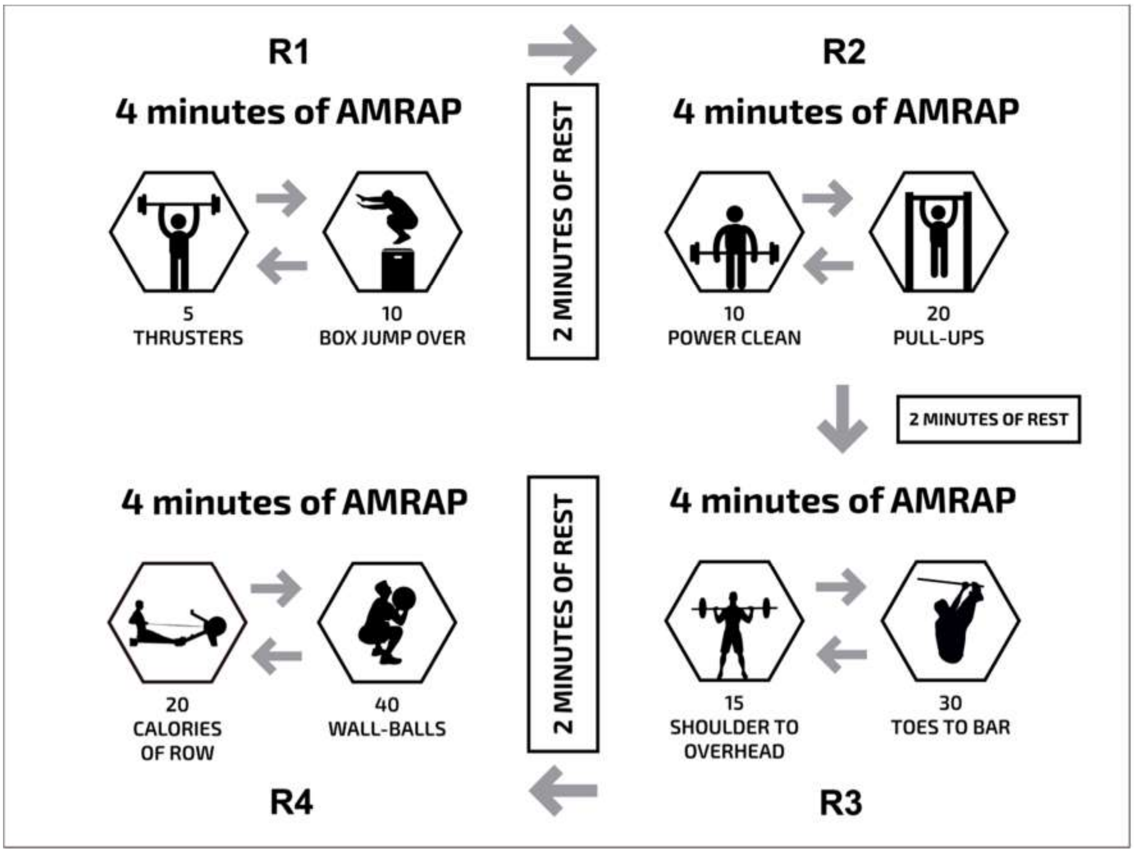

Figure 1. Metabolic conditioning: 4 min of as many rounds as possible (AMRAP) of 5 thrusters and 10 box jump over (round 1); 2 min of rest; 4 min of AMRAP of 10 power clean and 20 pull-ups (round 2); 2 min of rest; 4 min of AMRAP of 15 shoulder to overhead and 30 toes to bar (round 3); 2 min of rest; 4 min of AMRAP of 20 calories of row and 40 wall ball (round 4).

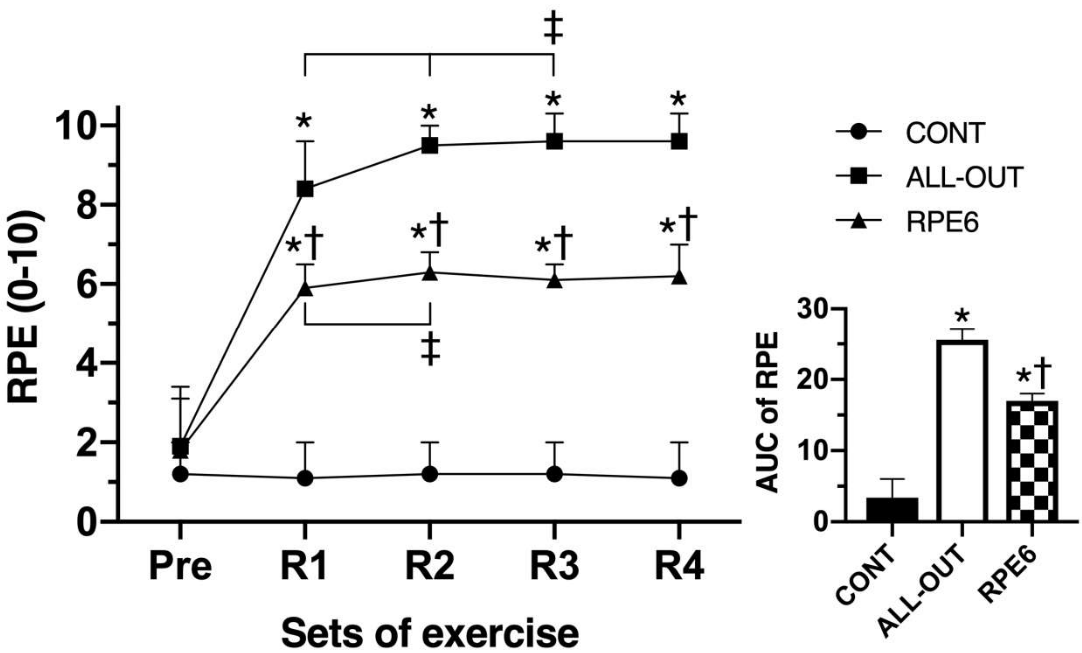

Figure 2. Ratings of perceived exertion (RPE) pre and at the end of round 1 (R1), R2, R3 and R4 and area under the curve (AUC) of RPE during functional fitness and control (CONT) sessions.

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Differences between sessions: * p ≤ 0.05 for CONT; † p ≤ 0.05 for ALL-OUT; Differences between time: ‡ p ≤ 0.05 for R1 and R2 in ALL-OUT and R1 in RPE6

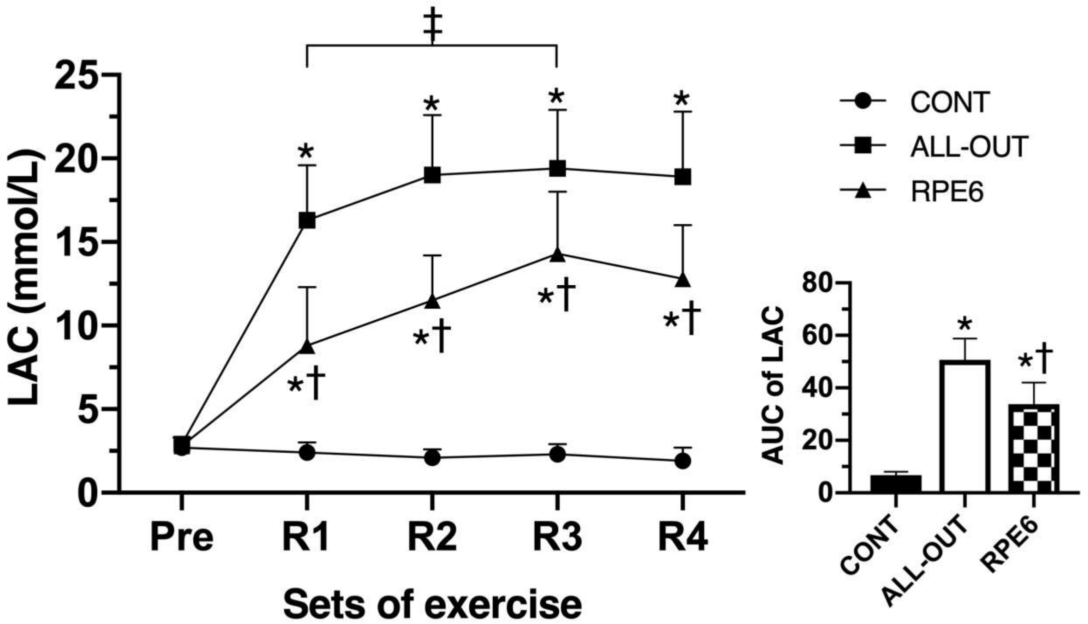

Figure 3. Blood lactate concentration (LAC) pre and at the end of round 1 (R1), R2, R3 and R4 and area under the curve (AUC) of LAC during functional fitness and control (CONT) sessions. Differences between sessions: * p ≤ 0.05 for CONT; † p ≤ 0.05 for ALL-OUT; Differences between time: ‡ p ≤ 0.05 for pre, R1 and R2 in both ALL-OUT and RPE6

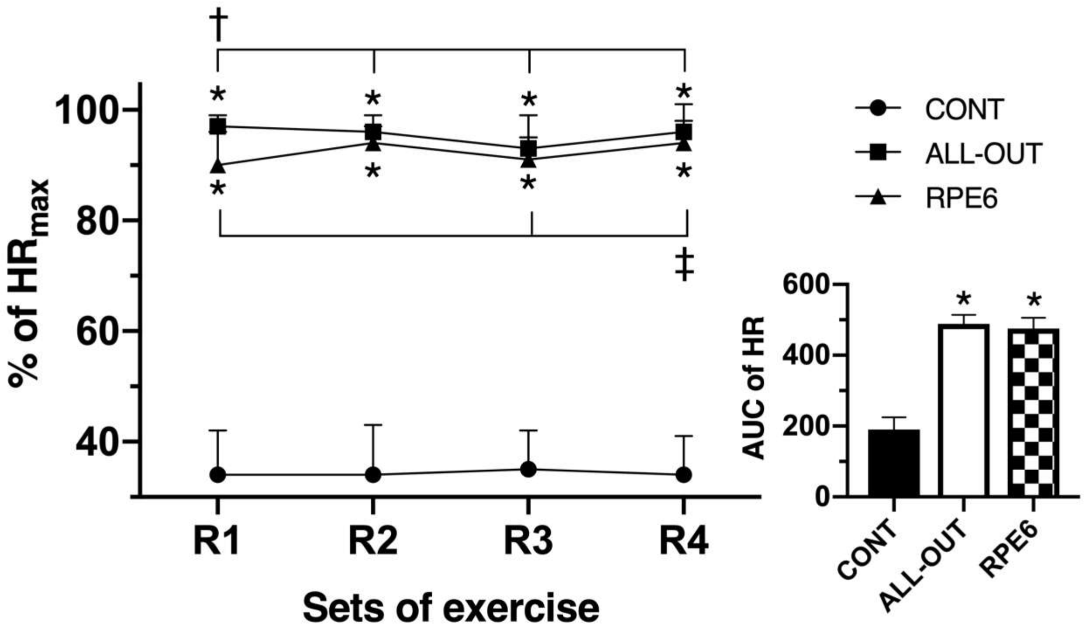

Figure 4. Percentage of maximal heart rate (HRmax) at the end of round 1 (R1), R2, R3 and R4 and area under the curve (AUC) of HRmax during functional fitness and control (CONT) sessions. Differences between sessions: * p ≤ 0.05 for CONT; Differences between time: † p ≤ 0.05 for R1, R2, R3 and R4 in ALL-OUT; ‡ p ≤ 0.05 for R1 and R3 in RPE6.

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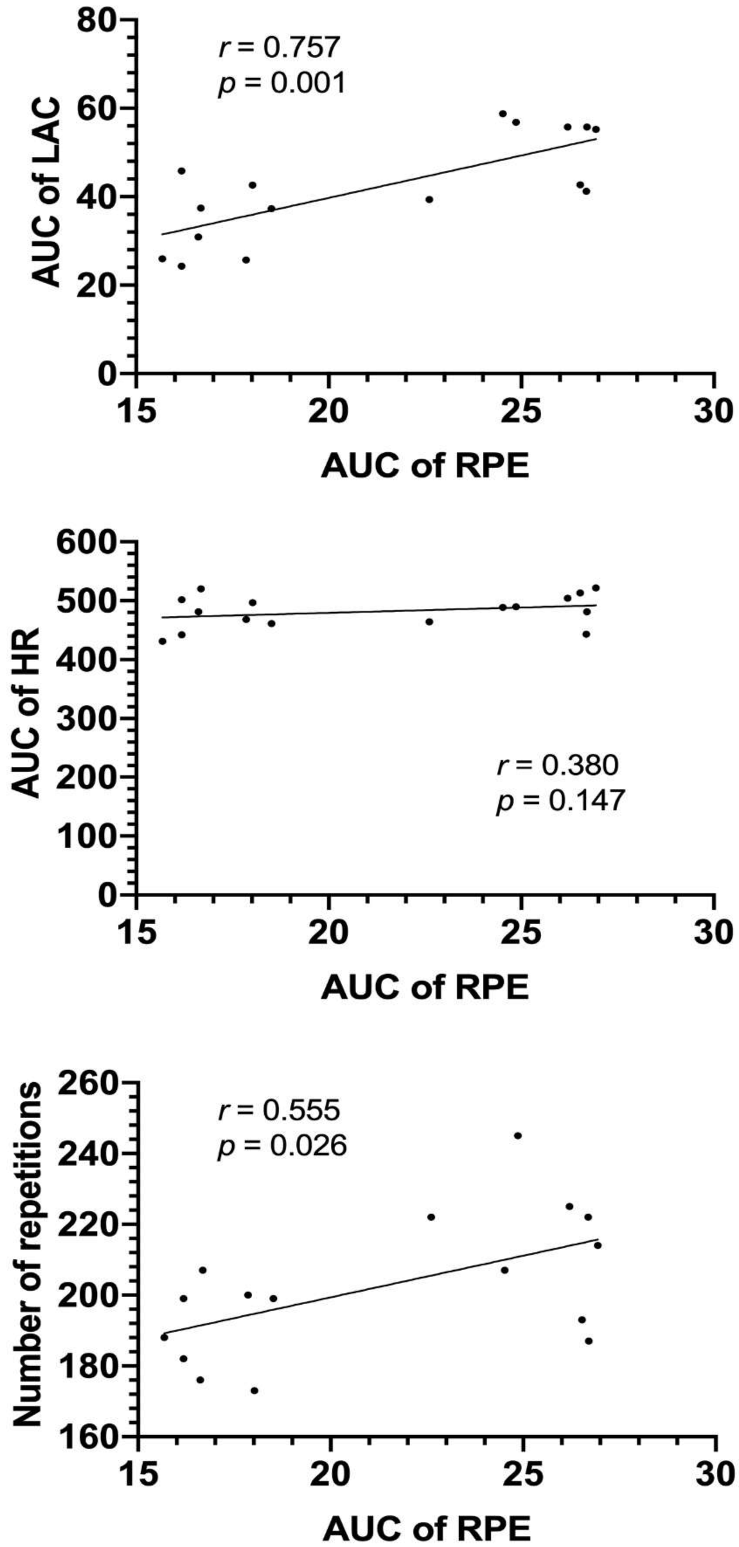

Figure 5. Correlations between the area under the curve (AUC) of ratings of perception exertion (RPE) and blood lactate concentration (LAC), heart rate (HR) and number of repetitions.

4. Discussion

These results support the hypothesis that RPE could be used to regulate intensity during high intensity metabolic conditioning in trained men. Moreover, the results demonstrated that: (1) the

RPE and LAC during the ALL-OUT session were higher than the RPE6 at all time points; (2) the ALL-OUT condition leads to too much undue fatigue in latter portion of the workout when the number of repetitions drops dramatically; (3) the HR response is similar during ALL-OUT and RPE6 conditions and (4) there was correlation between RPE, LAC and number of repetitions.

Functional-Fitness has been increasingly growing in popularity as it is considered a more enjoyable form of exercise when compared with traditional aerobic and resistance training [17]. In addition, it is done in a shorter period of time inducing similar positive outcomes reported in strength [18], performance [19] and body composition [20] compared to longer duration more traditional type resistance and aerobic type workouts. To the best of our knowledge, this is the first study designed to examine RPE as a viable tool for controlling the intensity of a metabolic training session in trained men. The findings in this study corroborate what has been reported in other investigations that showed the viability of this method in several exercise methods and sporting disciplines, including resistance training [11], high-intensity interval training [12] and swimming [13]. For example, Ciolac, et al. [12] found that HR response and walking/running speed were not different between high-intensity interval training sessions prescribed and regulated by HR or RPE in young individuals. Similarly, Ceci and Hassmen [21] analyzed two testing sessions consisting of both treadmill and track exercise at three different intensities: at RPE 11 (light exertion), followed by a RPE 13 (somewhat hard) trial and, a RPE 15 (hard) trial. The authors showed significant different values of HR, blood lactate, and velocity at the three RPE zones, and concluded that the RPE method functioned well as a means of monitoring and regulating exercise intensity in physically active males.

However, our study provides new insight into the perceptual and physiological responses of an all-out exercise bout. First, we assumed that RPE would be maximum (RPE of 10) but it was only rising to 10 in all participants by R3. This indicates that even in all-out exercises some regulation still occurs. It makes sense that the LAC response was very large and is associated with values similar to other all-out style assessments such as a 90 second Wingate or events such as all-out flat-water kayaking races or track cycling. Furthermore, an all-out strategy does lead to greater repetitions (Table 1) overall when compared to a sub- maximal intensity prescription of “hard to very hard” as prescribed in the RPE-6 session. However, as shown in Table 1, if the session had gone longer it is likely that the RPE6 session may have resulted in greater total reps completed compared to the all-out condition. This is because by R3 the RPE6 condition was completing more reps and this trend would likely continue to additional rounds of work due to less accumulated fatigue in the early part of the workout compared to an all-out strategy.

Although HR has been shown to a reliable tool for use during cardiovascular exercise due to its close relation with oxygen consumption, the use of HR as a way of estimating levels of intensity of training during strength exercises or involving intense participation of the upper limbs has been the subject of controversy. It has been shown that HR has a low correlation with VO_2 during weight training [22,23], especially because the number of repetitions and work duration plays a central role in the increase of HR during exercise. In addition, specific exercises that require a high level of contractions in the upper limbs, solicits a greater HR compared to VO_2 [23] and the presented exercise protocol had at least one upper body exercise every round. This cannot be discounted in this study, meaning the high heart rate response might be a combination of true O_2 demand by working muscle as well as additional heart rate response due to breath holds and thoracic pressure changes causing changes in the sinus rhythm and heart rate response. Yet, these results also point to the value of FFT as being more advantageous to aerobic conditioning compared to more traditional intermittent traditional resistance training and that a hard RPE intensity can produce similar HR response as an all-out intensity.

Regardless of the training method, a correct application of training intensity is one of the fundamental factors for positive physiological adaptations to occur leading to a concomitant improvement in performance [24,25]. On the other hand, excessive training performed at a high intensity will result in negative adaptations, including non-functional overreaching and/or overtraining. In this context, studies have shown that functional fitness practitioners have a tendency to develop symptoms of overtraining [8,9]. This tendency to develop symptoms of overtraining can be explained by the fact that a single session of metabolic conditioning of functional-fitness leads to increased acute oxidative stress [4], metabolic and inflammatory stress [5], high cardiovascular and RPE responses [6] and elevated sympathetic nervous system markers (i.e., plasma Epinephrine and Norepinephrine) [7]. As participation in Functional-Fitness programs often involve multiple training sessions in a week, it is possible that the frequent performance of metabolic sessions at a high intensity does not allow for recovery to occur between sessions. Seiler, et al. [26] demonstrated that training at higher intensities leads to higher levels of autonomic nervous system fatigue, that can often take up to 72 hours to recover. In line with these findings, it has been suggested that two to three high intensity training sessions might be the limit to what can be performed on a weekly basis, to allow for proper recovery between such sessions.

The use of RPE as a method to control training intensity could provide an alternative for participants and coaches to reduce the training intensity and thus, provide a training stimulus from which recovery will not be impaired. As the use of the CR-10 RPE scale is an inexpensive, non-invasive method of self-monitoring training intensity during metabolic conditioning of FFT that correlates with LAC, and with the number of repetitions completed, practitioners are encouraged to adopt it.

5. Conclusions

This study demonstrates that RPE may be a useful tool to prescribe and control training intensity during metabolic conditioning sessions of functional fitness due to its large correlation with lactate and number of repetitions completed. These findings are of importance in a practical setting, suggesting that coaches could use this method to prescribe training intensity in a practical, inexpensive way. This allows coaches and practitioners to better manipulate training loads and therefore, obtain better results and avoid negative outcomes, such as excessive fatigue and non-functional overreaching, by controlling their training sessions with a costless and practical approach.

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