Journal of Physical Education and Sport ® (JPES), Vol. 21 (5), Art 369, pp. 2776 - 2781, September 2021
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Influence of recovery mode on performance during sprint interval exercise

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Published online: September 30, 2021
(Accepted for publication September 15, 2021)
DOI:10.7752/jpes.2021.05369

Abstract:
Introduction: Interval exercise is an effective training strategy frequently used by athletes to improve their performance in sports. It mainly involves high-intensity interval exercise and sprint interval exercise. Among them, the recovery mode is an integral part of an exercise session and can be classified as active recovery and passive recovery. Problem Statement: It has been suggested that the recovery mode during a repeated interval session can influence the performance during an acute session of exercise. Purpose: The aim of the study was to compare the effect of different recovery modes on performance during repeated sprint interval exercise. Methods: A randomized crossover study design with 16 healthy men (age: 20.63 ± 2.68 years, BMI: 23.21 ± 2.91 kg/m^2, Body fat: 18.16 ± 4.28% kg, VO_2peak: 44.9 ± 5.2 ml.kg^{-1}.min^{-1}) recruited from a university population participated in this study who performed over three separate sessions with four repeated maximal 4 × 30 s all out active recovery, passive recovery or combined on a rowing ergometer. Results: No differences were found between recovery modes for VO_2 (PR: 42.96 ± 5.30; AR: 43.53 ± 5.71 and CR: 43.61 ± 4.18 ml.kg^{-1}.min^{-1}), distance covered (PR: 149.8 ± 16.14m; AR: 152.6 ± 16.29m; CR: 147.4 ± 10.53m) and mechanical power (PR: 369.2 ± 92.6W; AR: 376.3 ± 104W; CR: 362.5 ± 98.7W). Conclusion: The results of the present investigation suggest that the recovery mode does not influence performance during a sprint interval rowing exercise session in healthy men. The recovery periods longer than four min are sufficient for complete restoration of power output, independent of the recovery mode. From a practical application, maintaining performance during the training sessions is important for preserving the volume load and intensity throughout the period. Therefore, practitioners also have the option of employing a combination of different recovery modes over time, as this may help in maintaining the performance. These findings have shown that the recovery modes (AR, PR, CP) are equally effective for maintaining the performance during SIE.
Keywords: Athletic Performance; Endurance; Peak Oxygen Uptake; High-intensity interval training

Introduction

Interval exercise is an effective training strategy frequently used by athletes to improve their performance in sports. It is a time-efficient approach to exercise characterized by high-intensity workouts (submaximal, maximum, and supramaximal), followed by moments of recovery (Gibala e Mcgee, 2008). It mainly involves high-intensity interval exercise (HIIE) and sprint interval exercise (SIE). HIIE requires repeated efforts to be performed with vigorous-intensity ("almost maximum") (Gist et al., 2014). Efforts made with heart rate (HR) ≥ 80% HRpeak or equivalent are expressed as VO_2max, VO_2peak, VO_2reserve, or Rating of Perceived Exertion (RPE). SIE refers to efforts carried out in intensities equal to or greater than VO_2peak, including 'all out' (Buchheit e Laursen, 2013) or 'supramaximal' efforts (> 100% HRpeak, VO_2peak, or VO_2max).

In this context, a study by Buchheit and Laursen (2013) has shown that there are nine variables to be controlled during an HIIE or SIE session. Among them, the recovery mode is an integral part of an exercise session and can be classified as active recovery (AR) and passive recovery (PR). Previous studies have demonstrated that the recovery mode during a HIIE or SIE session can influence the performance during an acute session of exercise (Dupont et al., 2004).

Studies compared the effect of recovery mode (AR vs. PR) during an HIIE session on performance-related conflicting results to find out the best recovery mode to achieve higher performance (time to exhaustion, mean power, distance) during the exercise session (Bazuelo-Ruiz et al., 2021; Bogdanis et al., 1996; Kostoulas et al., 2018; Signorile et al., 1993; Toubekis et al., 2005). However, two recent systematic reviews by Madueno et al. (2019) and (Perrier-Melo et al., 2020) examined the physiological, perceptual, and performance effects of active versus passive recovery applied between repeated-sprints. They found that passive recovery facilities reduced physiological and perceptual demands as well as performance decrement when compared to active recovery. The majority of studies that analyzed the mechanism associated with better performance demonstrated that during PR, there was better creatine phosphate resynthesis, thermal exchange, and muscle reoxygenation (Dupont et al., 2007; Kriel et al., 2016; Ohya et al., 2013; Spencer et al., 2006). However, AR shows there is a

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slight normalization in pH levels and rapid blood lactate clearance when compared to PR, which can justify, for some studies, a superiority in achieving the best performance(Connolly et al., 2003).

On the other hand, little is known about the effects of combined recovery (CR) (passive + active or vice-versa) during a repeated interval exercise. Gmada et al. (2005) reported no difference between active, passive and combined recovery during an repeated interval exercise session on a cycle ergometer; however, they did not use both recovery strategies in the same training session, as well as the use of the rowing ergometer as a new possibility to improve physical conditioning, being an equipment with increasing use in fitness training centers (Kercher et al., 2021).

It is relevant to highlight that the previous studies did not include other forms of ergometer as like rowing. Therefore, it is unclear the effect of recovery mode during a repeated interval exercise on rowing ergometer. Therefore, the study aimed to compare the effects of recovery mode on performance during an SIE rowing session. It was hypothesized that a CR and PR would allow a higher performance compared to AR. So, this study aimed to compare the effect of recovery mode on performance during an SIE.

Materials & Methods

Participants

Sixteen healthy men (age: 20.63 ± 2.68 years, BMI: 23.21 ± 2.91 kg/m^2, Body fat: 18.16 ± 4.28% kg, VO_2peak: 44.9 ± 5.2 ml.kg^{-1}.min^{-1}) recruited from a university population participated in this study (as described in Table 1). None of these men had taken part in any regular training during the past six months. The participants were instructed to avoid other physical activities and not change their dietary patterns throughout the study period. All the participants participated in the study voluntarily and provided written informed consent, which was approved by the University Ethics Committee according guidelines of the Declaration of Helsinki.

Table 1. Physical and physiological characteristics (n= 16)

Age (years)	**Body mass (kg)**	**BMI (kg/m^2)**	**Body Fat (%)**	**VO_2peak (ml.kg^{-1}.min^{-1})**	**HRpeak (bpm)**	**Power peak (watts)**
20.63 ± 2.68	70.36 ± 10.25	23.21 ± 2.91	18.16 ± 4.28	44.9 ± 5.2	185. 44 ± 9.65	221.88 ± 49.05

BMI: body mass index, ml.kg^{-1}.min^{-1} : milliliters per kilograms per min, bpm : beats per min

Procedures

All participants were warned to maintain their usual diet and routine during the study period. A randomized crossover study design was administered to the participants. The experimental protocol consisted of five visits. All visits were performed at the same time of the week, and by the same researcher, with an interval of at least 72 hrs. All participants were instructed not to perform any kind of physical exercise 48 hours before the sessions.

During the initial visit, participants performed body composition measurement and familiarization with the maximal oxygen uptake (VO_2peak) test. On their second visit, they performed a VO_2peak re-test but a significant difference was not observed between the test and retest (p > .05). On their third to fifth visits, the participants were randomly divided into three groups who performed the protocol with AR, PR, or CR to verify the effect of the recovery mode on performance.

Body Composition

The body mass (kg – Filizola S.A, São Paulo, Brazil, accuracy of 0.1 kg) and height (professional stadiometer Sanny, São Paulo, Brazil, accuracy of 0.1 cm) were measured[(Stewart et al., 2011)]. Body composition (fat mass) was recorded using body scanning by dual-energy X-ray absorptiometry (DXA) (Hologic, Waltham, MA, United States), followed by calibration and procedures by guidelines (Heymsfield et al., 2014).

Maximal Incremental Test

Participants performed a maximal graded exercise test (GXT), using a Concept II model C rowing ergometer (Morrisville, VT, USA) to determine their heart rate peak (HRpeak), VO_2peak, and peak power (PP). The participants were connected to a breath-by-breath gas analyzer, and the test commenced with an initial light-intensity warm-up (25 W) on the ergometer for three min. After a warm-up, an additional 25 W was increased every min until volitional exhaustion (Buckley et al., 2015). During the GXT, heart rate (HR; Polar Electro H7, Bluetooth 5 kHz, Finland), respiratory and pulmonary gas-exchange variables were continuously measured using a telemetric portable breath-by-breath gas analyzer (Model Quark PFT – Cosmed – Rome). VO_2peak was considered when the participant reached > 90% HR peak, VCO_2 / VO_2 > 1.1 and / or voluntary exhaustion. The average final 30 s were used for the determination of VO_2peak. The power at the last completed stage was recorded as the PP.

Sprint Interval Exercise

The sprint interval exercise (SIE) was performed using a rowing ergometer. The SIE consisted of 28 min of interval exercise. The randomized allocation order was: i) AR, PR, and CR, ii) PR, CR, and AR, or iii) CR, AR, and PR. A standardized warm-up was performed before all the exercises. The warm-up was rowing for five min at 30 % PP. The SIE consisted of four sets of 30 s all-out sprints (rowing maximally) alternated with four minutes of AR (30 - 40 % PP) or PR (remained stationary on rowing ergometer) or CR (2 min of AR + 2 min of PR). Finally, the cool down comprised five min of rowing at 30 % PP. During the SIE, respiratory gas-exchange values were measured breath-by-breath using an automated gas-analysis system (Model Quark PFT – Cosmed – Rome) to determine oxygen uptake. The VO_2peak was determined to be the highest mean VO_2 attained in successive 30 s periods. For each sprint, average power output (defined as mean power for the 30 s sprint) and peak power (defined as the highest power achieved during 30 s sprint) were recorded using a rowing ergometer (PM5) display.

Statistical Analyses

The results are expressed as the mean ±SD. The normality of data was checked using the Shapiro-Wilk test. A two-way analysis of variance with the Bonferroni post hoc test was conducted to compare variables related to performance over time (Group *vs.* Time). The effect size (*ES*) was also measured. For all the statistics, the significance level was set at $p < .05$. All analyses were completed using GraphPad Prism 5.0 (GraphPad Software, Inc, La Jolla, CA).

Results

Cardiorespiratory Data During Repeated Row-based Sprinting

The effects of recovery mode on VO_2peak showed no significant difference between recovery strategies (p = .81), with mean values of 42.96 ± 5.30; 43.53 ± 5.71 and 43.61 ± 4.18 $ml.kg.min^{-1}$, for PR, AR, and CR, respectively, (PR vs. AR: *ES* = .11; AR vs CR: *ES* = .02; and PR vs. CR: *ES* = .14) (as shown in Figure 1).

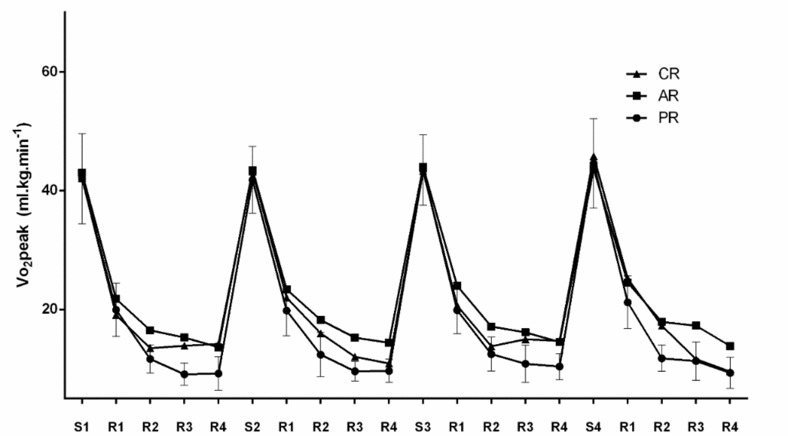

Figure 1. Oxygen uptake (VO_2) during the four sprints with active (AR), passive (PR) and combined recovery (CR). S: Sprint; R: Recovery; AR: Active recovery; CR: Combined recovery; PR: Passive recovery.

Total Distance During Repeated Row-based Sprinting

The mean (± SD) performance time of each bout for all sprints in each of the recovery modes (see Figure 2). The mean of total distance for each bout (see Figure 3), showed no difference between the three modes (PR: 149.8 ± 16.14m; AR: 152.6 ± 16.29m; CR: 147.4 ± 10.53m – PR vs. AR: p = .5, *ES* = .18; AR vs CR: p = .5 – *ES* = .39; and PR vs. CR: p = .52 – *ES* = .18). (as shown in Figure 2 and 3).

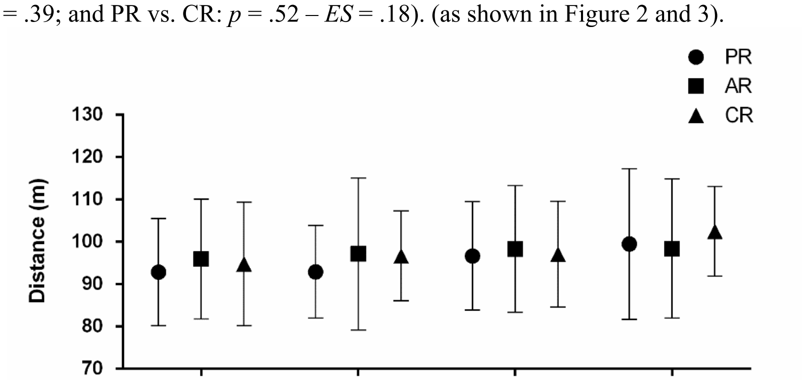

Figure 2. Total distance covered during the four sprints with active (AR), passive (PR) and combined recovery (CR). S: Sprint; AR: Active recovery; CR: Combined recovery; PR: Passive recovery.

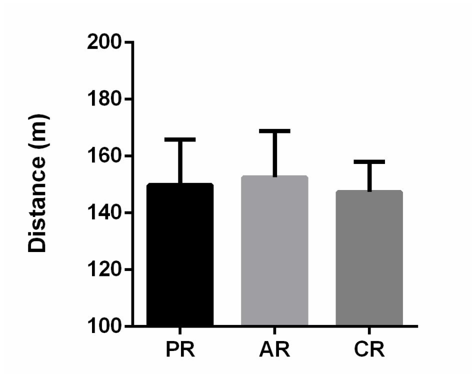

Figure 3. Total mean distance during session. AR: Active recovery; CR: Combined recovery; PR: Passive recovery.

Mechanical Power Data During Repeated Row-based Sprinting

Regarding the mean power output for each bout (see Figure 4), no significant differences were found between the three modes (see Figure 5) (PR: 369.2 ± 92.6 W; AR: 376.3 ± 104 W; CR: 362.5 ± 98.7 W; PR vs AR, p = .05; ES = .07; AR vs CR: p = .45 – ES = .14; and PR vs. CR: p = .45 – ES = .07). (as shown in Figure 4 and 5).

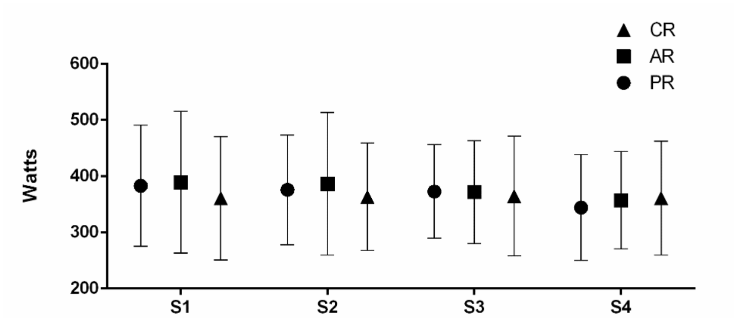

Figure 4. Mechanical power during the four sprints with active (AR), passive (PR) and combined recovery (CR). S: Sprint; AR: Active recovery; CR: Combined recovery; PR: Passive recovery.

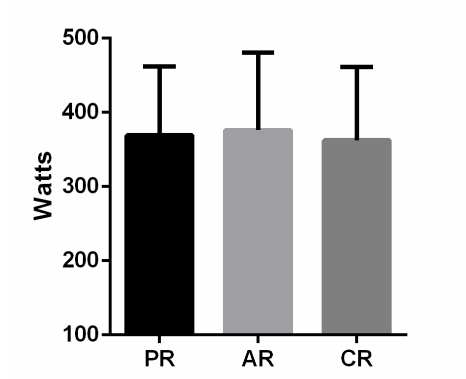

Figure 5. Total mean mechanical power during AR: Active recovery; CR: Combined recovery; PR: Passive recovery.

Discussion

To the author's knowledge, this is the first study to evaluate performance adaptations associated with recovery mode in rowers during a session of SIE. The initial hypothesis stated that it would be possible to achieve better performance levels with PR and CR. However, in contrast to our hypotheses, the results of the present study demonstrated that: a) no differences were found in VO_2peak between recovery modes; b) the peak power outputs produced during each bout were not significantly different between the recovery modes, and c) the total distance covered was not significantly affected by the recovery modes.

Previous studies have shown that when performing AR during SIE, there is a significant increase in metabolic response compared to PR (Bogdanis et al., 1996; Gmada et al., 2005; Spencer et al., 2008, 2006). In contrast, the results of the present study showed no difference in VO_2 between recovery modes. Our results are similar to those reported in the previous studies (Dupont et al., 2004; Kriel et al., 2016), even though the present study incorporated rowing intermittent exercise. A potential explanation for any difference between recovery modes could be a decrease in compensatory oxygen utilization in non-exercise-associated tissue. The period of recovery was at four min at 40 % probably increased blood flow during active recovery, possibly increasing the oxidative potential for PCr resynthesis.

To date, only two studies (Buchheit et al., 2009; Dupont et al., 2004) have investigated the effect of recovery modes (AR vs. PR) on total distance covered. In both studies, PR resulted in a greater distance being covered during intermittent sprint exercise. When the protocol was until exhaustion, PR was 41 % greater to AR. These studies analyzed the mechanisms associated with the decline in total distance covered during AR. Buchheit et al. (2009) showed that AR was associated with higher muscle deoxygenation, and Dupont et al. (2004) demonstrated that the deoxyhemoglobin values were significantly higher during AR than during PR. In our present study, no significant differences were found between the recovery modes (AR vs. PR vs. CR). Regardless of the recovery mode, four min (30% – 40 %) was sufficient for the restoration of the PCr substrate, and thus the performance achieved between PR and CR was similar (Spencer et al., 2006).

A previous study suggested that PR promoted higher power output than AR in sprints (cycle and running-sprints) (Wahl et al., 2013). Studies suggest that short active recovery intervals (< 50 s) can interfere with the speed of PCr resynthesis and lead to poor performance (Nalbandian et al., 2017). In the present study, PP and mean power values during bouts were similar between recovery modes. Previous studies have shown that when the recovery period is longer than 100 s, the performance is not affected by the recovery mode (Ohya et al., 2013). According to Kriel et al. (2016), the increase in deoxyhemoglobin in ventilation and the lower average power during short periods of recoveries (< 50 s), may indicate that a higher level of deoxygenation contributes to the decrease in mechanical power. Significant differences in deoxyhemoglobin between bouts indicate the specificity of oxygen use, with repercussions on muscle power during maximum sprints (Kriel et al., 2016).

There were a few limitations to this study. First, physiological parameters such as blood lactate concentration and changes in tissue oxyhemoglobin and deoxyhemoglobin were not measured. Second, the study population consisted of healthy men; therefore, these findings may not be extrapolated to other sports modalities. And third, such performance results need to be analyzed over a medium to long time to verify the possible physiological signs identified in this study in an acute way.

Conclusions

The present investigation suggest that the recovery mode does not influence performance during a sprint interval rowing exercise session in healthy men. The recovery periods longer than four min are sufficient for complete restoration of power output, independent of the recovery mode.

From a practical application, maintaining performance during the training sessions is important for preserving the volume load and intensity throughout the period. Therefore, practitioners also have the option of employing a combination of different recovery modes over time, as this may help in maintaining the performance. These findings have shown that the recovery modes (AR, PR, CP) are equally effective for maintaining the performance during SIE. The choice for the load control mode will become an individual specificity of the practitioner by controlling the power, distance or maximum oxygen consumption in effort, as it was verified that these three forms of monitoring are effective, regardless of the use strategies.

Conflict of Interests

No conflict of interest was reported by the authors.

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