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Original research

The effects of cold water immersion with different dosages (duration and temperature variations) on heart rate variability post-exercise recovery: A randomized controlled trial

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ABSTRACT

Objectives: The aim of the present study was to investigate the effects of cold water immersion during post-exercise recovery, with different durations and temperatures, on heart rate variability indices.
Design: Hundred participants performed a protocol of jumps and a Wingate test, and immediately afterwards were immersed in cold water, according to the characteristics of each group (CG: control; G1: 5′ at 9 ± 1 °C; G2: 5′ at 14 ± 1 °C; G3: 15′ at 9 ± 1 °C; G4: 15′ at 14 ± 1 °C).
Methods: Analyses were performed at baseline, during the CWI recuperative technique (TRec) and 20, 30, 40, 50 and 60 min post-exercise. The average HRV indices of all RR-intervals in each analysis period (MeanRR), standard deviation of normal RR-intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent RR-intervals (RMSSD), spectral components of very low frequency (VLF), low frequency (LF) and high frequency (HF), scatter of points perpendicular to the line of identity of the Poincaré Plot (SD1) and scatter points along the line of identity (SD2) were assessed.
Results: Mean RR, VLF and LF presented an anticipated return to baseline values at all the intervention groups, but the same was observed for SDNN and SD2 only in the immersion for 15 min at 14 °C group (G4). In addition, G4 presented higher values when compared to CG.
Conclusions: These findings demonstrate that if the purpose of the recovery process is restoration of cardiac autonomic modulation, the technique is recommended, specifically for 15 min at 14 °C.

1. Introduction

Post-exercise recovery has been extensively investigated in the scientific scenario,[22] including techniques to accelerate the recovery process after exercise. Furthermore, studies investigating the effects of cold water immersion (CWI), which consists of body segments immersed in water at temperatures below 15 °C, have been encouraging.[7]

Analysis of heart rate variability (HRV) indices as indicators of autonomic nervous system (ANS) activity,[2,5,8] which performs a significant role in maintaining homeostasis, has been studied.[5,9] During exercise, sympathetic activity is increased, while during the post-exercise period there is a concomitant progressive parasympathetic reactivation with a sympathetic withdrawal.[2] The balance between sympathetic and parasympathetic activity reflects autonomic recovery and restoration of cardiovascular homeostasis which is an important component of overall recovery.[20]

Considering that exercise acts as a stressor agent, which causes metabolic and autonomic changes,[4,12] it is important to understand the possible post-exercise effects of CWI on ANS. Studies[2,5,8] suggest that CWI results in better ANS activity post-exercise, anticipating the recovery of HRV indices. This can potentially improve the adaptation to training loads or at least reduce stress-related symptoms[23] leading to an imbalance stress-recovery[15] and can confer a great cardioprotective effect.[20]

Bastos et al.[5] observed higher cardiac autonomic modulation on post-exercise recovery after CWI application performed at 11 ± 2 °C for 6 min, with higher parasympathetic indices compared to other

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recuperative techniques. The authors propose time and temperature application of this technique based on previous experience. This design is one of the various strategies commonly used. Pastre et al.,[22] in a systematic review, evidenced inconsistencies in studies using recovery techniques and attribute this to the variety of applications methods as immersion of members or total body, temperature and time of application used in CWI and the models of physical stress. The lack of the scientific literature refers to the absence of the association between dosages of intervention and the results. Therefore, it seems pertinent to investigate variables such as duration and temperature during CWI application.

The aim of this study was to investigate the effects of CWI on HRV indices as a post-exercise recovery technique, using different durations and temperatures. It was hypothesized that CWI, regardless of the application dosage, would be able to promote better autonomic modulation, thus anticipating the recovery moment. In addition it is believed that the immersion dosage is a decisive factor for optimizing the recovery of HRV indices, and CWI used for long durations and lower temperatures will present the positive effects already mentioned in previous studies.

2. Methods

Hundred young healthy male participants (aged 21.73 ± 2.92 years, height 1.75 ± 0.06 m, weight 74.22 ± 10.15 kg, BMI 24.15 ± 2.99 kg m^{-2}) were recruited, with a minimum classification requirement of being physically active according to the International Physical Activity Questionnaire (IPAQ). To be included, participants could not be smokers, alcoholics, using drugs that influenced cardiac autonomic activity or have cardiovascular, metabolic or endocrine diseases, as reported in a previous interview.[5]

To determine the sample size a priori knowledge was used, based on Bastos et al.[5] findings for SDNN, which represents the activity of both ANS branches, indicating the overall behavior of HRV.[29] A sample size of 18 participants per group was stipulated by a test of hypothesis (two-tail), with 5% level of significance and 80% power. The participants were randomized (*Microsoft Excel* software) and allocated into five groups, one control (CG—passive recovery), and four intervention (G1, G2, G3 and G4).

Following the analysis, there was some data loss due to the time series presenting less than 95% sinus beats. There was no loss in CG ($n = 20$), one loss in G1 ($n = 19$) and G2 ($n = 19$), two losses in G3 ($n = 18$) and no losses in G4 ($n = 20$).

All procedures were approved by the Research Ethics Committee of the Univ. Estadual Paulista (Protocol 51903/2012) and were performed in a laboratory with an average temperature of 22.0 ± 2.34 °C and relative humidity between 40% and 60%, between 5 and 10pm to avoid circadian variation.[5] Participants were advised not to perform vigorous exercise for either 24 h before and during the study, refrain from drinks and stimulants containing caffeine and any other supplements that might promote recovery. However, it was not carried out based on any monitoring beyond questioning the participants.

In order to capture the RR-intervals parameters, for further analysis of HRV, a chest belt was placed over the precordium region and a heart rate receiver (Polar RS800CX, Polar Electro-Oy, Finland) on the wrist.[12] During capture, the participants remained at rest in a sitting position breathing spontaneously.

The exercise protocol consisted of a jumping protocol and a short-duration maximal cycling test. The jumping protocol was composed of 10 sets of 10 maximal vertical jumps with a 1 min break between sets. Prior to starting the exercise, a maximal vertical jump was performed with a chalk mark made by the fingertips at the highest point of the jump. This mark was subsequently used as a target height that the participant attempted to maintain for each jump. On landing, participants were instructed to position their hands on their hips and adopt a knee joint angle of approximately 90° to avoid compensation.[28]

Immediately after, participants performed the short-duration maximal cycling test, consisting of a Wingate Test, on a cycloergometer (Biotec 2100-Cefise, Brazil), which triggers cardiac autonomic derangement.[18] The participants performed a 5 min warm-up, consisting of pedaling with a load of 1.0 kg at 60–90 rpm and sprints in the 2nd and 4th min, followed by maximum pedaling for 30 s with a load of 0.075 kp kg^{-1} of participant's body mass.[18] These stress protocols were considered to cause exhaustion in both musculoskeletal and metabolic systems.

Immediately after the stress protocol, an interval of 1 min was allowed for the transition to the recovery intervention and participants from the intervention groups were immersed up to the height of anterior–superior iliac spine, whilst remaining seated. The duration and water temperature of CWI were established in accordance with the characteristics of each group. G1 remained immersed for 5 min at 9 ± 1 °C; G2: 5 min at 14 ± 1 °C; G3:15 min at 9 ± 1 °C and G4: 15 min at 14 ± 1 °C. The immersion duration was controlled by a timer and the temperature was controlled by putting ice and stirring the water, and constantly evaluated by a thermometer with ± 0.3 °C accuracy. CG performed passive recovery seated for 15 min. These durations and temperatures of immersion were established in accordance with the most commonly used strategies in the literature[7,30] and those that allowed a more comprehensive assessment of CWI effects. Participants were not informed either which group they belonged to regarding intervention duration and temperature or which intervention was considered therapeutic.[11] After the recovery intervention, participants remained seated. The total recovery time was 75 min including the time the participant remained immersed.

HRV analysis was performed from RR-intervals series at a sampling rate of 1000 Hz analyzed using the software Polar Pro Trainer 5.0. Digital filtering was supplemented by manual filtering in order to remove the artifacts, ectopic and premature beats, and only series with more than 95% sinus beats were included.[12]

The extraction of each cardiac period (RR-interval) was analyzed using Kubios HRV Analysis Software 2.0 for Windows software (The Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland), and a fixed number of 256 consecutive RR-intervals[12] was considered at baseline (20 min with the participants at rest, of which the final 256 RR-intervals were selected), during the recuperative technique (TRec) (for intervention groups, the final 256 RR-intervals for 5 min for G1 and G2, for 15 min for G3 and G4, and for 5 or 15 min, for subsequent comparison with the appropriate intervention groups) and at 20, 30, 40, 50 and 60 min after exercise (128 RR-intervals before and after each time).

For analysis in the time domain (TD), Mean RR (average of all RR-intervals in each analysis period), RMSSD (square root of the average squared differences between adjacent normal RR-intervals) and SDNN (standard deviation of normal RR-intervals) indices were analyzed[26,29] expressed in milliseconds.

In the frequency domain (FD) the spectral components of very low frequency (VLF) (0.00–0.04 Hz); low frequency (LF) (0.04–0.15 Hz) and high frequency (HF) (0.15–0.4 Hz)[29] were utilized, expressed in ms^2, calculated using Fast Fourier Transform.[12] VLF assessed from short-term recordings, although tedious measure, was considered here for analysis.

For the quantitative analysis of the Poincaré plot (PP), SD1 (scatter of points perpendicular to the line of identity) and SD2 (scatter points along the line of identity) were utilized.[16]

To analyze the sample characteristics considering anthropometric and age data the descriptive statistical method was used and