EFFECTS OF IMMEDIATE MECHANOTHERAPY AND INTERMITTENT CONTRAST WATER IMMERSION ON SUBSEQUENT CYCLING PERFORMANCE

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ABSTRACT

Purpose: Finding the balance between the training, the competition, and recovery is a crucial component for maximal sports performance. A huge range of sport recovery methods is presented as an important part of training programs. In recent years, there has been an increasing interest in using the contrast water immersion and massage and its effect on subsequent muscle function. Recent studies have shown that the contrast water immersion affects the maximal force, which can be useful for subsequent repeated performance. This study aims to investigate the differences between using immediate mechanotherapy and contrast water immersion on cycling performance.
Methods: Eight physically active male participants (age 27.1 ± 2.32 years; body mass 77.38 ± 5.43 kg; body height 1.78 ± 0.05 m; body fat 10.12 ± 2.23 %; maximum heart rate 182 ± 4 beats·min^{-1}; VO_{2max} 47.92 ± 7.16 mL.kg^{-1}.min^{-1}) volunteered and gave written informed consent to participate in this study. Participants completed three trials, each separated by one week. Each trial consisted of two “all-out” exercise bouts (30-20-10 s) against the load resistance of 0.07 kg/body weight. Three minutes recovery phase was between the “all-out” exercise bouts (1 W/kg; a pedal rate of 70–75 rpm). Following this, the selected recovery strategy was applied for 24 minutes (PAS-passive recovery, MT-massage therapy, CWI-contrast water immersion). The effect of recovery was assessed through changes in performance parameters, blood lactate concentration, and blood gases analyses.
Results: The results obtained from the analysis showed positive statistical significance difference between using PAS vs. MT ($p = 0.0313$) and PAS vs. CWI ($p = 0.0441$) for peak power. Interestingly, there were similar differences in fatigue index when we had compared PAS vs. MT and PAS vs. CWI. A decrease in lactate levels overtime was the highest for CWI.
Conclusion: The results of this study indicated that CWI and MT could be considered as a useful method in sports recovery. The results of this research support the idea that passive recovery is not the right way of recovery, especially when the athletes expect subsequent performance. Future trials should assess the impact of water temperature and different massage techniques on performance and also for subjective feelings of athletes.

Keywords: anaerobic performance; blood lactate; sports recovery; massage therapy

Introduction

In the last few years, there has been a growing interest in sports recovery not only for performance enhancement but also for injury prevention. A large and growing body of literature has investigated numerous passive and active recovery methods, such as massage therapy, cold water immersion, cryotherapy, contrast water immersion, compression therapy, deep water running, stretching, electromyostimulation, hyperbaric oxygen therapy or carbohydrate replenishment (Barnett, 2006; Leeder, Gissane, van Someren, Gregson, & Howatson, 2012; Nelson, 2013; Struhar & Kumstat, 2017; Struhár, Kumstát, & Králová, 2018; Versey, Halson, & Dawson, 2013; Kumstát, Rybářová, Thomas, & Novotný, 2016). However, a significant problem with the recovery type is using in a real sports practice because of the economic burden or availability recovery techniques. Sports training and competition may usually decrease the next performance. This physiological consequence of intensive physical activity can last hours even days which create a situation when the athlete is not able to train at the required intensity. The imbalance between the proper recovery and training stress can lead to functional or non-functional overreaching or overtraining syndrome. Not only anecdotal evidence also proved to decrease physical performance, but also dysfunction of pathways and response in inflammatory and metabolic systems (Meeusen et al., 2013).

Some methods, like cryotherapy or electro-myostimulation are challenging to perform in the immediate phase of recovery. For this reason, it is essential to find alternatives which are not so expensive and time- consuming and also not required the unique proprieties. In recent years, there has been an increasing interest in contrast water immersion (CWI) which means alternating immersion in hot and cold water. The protocols of CWI usually consists of 0.5–3 min in one temperature followed by the same time in contrast temperature (Coffey, Leveritt, & Gill, 2004; D. Higgins & Kaminski, 1998; Vaile, Halson, Gill, & Dawson, 2008). The temperatures vary from 10 to 16°C for cold water and 40 to 46°C for hot water. The exact mechanism of CWI remains uncertain. Firstly, alternating warm and cold water is one of the key factors. Immersion of body part into the hot water evokes superficial vasodilation while cold water immersion is often associated with vasoconstriction. CWI reduces the inflammatory process and also alleviates acute pain after intense physical activity.

Another standard recovery method is massage because of its simplicity of use. However, the main effects are still unclear and often under investigation of sports scientists (Best & Crawford, 2017; Joseph, Hancharoenkul, Sitilertpisan, Pirunsan, & Paungmali, 2018; Resnick, 2016). Massage is often used to decrease pain and to alleviate delayed of muscle soreness. It is essential to mention that classical or sports massage do not statistically increase the blood flow, which is often described as the main effect of massage therapy (Hinds et al., 2004). However, the findings from the study of Crane (Crane et al., 2012) proved that massage attenuated the production of the inflammatory cytokines and interleukin-6 (IL-6). Subsequently, that is the real evidence that the massage can be considered beneficial by reducing inflammation for athletes.

The main aim of this investigation is to assess the effect of immediate mechanotherapy and CWI on cycling performance.

Methods

Participants

Healthy physically active male participants (age 27.1 ± 2.32 years; body mass 77.38 ± 5.43 kg; body height 1.78 ± 0.05 m; body fat 10.12 ± 2.23 %; maximum heart rate 182 ± 4 beats·min^{-1}; VO_{2max} 47.92 ± 7.16 mL·kg^{-1}·min^{-1}) volunteered and gave written informed consent to participate in this study. Participants had the right to withdraw from the study at any time. Prior to undertaking the investigation, ethical clearance was obtained from the Research Ethics Committee of Masaryk University. Exclusion criteria included athletes with (a) potential medical health problems (b) orthopedic history of back, knee and ankle in the six months preceding the study (c) taking drugs related to performance enhancement

Participants were asked to refrain from alcohol and caffeine products and strenuous exercise for the 24 h prior testing day. However, we advised continuing their normal levels of physical activity. Participants were all recreationally active (running, cycling, and tennis) and were familiar with the experimental testing methods used in the study.

Study design and ethical aspects

The study evaluated the effectiveness of three frequently used selected recovery strategies on subsequent cycling performance. Participants performed the three experimental trials carried out at the same time of day separated by seven days. One week before the study, age, body height, and weight were recorded, and participants performed a familiarization trial on a cycle ergometer (Lode Excalibur Sport). They also performed a shortened example of recovery strategies (passive recovery, massage therapy, and contrast water immersion). All experimental measurements were conducted in the Human Performance Laboratory of Faculty of Sports Studies.

On the day of testing, the participant randomly chose one type of recovery strategy without knowing the type. The testing protocol (Test I., Test II.) started with lactate (LA) and blood gases (BG) measurements. After initial testing biochemical parameters, the ergometer seat height was adjusted, so the participant´s legs had approximately 2–5° bend in the knee at leg extension. The test started with the warm-up phase (1 W/kg; a pedal rate of 70–80 rpm). Following this, the participant was instructed to pedal three times "all-out" exercise bouts (30-20-10 s) against the load resistance of 0.07 kg/body weight. Three minutes recovery phase was between the "all-out" exercise bouts (1 W/kg; a pedal rate of 70–75 rpm). Finally, LA activity and BG analyses were measured after the last "all-out" exercise bout. In the follow-up phase of the study, the selected recovery strategy was applied for 24 minutes. After the recovery strategy, the same testing protocol was repeated (without the recovery strategy). Participants were advised to take a carbohydrate-rich meal 2 hours before testing. During the testing, only drinking water was allowed ad libitum.

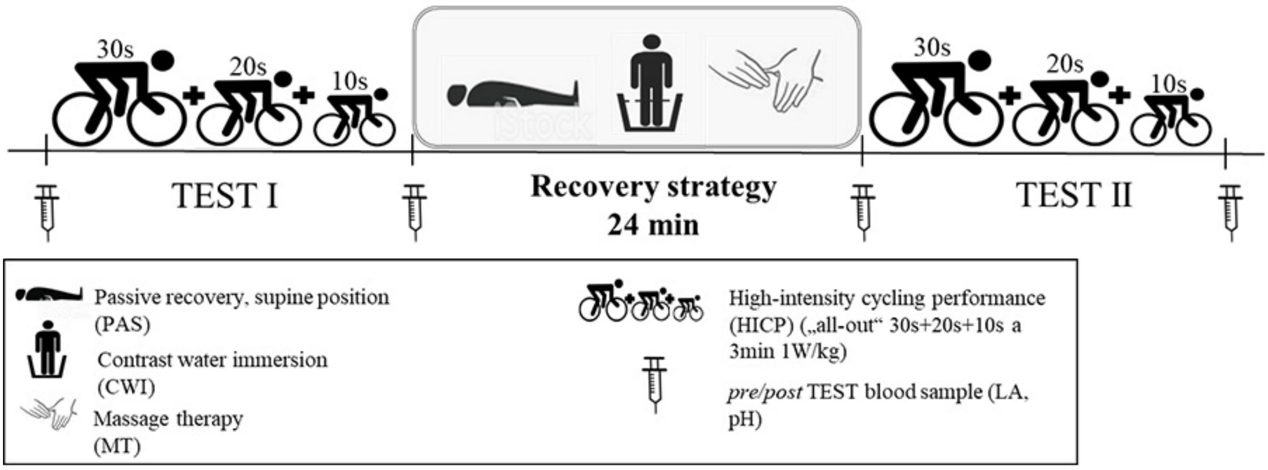

Figure 1 *Experimental design*

Characteristics of the treatments protocols

All selected strategies were used after Test I.

- *Passive recovery (PAS)*

The passive strategy was done in a precisely controlled supine position on a massage table. Head, knees, and feet were approximately at the same level. This strategy was completed in an air-conditioned laboratory at a temperature of 22°C. Participants stayed in this position for 24 min.

- *Massage therapy (MT)*

A licensed massage therapist with eight years of experience completed a 24 min leg massage (12 min for each side). The therapy was done in the supine position by using a conventional massage emulsion (EMSPOMA white). For this study, Western massages strokes were used (effleurage, petrissage, friction, tapotement, and the final effleurage).

The massage therapy protocol started with 1 min of superficial effleurage and 1 min of deep effleurage. Subsequently, the therapist performed compressive effleurage (1 min), friction with both palms (1.5 min) and petrissage (1.5 min) on calf muscles (performed with the bent knee). Then, compressive effleurage with four fingers and friction with both palms were administrated on iliotibial band (2 min). Afterward, the therapist performed petrissage on the thigh (2 min). Finally, the tissues of the thigh were agitated with tapotement (2 min; tapping, pinching, and hacking).

- *Contrast water immersion (CWI)*

The CWI protocol consisted of alternating 6 min immersions in tanks of cold (10–11 °C) and warm water (40–41 °C), repeated two times (10 s transfer time). CWI was done in standing position at height of fossa poplitea. The temperature of the water was constantly monitored. In case of higher or lower temperature, the researches adjusted the temperature according to the actual state.

Measures

Preliminary VO_{2max} test

All participants completed a maximal effort incremental cycling performance test on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). The incremental step test was completed two weeks before the study.

Verbal encouragement was provided at the end of the test to ensure that a maximal effort was reached. Especially, participant kept the cadence between 70–75 rpm during the whole test.

The test started with a warm-up phase without pedal load (2 min, 0 W) and then 4 min the self-selected pace for 4 min. The self-selected phase was completely according to the subjective decision of each participant (70–130 W). After the warm-up phase, power output was increased by 25 $W.min^{-1}$ until the participant was unable to maintain the expected work output (the pedal rate fell by > 10 rpm). The maintenance of expected pedal frequency was the first criterion of test validity. In addition of this, at least two criterions had to be filled for acceptance of the VO_{2max} measurement (1) The presence of a “plateau” in VO_2 ($\Delta VO_2 \leq 150$ mL/min) (2) respiratory exchange ratio (RER) > 1.15 at the end of the test (3) heart rate (HR) is within 10 $b.min^{-1}$ of the age-predicted maximum

Analysis of Blood Lactate (LA)

LA concentration was measured through a portable lactate analyzer Lactate Plus device (manufactured by Nova Biomedical) which analyzed a capillary blood sample obtained from finger-prick with a lancet. Blood lactate was measured four times before and after the test (Test I., II.).

Capillary blood gas analysis

Blood gas analysis was conducted by an electrochemical apparatus Gastat Navi (Techno MedicaCo., Ltd.). Whole blood samples were collected by finger prick using a sterile single-use lancing device. Blood sample of ~60 µl was collected into plain heparinized capillary tubes analyzed for pH.

Cycling performance

Each participant was instructed to finish bouts of maximum cycling performance on a cycle ergometer (Lode Excalibur Sport). The maximum cycling performance (CP) test consisted of three bouts of maximal effort (“all-out”) exercise (1) 30 s (2) 20 s (3) 10 s. The load resistance of the flywheel was set up on 0.075 kg of a subject's body weight. For this verbal study, encouragement was given during the bouts of exercise to ensure that the participant performed their maximal cycling capacity. The inconsistency of verbal encouragement can influence the cycling performance of the participant. Because of this, the Rocky movie motivational music for training and working played during each bout of the maximum cycling performance.

For the study, peak power, relative peak power, fatigue index, and maximum cadence were recorded during the three bouts maximum cycling performance test.

Statistical analysis

Data analyses were performed using Statistica 12.0 program. Descriptive statistics (mean ± SD) for the different variables were calculated. Normality assumptions for all data (pre and post) were checked respectively with Shapiro-Wilk test. The level of significance was set at $p < 0.05$.

Results

The overall performance measurement results are summarized in Table 1. The results obtained from the analysis showed positive statistical significance difference between using PAS vs. MT ($p = 0.0313$) and PAS vs. CWI ($p = 0.0441$) for peak power (20 s performance). Further statistical tests also revealed statistical significance between TEST I vs. TEST II (CWI, 10 s, $p = 0.0455$; MT, 20 s, $p = 0.0395$).

Table 1 *Descriptive data from repeated high-intensity cycling performance (HICP)*

PAS	**30 s**		*p*	**20 s**		*p*	**10 s**		*p*
	TEST I	**TEST II**		**TEST I**	**TEST II**		**TEST I**	**TEST II**	
Peak Power (W)	751.21 ± 23.40	782.75 ± 69.18	*NS*	798.23 ± 11.50	802.32 ± 59.80	*NS*	801.04 ± 27.21	814.33 ± 36.00	*NS*
Fatigue Index (%)	61.05 ± 13.43	60.52 ± 12.86	*NS*	51.50 ± 9.40	53.71 ± 11.87	*NS*	29.47 ± 5.66	31.45 ± 7.51	*NS*
CWI	**30 s**		*p*	**20 s**		*p*	**10 s**		*p*
	TEST I	**TEST II**		**TEST I**	**TEST II**		**TEST I**	**TEST II**	
Peak Power (W)	759.61 ± 29.02	769.14 ± 29.18	*NS*	801.05 ± 94.14	805.93 ± 156.01	*NS*	789.14 ± 63.22	824.34 ± 54.12	*0.0455**
Fatigue Index (%)	52.65 ± 5.71	53.95 ± 7.08	*NS*	59.04 ± 7.12	60.08 ± 5.09	*NS*	31.98 ± 5.70	32.27 ± 6.08	*NS*
MT	**30 s**		*p*	**20 s**		*P*	**10 s**		*p*
	TEST I	**TEST II**		**TEST I**	**TEST II**		**TEST I**	**TEST II**	
Peak Power (W)	778.21 ± 94.30	786.14 ± 89.24	*NS*	756.72 ± 54.60	798.89 ± 45.94	*0.0395**	802.33 ± 78.12	815.45 ± 64.19	*NS*
Fatigue Index (%)	49.58 ± 7.20	48.18 ± 6.15	*NS*	45.60 ± 7.38	49.18 ± 5.61	*NS*	39.53 ± 10.30	41.14 ± 9.54	*NS*

*$p < 0.05$; NS: not statistically significant

PAS – Passive recovery; **MT** – Massage therapy; **CWI** – contrast water immersion

In our paper, the focus of attention was also for assessing the lactate clearance. One of the more significant findings to emerge from this study is that the rate of decrease LA concentration was higher (TEST II_{pre}-TEST I_{post}) for CWI 1.53 ± 0.35 mmol/L, compared with PAS 0.5 ± 0.24 mmol/L ($p = 0.0348$).

It is equally important to mention that the similar results were found for MT 1.37 ± 0.19 mmol/L, compared with PAS 0.5 ± 0.24 mmol/L ($p = 0.0414$).

Discussion

This study assessed the effects of contrasts water immersion, massage therapy and passive recovery on performance and biochemical indicators of exercise-induced muscle fatigue. Firstly, we decided to use CWI. The protocol consisted of alternating 6 min immersions in tanks of cold (10–11 °C) and warm water (40–41 °C), repeated two times (10 s transfer time). The decrease in temperature tissue can stimulate cutaneous receptors. This can affect decreasing the swelling and also inflammation process in the human body (Enwemeka et al., 2002). Cold also decreases nerve conduction velocity in tissues affected by cold temperature which affect muscle pain. Subsequently, we can expect better performance, especially if the athletes have to produce maximal power several times during the match or competition. After the application of cold therapy, superficial heating by warm water was used. It is believed that it causes decreasing sympathetic nerve drive (Cochrane, 2004). This process increases circulation by vasodilation of blood vessels. It has been found higher 10 s peak performance (Pre-test: 789.14 ± 63.22 vs. Post-test: 824.34 ± 54.12; $p = 0.0455$) after the application of CWI. Similar results were found in the rate of decrease LA concentration (TEST II_{pre}-TEST I_{post}) for CWI 1.53 ± 0.35 mol/L, compared with PAS 0.5 ± 0.24 mmol/L ($p = 0.0348$). These results are consistent in good agreement with other studies which have shown that CWI (T. R. Higgins, Greene, & Baker, 2017; Hing, White, Bouaaphone, & Lee, 2008; Versey et al., 2013).

The present study was also designed to determine the effect of MT on performance. MT is extensively used in sports training because of its effect of lactate removal and decreasing edema and pain (Weerapong, Hume, & Kolt, 2005). However, we can also expect the physiological effect through ß-endorphins Statistical analysis showed significant differences between 20 s peak performance (Pre-test: 756.72 ± 54.60 vs. Post-test: 798.89 ± 45.94; $p = 0.0455$). This fact can be explained by neurological mechanisms. A neural-gating mechanism in the spinal cord is activated during massage therapy. In the literature, several theories have been proposed to explain this mechanism. Stimulus from massage stimulates large fast nerve fibers (Hall, 2016). This means that slower nerve fibers can be blocked for detecting the pain (Weerapong, Hume, & Kolt, 2005). The findings of this study support this idea. On the other hand, objective data for supporting this idea is still missing. MT also influence the biochemical process in our body especially the higher production of serotonin. Serotonin has a crucial role in pain modulation in both central and peripheral nervous systems. The higher level of serotonin which is produced during the MT can have a positive effect on peak performance during the tests.

The present study is one the first which analyze the effect of CWI and MT and PAS in one study design. The findings support the idea of using recovery modalities(CWI, MT) in sports practice.

Conclusion

Contrast water immersion and massage therapy as the recovery modalities gained massive popularity in recent years. However, most of the previous studies do not take into account the comparison between recovery modalities. From the outcome of our investigation, it is possible to conclude that MT and CWI as recovery modalities is beneficial for anaerobic type of physical activity.

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