Effects of Post-Exercise Recovery Interventions on Physiological, Psychological, and Performance Parameters

Authors C. Cortis[1], A. Tessitore[1], E. D'Artibale[1], R. Meeusen[2], L. Capranica[1]

Affiliations
[1] University of Rome Foro Italico, Department of Human Movement and Sport Sciences, Rome, Italy
[2] Vrije Universiteit Brussel, Human Physiology & Sports Medicine, Brussels, Belgium

Key words
- active recovery
- passive recovery
- near-infrared spectroscopy
- oxygen consumption
- countermovement jump

Abstract

At present, there is no consensus on the effectiveness of post-exercise recovery interventions on subsequent daily performances. The purpose of this study was to compare the effectiveness of 20 min low-intensity water exercises, supine electrostimulation, and passive (sitting rest) recovery modalities on physiological (oxygen consumption, blood lactate concentration, and percentage of hemoglobin saturation in the muscles), psychological (subjective ratings of perceived exertion, muscle pain, and feeling of recovery), and performance (countermovement, bouncing jumping) parameters. During three experimental sessions, 8 men (age: 21.9 ± 1.3 yrs; height: 175.8 ± 10.7 cm; body mass: 71.2 ± 9.8 kg; VO_{2max}: 57.9 ± 5.1 $ml \cdot kg \cdot min^{-1}$) performed a morning and an afternoon submaximal running test. The recovery interventions were randomly administered after the first morning tests. Activity and dietary intake were replicated on each occasion. ANOVA for repeated measures ($p < 0.05$) showed no difference between the morning and afternoon physiological (ratios: range 0.90–1.18) and performance parameters (ratios: range 0.80–1.24), demonstrating that post-exercise recovery interventions do not provide significant beneficial effects over a limited time period. Conversely, subjects perceived water exercises (60 %) and electrostimulation (40 %) as the most effective interventions, indicating that these recovery strategies might improve the subjective feelings of wellbeing of the individual.

Introduction

Physical exercise is a remarkable stressor for the physiological and psychological aspects of the individual and monitoring recovery is important to identify the appropriate individual's training loads to maximize performance, especially when training regimens include multiple daily sessions. Actually, the morning session might compromise the working capacity of athletes during the following afternoon training when performance decrements, and physiological and psychological disturbances might occur. In fact, research has shown that a protocol including two consecutive graded incremental exercise tests performed with a 4 h rest interval could be a good indicator of the recovery capacity of the athlete and of his/her ability to perform the second bout of exercise normally [34, 35].

To facilitate the recovery process, different post-exercise recovery modes have been suggested, broadly classified into two categories [6, 28]: 1) passive recovery, which involves upright, sitting, and supine rest, showers, massages, saunas and electrostimulation; or 2) active warm-down, which includes low-intensity exercises (i.e., jogging, cycling, technical exercises, chalistenics, stretching, and water exercises). In particular, studies that have compared the effects of different recovery modes generally have used passive recovery in a seated position as a control group [22, 30, 48, 49]. Conversely, electrostimulation aiming to facilitate the recovery process by increasing blood flow and metabolite washout of muscles [3, 22, 30] has been studied in a supine position [48, 49]. Finally, active water exercises are recommended to enhance stretching and recovery from musculoskeletal fatigue, improve heat dissipation [16], increase physiological and psychological indices of relaxation [37], and decrease spinal loading [15].

Several authors tested the hypothesis that active recovery would lead to a better maintenance of exercise performance in subsequent bouts of exercise performed during a single experimental session [11, 12, 13, 17, 19, 21, 22, 24, 30, 32, 45].

accepted after revision
January 10, 2010

Bibliography
DOI http://dx.doi.org/10.1055/s-0030-1248242
Published online:
February 23, 2010
Int J Sports Med 2010; 31: 327–335 © Georg Thieme Verlag KG Stuttgart · New York
ISSN 0172-4622

Correspondence
Prof. L. Capranica
IUSM, Department of Human Movement and Sport Sciences
P.za L. De Bosis, 15
00135 Rome
Italy
Tel.: +39/6 36 733 207
Fax: +39/6 36 733 330
laura.capranica@iusm.it

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

However, an experimental protocol that elicits high muscle soreness lacks an ecological validity because in reality no coach would intentionally induce severe muscle fatigue in his/her athletes. To our knowledge, only one study included athletes undergoing a twice a day training program in a real life setting (i.e., without any manipulation of the experimental condition) with the aim to examine the efficacy of recovery interventions in maintaining sprinting and jumping performances before starting the afternoon training session [48]. Because the different methodological approaches originated inconsistent findings, Barnett [3] claimed that further research is needed to solve the ambiguity of the relation between recovery interventions, athletic performance, and physiological and psychological parameters. In fact, to explain the multi-factorial aspects of the recovery process there is a need for interdisciplinary research including a combination of measures and controlling for several potential confounding variables, such as the fitness level, diet, hydration, and sleep of individuals [3,48,49].

Recently, a multiple system approach of measurement (performance, psychological, hormonal) has been adopted in field situations to ascertain the effectiveness of passive vs. active recovery interventions following pre-season soccer training that included two daily sessions [48], and futsal games scheduled twice a week [49]. Despite no difference emerging between recovery interventions in anaerobic performances, recovery-stress state, and hormonal responses, the athletes declared to feel significantly more recovered following electrostimulation and water exercises compared to dry exercises and sitting rest. Thus, the authors called for further research to explore more sensitive markers of recovery and to assess whether electrostimulation and water exercises could facilitate aerobic rather than anaerobic parameters. In fact, during training sessions submaximal exercises are more frequent than maximal ones, contributing to the maintenance of the less persistent all-out performances.

Although it is conceivable to assume that recovery interventions might enhance the individual's capabilities to exercise at submaximal intensities during a second daily exercise session, to our knowledge no research has tested the hypothesis that they have any effect on the aerobic variables at ventilatory (i.e., oxygen consumption), muscle (i.e., blood deoxygenation and lactate concentration) and psychological (i.e., subjective ratings of perceived exertion, muscle pain, and feeling of recovery) levels. Thus applying a multiple system approach of measurement, this study aimed at determining the effectiveness of active and passive recovery interventions performed immediately after the morning training to maximize the aerobic and anaerobic working capacity of individuals as well as their psychological recovery status during the afternoon training session. Based on the direct relationship between these variables, it was hypothesized that during the afternoon sessions increases in the physiological parameters at a given exercise load, decreases in anaerobic performances, and disturbances in psychological parameters would reflect the under-recovery status of the individual.

Methods

Experimental approach to the problem

The local human research committee approved this study mainly designed to explore the effectiveness, if any, of three immediate post-exercise recovery interventions (i.e., sitting rest, water exercise, and supine electrostimulation). This investigation has been performed in accordance with the ethical standards of the International Journal of Sports Medicine [20]. The results could be relevant for athletes training on a twice-daily schedule who are interested in recovery interventions that could maintain or enhance their performance during the afternoon session, avoiding excessive strain on biological systems.

Because under-recovery could be characterized by performance decrements, physiological variations, and psychological disturbances, the experimental design included a multiple-system approach of measurement [48,49] and two daily incremental exercise tests, which proved to be a good protocol for the evaluation of the recovery capacity of the individual [34,35]. In sport sciences a strong relationship between exercise load and whole body metabolic parameters (i.e., oxygen consumption, VO_2; blood lactate concentration, [HLa]), heart rate, and subjective perception of fatigue has been established [1,7]. More recently near infrared spectroscopy became widely used to measure hemoglobin oxygen saturation in tissue ($\%StO_2$), yielding an estimate of the muscle oxygenation status in relation to exercise intensity, with a gradual decrease as a function of VO_2 and accumulation of lactate in blood [4,9,14,33,36,38,44]. Hence, this measure can nonivasively evaluate the relative changes in the balance between oxygen delivery and utilization at muscle level at submaximal exercise load, especially when combined with cardiorespiratory responses [39]. Thus, cardiac, ventilatory and muscular parameters were selected to investigate the aerobic performances, while blood lactate concentration and vertical jump measures were used to explore the anaerobic ones. The exercise protocol included four 5 min steps at incremental running velocities (i.e., 6, 8, 10, 12 $km \cdot hr^{-1}$, respectively). A speed of 12 $km \cdot h^{-1}$ was chosen being the highest speed tolerated for 5 min by the participants at submaximal intensity. To ensure steady-state conditions of ventilatory parameters and muscle oxygenation status measurements, data were considered from the end of the third minute of each workload. Finally, considering that the psychological state of the individual might help maintain his/her performance, subjective indices of stress-recovery status were explored.

The sample size of studies on the effects of recovery interventions and on muscle deoxygenation during exercise usually included a limited number (range: 7–12) of participants [11,14,26,49] because of the difficulty to involve participants in highly controlled experimental conditions over time. During the two-week experimental period of this study, variations in lifestyle that might determine confounding factors were controlled by recruiting participants from the Italian Army. Thus, it was ensured that recruits maintained the same lifestyle during the experimental period and that they refrained from high-intensity physical activities the day prior to the experimental session. In addition to the highly controlled lifestyle of the soldiers, during the experimental sessions participants received a standard meal (total caloric intake 900 kcal: 58% carbohydrates, 27% lipids, 15% proteins) and were provided with individual coloured bottle to monitor their fluid intake [34,48,49].

Participants performed five experimental sessions, with a three-day interval between tests. The first session was designed to collect the participant's anthropometric measurements and maximal oxygen consumption (VO_{2max}). A second trial was organized to familiarize the subjects with the experimental setting, consisting of 8 data collection stages (▶ **Table 1**) at 9:00 (morning pre-exercise), 9:30 (morning submaximal incremental exercise), 10:00 (morning post-exercise), 10:30 (recovery

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

Table 1 Schema of the experimental design (La = Blood Lactate; CMJ = Counter Movement Jump; BJ = Bounce Jumping; VO_2 = Oxygen Consumption, VCO_2 = Carbon Dioxide Production; HR = Heart Rate; RPE = Rate of Perceived Exertion; $\%StO_2$ = Percentage of Hemoglobin Saturation).

Time (h:min)	Stages	Data Collection
9:00	morning pre-exercise	La, body mass, questionnaires, warm-up, CMJ, BJ.
9:30	morning submaximal test	VO_2, VCO_2, HR, RPE, $\%StO_2$, La
10:00	morning post-exercise	La, body mass, CMJ, BJ
10:30	recovery intervention	
11:00	morning post-recovery intervention	CMJ, BJ
12:00	lunch	
16:00	afternoon pre-exercise	La, body mass, warm-up, CMJ, BJ
16:30	afternoon submaximal test	VO_2, VCO_2, HR, RPE, $\%StO_2$, La
17:00	afternoon post-exercise	La, body mass, CMJ, BJ

intervention), 11:00 (post-recovery intervention), 16:00 (afternoon pre-exercise), 16:30 (afternoon submaximal incremental exercise), 17:00 (afternoon post-exercise). In agreement with the literature [34, 48, 49], this time schedule provides sufficient time to perform pre-exercise, post-exercise, and post-recovery assessments, and to ensure sufficient postprandial time before the afternoon evaluations.

During the familiarization session the recovery intervention consisted of 8 min jogging, 8 min walking and running sideways and backwards, and 4 min stretching. During the experimental sessions, the morning exercise performance was followed by one of the three studied recovery protocols: 1) sitting rest (R); 2) shallow water-aerobic exercises with no buoyancy aids (W: 8 min jogging, 8 min walking and running sideways and backwards, and 4 min stretching) performed at a moderate intensity (60 % of individual HR_{max}); and 3) electromyostimulation (E) lying supine (SportP, Compex, Basel, Switzerland). For E recovery, impulses with 1 Hz decrements every 2 min starting from 9 down to 7 Hz, and every 3 min starting from 7 down to 2 Hz were administered. Monopolar impulses of 100 mA (rise time = 1.5 µs; pulse width = 340 µs; fall time = 0.5 µs) were used for the four channels. The participants selected the most comfortable intensity (i. e., between level 20 and 30). Electrodes were placed on the rectus femoris, vastus medialis and vastus lateralis, one electrode to be on the widest part of the muscle belly and the other on the insertion of the same muscle. Recovery interventions lasted around 20 min, according to the duration of the E recovery program and to the literature [22, 43, 48, 49].

A within-subjects design was used with the experimental trials conducted in a randomized counterbalanced order so that all the subjects performed the three 20 min recovery protocols at the end of the experimental period. Participants were required to wear the same athletic equipment (i. e., underwear, standard issue cotton station shorts, cotton T-shirt, socks and gym shoes) and measurements were conducted at the same time of the day to minimize the effect of diurnal variations on the selected parameters. The stability of the subjects' body mass, and aerobic and anaerobic performances during the experimental period was established comparing the data collected during the morning sessions. If these parameters were found to be stable, differences emerging in the dependent variables would be attributed to the recovery interventions.

Subjects

Eight men (age: 21.9 ± 1.3 years; height: 175.8 ± 10.7 cm; body mass: 71.2 ± 9.8 kg; body fat: 11.1 ± 4.4 %; VO_{2max}: 57.9 ± 5.1 ml·kg·min^{-1}; HR_{max}: 185 ± 5 beat·min^{-1}; [HLa_{max}]: 9.7 ± 2.2 mmol·l^{-1}) recruited from the military population in Rome provided their written consent to participate in this study. On average, they had completed 2.0 ± 0.3 years of military service, which included 1 h daily military activities (i. e., flag raising, marching with and without weapons, physical training, weapon training, etc.). Twice a week they also engaged in amateur team sports (i. e., soccer, futsal, volleyball).

Anthropometric measurements

Body mass was determined with an accuracy of 100 g (Seca, Hamburg, Germany) and percentage of body fat was ascertained by means of skinfold thickness evaluations on the right side of the body, with participant in the standing position. Skinfold thickness to the nearest 0.2 mm at the abdomen, axilla, chest, subscapula, suprailium, thigh, and triceps was measured three times by means of a Lange calliper (Cambridge Scientific Instruments, Cambridge, MD, USA) to calculate the individual's percentage of total body fat relative to age, according to Jackson and Pollock [25].

Maximal oxygen uptake evaluation

To assess VO_{2max}, the participants were familiarized with the treadmill (RunRace HC 1200, Technogym, Gambettola, Italy) exercise protocol and were instructed to avoid food for at least 2 h before exercise testing. Furthermore, subjects were required to refrain from caffeine at breakfast. Following a 5 min warm-up running (i. e., light jogging at 6 km·h^{-1} with a 0 % slope), participants were continuously urged to complete the highest exercise intensity possible. The initial speed was 8 km·$h^{-1}$and was increased by 2 km·h^{-1} every 2 min until the workload corresponding to the maximal oxygen consumption was reached. Testing was also terminated when severe fatigue, exhaustion or dyspnea occurred. A 5 min active recovery at 6 km·h^{-1} with a 0 % slope was allowed. During the test, heart rate (HR), oxygen consumption (VO_2), carbon dioxide production (VCO_2), and ventilation (VE) were recorded as averaged values every 5 s by a open-circuit oxygen uptake measurement system (PFT Cosmed, Rome, Italy). The PFT Cosmed flow meter was calibrated with a 3 L syringe (Hans Rudolph Inc, Dallas, TX, USA), and the gas analyzer was calibrated with known gas mixtures (16 % and 20.9 % O_2; 5 % and 0.03 % CO_2). Determinations of blood lactate concentrations [HLa] were performed at rest, at every stage and at the third, sixth, and ninth minute of the recovery phase using capillary blood from a fingertip immediately analyzed with an Accusport Lactate Analyser (Roche, Basel, Switzerland). The criterion used to assess the individual's VO_{2max} was the occurrence of a plateau or a VO_2 increase < 1 ml·kg^{-1}·min^{-1} despite further increases in the exercise intensity, a respiratory exchange ratio greater or equal to 1.15, a HR in excess of 90 % of age predicted HR_{max} (220-age), and [HLa] higher than 9 mmol·l^{-1}.

Measurements during the incremental running test

During the incremental submaximal running bouts, HR, VO_2, VCO_2, and VE were measured, averaging values every 5 s by an open-circuit oxygen uptake measurement system (PFT Cosmed, Rome, Italy). The Borg's scale of perceived exertion for the whole body (RPE) between 6 (no exertion at all) and 20 (maximal exertion) [8] was administered after the third minute of each step.

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

Determinations of [HLa] were performed at rest, at the third minute of every stage and at the third, sixth, and ninth minute of the recovery phase using capillary blood from a fingertip which was immediately analyzed (Accusport Lactate Analyser, Roche, Basel, Switzerland).

To measure the percentage of hemoglobin saturation in tissue (%StO_2) the noninvasive technique based on spectrophotometric principles was used. Oxygen saturation measurements on humans during exercise have been previously validated [31]. In this study %StO_2 was collected continuously every 3.5 s throughout the entire protocol on the left leg with InSpectraTM tissue spectrometer (Hutchinson Technology Inc., Hutchinson, MN, USA). A 25 mm probe was placed on the skin over the quadriceps muscle at the mean distance of the rectus femoris muscle. To be able to maintain the same point throughout the protocol, a surgical marker was used to mark the probe placement. The probe was connected to a cable containing transmitting and receiving optical fibres, using wavelength signals between 650 and 810 nm, which are differently absorbed by hemoglobin and oxyhemoglobin. The cable was linked to the photosensitive detector in the spectrometer. The probe and the skin were covered with dark tape to prevent contamination from ambient light. The detector signal was processed and displayed as percentage of hemoglobin oxygen saturation in tissue. To enable continuous measurement during exercise avoiding interferences, the StO_2 monitor was positioned next to the treadmill. StO_2 monitor was linked to a computer, therewith enabling the visualization of StO_2 data and their recording for later analysis. Before beginning the submaximal exercise, subjects rested on the treadmill and the near- infrared spectroscopy unit was calibrated according to the manufacturer's specifications and protocol. All data files contained marks to indicate the start and the end of each running step. The VO_2, HR and %StO_2 values registered during the last two minutes of each running step were averaged and mean values were considered for further analysis.

Vertical jump measurements

Throughout the study vertical jump tests were administered in the same order (i.e., counter movement jump: CMJ; and bouncing jumping: BJ). Pre-exercise measurements were preceded by a 15 min active warm-up on a cycle ergometer (40–60% of maximal heart rate). Jump performances were evaluated by means of an optical acquisition system (Optojump, Microgate, Udine, Italy), developed to measure with 10^{-3} s precision all flying and ground contact times. The Optojump photocells are placed 6 mm from the ground and are triggered by the feet of the participant at the instant of take-off and are stopped at the instant of contact on landing. Then, calculations of the height of the jump are made. For CMJ, from the standing position and keeping the hands on the hips, the participants were required to bend their knees to a freely chosen angle, which was followed by a maximal vertical thrust. For BJ, participants performed seven consecutive jumps. Participants were instructed to keep their body vertical throughout the jump, and to land with knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated. For each test, participants were allowed two trials with a 3 min recovery period. Thus, their best performance was used for statistical analysis and ratios between post-recovery and pre-exercise values were calculated.

Diet and fluid intake

For each experimental session pre-, post-exercise, and post-recovery session body mass were determined with an accuracy of 100 g. Since recovery takes place with appropriate diet and fluid intake, the participants were encouraged to drink before, and after the running test to meet their re-hydration needs. The participants were instructed to drink only from their own coloured bottles and not to spit out any drink. Observers monitored the drinking behaviour to ensure that participants used only the correct bottles and that they did not discard any fluid. All bottles were weighed in the morning and after the afternoon test stage to establish the volume of each participant's water intake consumed during the experimental session. Furthermore, the standard meal was administered during the first two hours of the rest period under the supervision of an observer.

Subjective ratings

The psychological status of the individual was explored by means of questionnaires designed to represent his recovery-stress state or to assess potentially stressful events and their consequences on general fatigue and on muscle groups. According to the literature [48,49], the RPE for the whole body [8], the CR10 scale of perceived muscle pain (RMP) for lower limbs between 0 (nothing at all) and 11 (maximum pain) [8], the 7-point Likert scale of the individual's recovery-stress state (RestQ Sport) [27], the sleep quantity [42], and the 10-point Likert scale (from 1 "not at all" to 10 "very, very much") of the subjective perception of recovery ("how do you feel recovered following this recovery intervention?" and "how did you like this recovery intervention?) [48,49] questionnaires were administered. To explore the effects of recovery interventions on the recovery-stress state of participants, the nineteen scales of the RestQ were analyzed separately. High scores in the general stress, emotional stress, social stress, conflicts/pressure, fatigue, lack of energy, physical complaints, disturbed breaks, emotional exhaustion, and injury scales reflect intense subjective stress. However, high scores in the success, social recovery, physical recovery, general well being, sleep quality, being in shape, personal accomplishment, self-efficacy, and self-regulation scales reflect an adequate recovery.

Statistical analysis

Data are presented as mean ± SD and the criterion for significance was set at an alpha level $p<0.05$. Statistical analyses were conducted using the statistical package StatView for Macintosh (version 5.0.1, SAS Institute Inc., Cary, NC, USA). A preliminary analysis of variance and intraclass correlation coefficients (ICCs) evaluated the stability of morning conditions of participants. An ANOVA for repeated measures verified differences between morning sessions for BJ, CMJ, RMP, RPE, and body mass. A 3 (morning session: first, second, and third) × 4 (exercise intensity: 6, 8, 10, and 12 $km \cdot hr^{-1}$) ANOVA for repeated analysis was applied to HR, VO_2, %StO_2, RPE, and [HLa] values recorded during the running test.

Differences between recovery interventions for BJ and CMJ morning values were ascertained by means of a 3 (recovery intervention: R, E, and W) × 3 (measurement stage: pre-exercise, post-exercise, post-recovery) ANOVA for repeated measures. Furthermore, BJ, CMJ, and body mass collected during the morning and afternoon sessions were submitted to a 3 (recovery intervention: R, E, and W) × 2 (measurement stage: pre-and post-exercise) × 2 (exercise bout: morning and afternoon) ANOVA for

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

repeated measures. To evaluate the effect of the submaximal running test on jump performances, pre- and post-exercise ratios were calculated. Ratios were submitted to a 3 (recovery intervention: R, E, and W) × 2 (exercise bout: morning and afternoon) ANOVA for repeated measures.

Differences between recovery interventions for VO_2, HR, $\%StO_2$, RPE, and [HLa] values collected during the running tests were submitted to a 3 (recovery intervention: R, E, and W) × 4 (exercise intensity: 6, 8, 10, and 12 $km \cdot hr^{-1}$) × 2 (exercise bout: morning and afternoon) ANOVA for repeated measures. Because chronobiological variations might influence morning-to-evening exercise responses [2] and performances [12, 48], ratios between afternoon and morning assessments were calculated to evaluate the degree of recovery from the morning exercise, interpreting values between 0.90 and 1.0 as a complete recovery. Ratios were submitted to a 3 (recovery intervention: R, E, and W) × 4 (exercise intensity: 6, 8, 10, and 12 $km \cdot hr^{-1}$) ANOVA for repeated measures.

An ANOVA for repeated measures with recovery interventions as independent variables was applied to sleeping time, water intake, RMP, RestQ subscales, and Likert parameters. If the overall F test was significant, post hoc Fisher protected least significant difference comparisons were used and the Bonferroni alpha level correction was applied to eliminate an inflated Type 1 error for multiple comparisons. Furthermore, to provide meaningful analysis for comparisons from small groups, the Cohen's effect sizes (ES) were also calculated. An ES 0.2 was considered trivial, from 0.3 to 0.6 small, <1.2 moderate and >1.2 large.

Results

▼

Stability of morning conditions of subjects and submaximal running load

Pre-exercise measurements showed no difference between experimental sessions, with ICCs of 0.48, 0.71, 0.74, 0.84, 0.99 for BJ, RMP, CMJ, RPE, and body mass, respectively. Comparing the exercise load administered during the morning sessions, a main effect emerged only between running intensities, with progressively increasing values for HR ($F_{(3,36)} = 80.55$; $p < 0.0001$), VO_2 ($F_{(3,36)} = 154.63$; $p < 0.0001$), RPE ($F_{(4,48)} = 27.12$; $p < 0.0001$) and [HLa] ($F_{(4,48)} = 6.63$; $p = 0.001$), and progressively decreasing values for $\%StO_2$ ($F_{(3,36)} = 8.13$; $p = 0.0012$). These variables showed high ICCs ranging from 0.95 to 0.99 and low ES (range: 0.04–0.54). Therefore, it was possible to submit dependent variables to comparisons between the recovery interventions.

Effects of recovery interventions on body mass, water intake, and sleep

Subjects' body mass was significantly higher ($F_{(1,12)} = 93.08$; $p < 0.0001$; $ES < 0.2$) before (71.8 ± 9.7 kg) than after (71.4 ± 9.7 kg) the running tests, and significantly ($F_{(1,12)} = 70.36$; $p = 0.0002$; $ES = 0.05$) lower in the morning (71.2 ± 9.7 kg) than in the afternoon (71.9 ± 9.7 kg) session, with no difference between recovery interventions. No difference between experimental sessions ($ICC = 0.74$) emerged for the water intake of subjects (1534 ± 529 ml) during the three experimental sessions. Individuals reported 7.0 ± 0.5 h of sleep with no disturbances, independent of recovery interventions.

Effects of recovery interventions on physiological parameters collected during the running tests

Table 2 reports the descriptive statistics for the physiological and RPE data collected during the morning and afternoon running bouts. None of these variables showed a main effect for recovery interventions. From the comparison of HR values, main effects for exercise intensity ($F_{(3,36)} = 113.23$; $p < 0.0001$; $ES > 1.2$) and exercise bout ($F_{(1,36)} = 13.80$; $p = 0.0099$; $ES < 0.06$) emerged. Higher values were registered in the afternoon (62 ± 8, 77 ± 6, 87 ± 7, 94 ± 11% HR_{max}) compared with those registered in the morning (55 ± 5, 73 ± 8, 86 ± 8, 91 ± 9% HR_{max}). For VO_2 values only running intensity showed a main effect ($F_{(3,36)} = 173.92$; $p < 0.0001$; $ES > 1.2$), with progressive increases corresponding to 38 ± 8, 62 ± 15, 78 ± 16, 87 ± 14% VO_{2max}, respectively. With increasing exercise intensity also $\%StO_2$ showed differences ($F_{(3,36)} = 8.91$; $p = 0.0008$; $ES > 1.2$), although in the opposite direction (i.e., 76 ± 12, 74 ± 9, 68 ± 10, 60 ± 12 $\%StO_2$ at 6, 8, 10, and 12 $km \cdot h^{-1}$ running speed, respectively). Although this variable showed an overall exercise bout × exercise intensity × recovery intervention interaction ($F_{(6,36)} = 2.51$; $p = 0.039$), post-hoc analysis did not show any difference between recovery interventions in the afternoon training session. For RPE main effects emerged

Table 2 Means and standard deviations of the parameters measured during the incremental submaximal running test.

		Running Velocity							
		6 $km \cdot h^{-1}$		8 $km \cdot h^{-1}$		10 $km \cdot h^{-1}$		12 $km \cdot h^{-1}$	
	Recovery	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**	**Morning**	**Afternoon**
heart rate ($beat \cdot min^{-1}$)	sitting rest	104 ± 6	115 ± 8	137 ± 13	144 ± 11	160 ± 9	162 ± 8	170 ± 14	173 ± 9
	electrostimulation	100 ± 6	117 ± 13	131 ± 12	140 ± 13	155 ± 7	159 ± 7	167 ± 12	168 ± 11
	water exercises	102 ± 9	112 ± 5	136 ± 14	141 ± 13	160 ± 8	160 ± 8	171 ± 15	174 ± 7
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	sitting rest	19.7 ± 2.6	20.2 ± 2.7	31.2 ± 5.3	30.7 ± 5.0	41.2 ± 4.4	40.9 ± 3.8	45.3 ± 7.7	46.4 ± 4.8
	electrostimulation	18.5 ± 2.6	19.7 ± 3.4	31.7 ± 4.7	31.0 ± 5.0	39.6 ± 4.1	39.7 ± 3.9	46.2 ± 5.0	42.7 ± 5.8
	water exercises	18.4 ± 2.3	17.9 ± 2.4	32.7 ± 5.4	33.7 ± 4.9	39.7 ± 4.2	38.2 ± 4.3	46.1 ± 6.6	44.6 ± 5.3
$\%StO_2$	sitting rest	76 ± 10	80 ± 9	77 ± 9	78 ± 9	72 ± 7	71 ± 11	64 ± 2	64 ± 9
	electrostimulation	70 ± 15	76 ± 14	66 ± 14	73 ± 8	60 ± 15	68 ± 11	52 ± 15	61 ± 15
	water exercises	75 ± 11	79 ± 9	75 ± 8	75 ± 6	71 ± 7	68 ± 6	63 ± 2	57 ± 8
RPE (pt)	sitting rest	7 ± 2	7 ± 1	9 ± 2	11 ± 2*#	11 ± 4	13 ± 4*§	15 ± 4	14 ± 5
	electrostimulation	7 ± 1	7 ± 3	9 ± 3	9 ± 3	12 ± 4	11 ± 4	14 ± 4	14 ± 4
	water exercises	7 ± 2	8 ± 2	9 ± 3	9 ± 3	11 ± 4	12 ± 4	14 ± 4	15 ± 4

* = differences ($p < 0.05$) with respect to morning values

\# = differences ($p < 0.01$) with respect to Electrostimulation and Water Exercise afternoon values

§ = differences ($p < 0.05$) with respect to Electrostimulation afternoon values

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

Table 3 Means and standard deviations of the countermovement (CMJ) and Bouncing (BJ) jump performances.

		Morning			Afternoon	
Vertical Jump	**Recovery**	**Pre-Exercise**	**Post-Exercise**	**Post-Recovery**	**Pre-Exercise**	**Post-Exercise**
CMJ (cm)	sitting rest	31 ± 2	33 ± 2	31 ± 2	30 ± 2	33 ± 2
	electrostimulation	31 ± 3	33 ± 3	31 ± 2	31 ± 3	33 ± 3
	water exercises	30 ± 2	33 ± 2	32 ± 3	30 ± 4	33 ± 2
BJ (cm)	sitting rest	25 ± 2	24 ± 4	23 ± 2	24 ± 2	25 ± 3
	electrostimulation	26 ± 2	26 ± 2	25 ± 2	24 ± 4	25 ± 4
	water exercises	23 ± 2	25 ± 4	25 ± 4	24 ± 5	24 ± 3

Table 4 Means and standard deviations of the ratios between the afternoon and morning parameters measured during the running performances.

Variable	**Recovery Intervention**	**Running Velocity**			
		6 km·h^{-1}	**8 km·h^{-1}**	**10 km·h^{-1}**	**12 km·h^{-1}**
heart rate	sitting rest	1.09 ± 0.03	1.05 ± 0.04	1.01 ± 0.01	1.05 ± 0.09
	electrostimulation	1.18 ± 0.03	1.07 ± 0.02	1.03 ± 0.03	0.98 ± 0.08
	water exercises	1.10 ± 0.09	1.03 ± 0.03	1.00 ± 0.02	0.99 ± 0.01
VO$_2$	sitting rest	1.03 ± 0.05	1.04 ± 0.04	1.00 ± 0.02	1.01 ± 0.21
	electrostimulation	1.07 ± 0.05	0.99 ± 0.08	1.00 ± 0.05	0.93 ± 0.15
	water exercises	0.97 ± 0.04	0.97 ± 0.04	0.96 ± 0.03	0.97 ± 0.05
%StO$_2$	sitting rest	1.05 ± 0.07	1.00 ± 0.11	0.97 ± 0.14	0.98 ± 0.18
	electrostimulation	1.12 ± 0.15	1.13 ± 0.15	1.17 ± 0.18	1.22 ± 0.24
	water exercises	1.06 ± 0.09	1.01 ± 0.11	0.96 ± 0.10	0.90 ± 0.13
RPE	sitting rest	1.13 ± 0.18	1.32 ± 0.37	1.14 ± 0.11	0.99 ± 0.14
	electrostimulation	1.10 ± 0.28	1.01 ± 0.09	0.96 ± 0.07	1.03 ± 0.09
	water exercises	1.09 ± 0.13	1.09 ± 0.12	1.10 ± 0.20	1.06 ± 0.12
blood lactate	sitting rest	0.94 ± 0.23	1.07 ± 0.30	1.03 ± 0.41	0.80 ± 0.23
	electrostimulation	1.19 ± 0.37	1.01 ± 0.39	0.93 ± 0.28	0.96 ± 0.19
	water exercises	1.04 ± 0.40	0.96 ± 0.38	0.86 ± 0.09	0.85 ± 0.16

for exercise bout ($F_{(1,36)} = 6.35$; $p = 0.045$; ES = 0.07) and exercise intensity ($F_{(3,36)} = 33.10$; $p < 0.0001$; ES = 0.4–0.7). Recovery intervention showed a difference only in the interaction with exercise bout and exercise intensity ($F_{(3,36)} = 2.73$; $p < 0.028$). Post-hoc analysis showed differences during the afternoon session between R and the other two recovery interventions for the 8 km·h^{-1} running speed, and between R and E for the 10 km·h^{-1} running speed. For [HLa] only a main effect for step ($F_{(4,48)} = 22.37$; $p < 0.0001$; ES ranging from 0.90 and 0.99) emerged. Lowest values were recorded during the 6 km·hr^{-1} (2.2 ± 0.7 mmol·l^{-1}) and 8 km·hr^{-1} (2.4 ± 0.6 mmol·l^{-1}) running steps and highest values during the 10 km·hr^{-1} (4.1 ± 1.7 mmol·l^{-1}) and 12 km·hr^{-1} (4.8 ± 2.2 mmol·l^{-1}) ones. Peak lactate values (4.9 ± 1.7 mmol·l^{-1}) emerged at the third (67 %) and sixth (33 %) minute of the post-exercise phase.

Effects of recovery interventions on jumping performances

▸ **Table 3** reports the performances registered during the five data collection stages for jump performances. No main effect emerged between recovery interventions and daily experimental sessions. Only CMJ showed a main effect for measurement stage ($F_{(1,12)} = 36.79$; $p = 0.0009$; ES = 0.01–0.6), with higher values for post-exercise performances (33.1 ± 2.4 cm) than pre-exercise ones (30.6 ± 2.6 cm), maintaining the same trend in the morning and in the afternoon. Values registered after the administration of the recovery interventions (31.6 ± 2.2 cm) were similar to pre-exercise ones.

Effects of recovery interventions on ratios

For the physiological parameters afternoon/morning ratios (▸ **Table 4**) ranged between 0.90 to 1.18, with no differences between recovery interventions. Also post-test/pre-test ratios of jump performances (▸ **Table 5**) approached 1.0 (CMJ = 0.99 ± 0.06; BJ = 0.98 ± 0.12) with no differences between recovery interventions.

Table 5 Means and standard deviations of the ratios between the pre- and post-exercise vertical jump performances.

	Recovery Intervention	**Morning**	**Afternoon**
countermovement jump	sitting rest	1.00 ± 0.03	1.00 ± 0.05
	electrostimulation	1.00 ± 0.04	0.97 ± 0.04
	water exercises	0.99 ± 0.12	0.99 ± 0.04
bouncing jumping	sitting rest	0.98 ± 0.08	1.04 ± 0.08
	electrostimulation	0.94 ± 0.09	0.97 ± 0.10
	water exercises	1.00 ± 0.23	0.99 ± 0.10

Effects of recovery interventions on subjective ratings

Low subjective perception of muscle pain (2.3 ± 2.1, corresponding to light pain) was registered, with no difference between recovery interventions and daily sessions. The stress-recovery state of the participants assessed by means of the RestQ Sport questionnaire (▸ **Fig. 1**), showed low mean values for the stress-associated activity scales (range: 0.6–1.8) and high values for the recovery-oriented scales (range: 2.2–4.1), with no difference emerging between recovery interventions. No participant reported sitting rest as the most effective (electrostimulation = 60 %; water exercises = 40 %) or appreciated (water exercises = 60 %; electrostimulation = 40 %) recovery intervention.

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

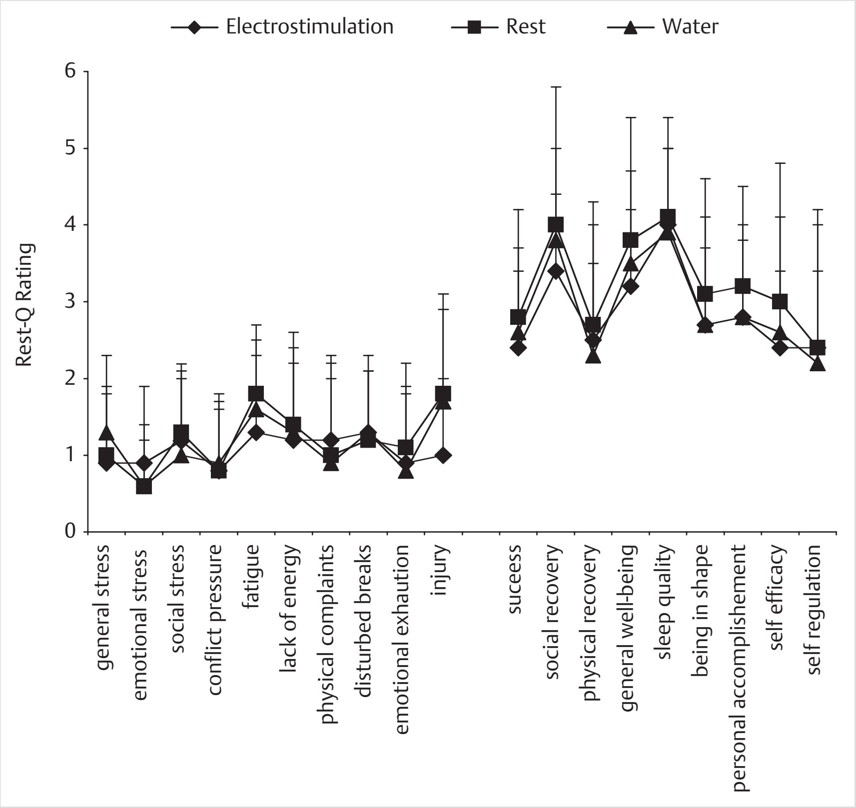

Fig. 1 Means and standard deviations of the 19 Items of the RestQ Sport Questionnaire in relation to the three recovery interventions. Rating Scale: 0 = "Never"; 1 = "Seldom"; 2 = "Sometimes"; 3 = "Often"; 4 = "More Often"; 5 = "Very Often"; 6 = "Always".

Discussion

The main finding of this study was that passive and active recovery interventions did not induce significant differences in aerobic, anaerobic, and stress-recovery status parameters in relation to two daily experimental sessions (i.e., submaximal exercise and pre- and post-exercise measurement stages), organized with a 4.5 h rest in between according to the literature [34,35] and the training schedule of athletes who adopt a twice-daily training regimen [48]. Furthermore, interesting results concern: a) a minor morning-to-evening differences emerged, although larger chronobiological aspects of exercise were expected [2,12,48]; and b) after the incremental running bouts participants not only maintained their BJ performances, but also improved their CMJ ones, substantiating previous findings on improvements in all-out jumping capabilities as a result of previous neuromuscular activation [5,50].

Reviewing chronobiological aspects of exercise, Atkinson and colleagues [2] claimed that a 10 % morning-to-evening difference could be expected for HR and VO_2 values, with lower HR or VO_2 responses to a given intensity of exercise in the morning. The present findings showed similar morning-to-afternoon patterns only for HR values registered at the lowest running speed (12 %), while differences tended to decrease (ranging from 5 % to < 2 %) with increasing running speed. Actually, it has to be considered that in this study the subjects underwent two daily exercise sessions, and these responses could mainly result from cumulative training.

The lack of difference between recovery interventions is in line with previous studies that reported no benefits in performance following active recovery interventions in athletes [32,46,48,49]. Several factors might have more impact on the recovery process than any of the interventions employed, such as the young age [40], the good athletic condition [46], the well-balanced dietary regimen [29,32], euhydration [27], sufficient sleep [42], and low level of psychological distress [28] of the individual. Furthermore, studying with a two bout exercise protocol the recovery capability of athletes who have been classified over-trained and non-functionally over-reached (i.e., athletes who tend to underperform because of their already ascertained reduced recovery capability), Meeusen et al. [34] claimed that aerobic performance, [HLa], and heart rate might not be sensitive enough to detect changes as a result of fatigue. It has to be noted that the present study included normally performing individuals, with a good level of stress-recovery status, aerobic capacity, and ability to exchange lactate during exercise [10]. Thus, differences due to various recovery interventions are likely to be so small they will be difficult to detect [23].

According to the literature [21,48,49], the psychological regeneration after training has been examined in conjunction with physiological restoration. In fact, some authors [30,41,47–49] claimed that active recoveries may help maintaining a positive attitude of the athletes toward exercise, preventing the subjective feelings of monotony of training responsible for decrements in performance [18]. Despite the lack of differences in the physiological and performance parameters as a result of the recovery interventions, following seated rest recovery the subjects reported higher rates of perceived exertion running at 8 and 10 $km \cdot hr^{-1}$ speeds. Furthermore, supine electrostimulation was attributed the highest effectiveness and water exercises were the most appreciated recovery mode. These findings provide some scientific support for the use of these recovery interventions that could promote a feeling of well-being. Thus, despite the use of recovery strategies after exercise to enhance performance in a subsequent daily training is doubtful, its potential to bring psychological benefits should not be overlooked [21]. In

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

fact, psychological factors influencing the individual's performance are crucial for athletes and coaches could consider the administration of recovery strategies to achieve an optimal balance between the subjective feelings of exercise load and recovery [48].

In conclusion, the current study confirms that post-exercise recovery interventions do not represent performance enhancement modalities in young individuals over a limited time period. It is possible to hypothesize that longitudinal research protocols could be more successful in providing valuable information for the coach on the effectiveness of recovery interventions on cumulative training. However, controlling the training process over time is very demanding and challenging, mainly because of the different aspects that have to be recorded and the multifactorial effects that might lead to inconsistency in the results. Recently, validated on-line training diaries for different sport disciplines are available (i.e., www.blits.com). They include morning and afternoon evaluations of different aspects of training (i.e., performance, physiological, and psychological), and allow the monitoring of the overall strain and the control for confounding factors over time. Therefore, further studies on post-training recovery interventions that maintain longitudinal ecological settings are strongly recommended.

Acknowledgements

▼

The authors would like to express their gratitude to the soldiers and Colonel Capitini of the Italian Army (Esercito) for their support when carrying out the experimental sessions. A special thank to Hutchinson Technology Inc. for the generous use of the InSpectraTM Tissue spectometer for data collection.

References

1 *Astrand PO*, *Rodahl K*. Textbook of Work Physiology. Physiological Basis of Exercise. New York, NY: McGraw Hill; 1986

2 *Atkinson G*, *Drust B*, *George K*, *Reilly T*, *Waterhouse J*. Chronobiological considerations for exercise and heart disease. Sports Med 2006; 36: 487–500

3 *Barnett A*. Using recovery modalities between training sessions in elite athletes: does it help? Sports Med 2006; 36: 781–796

4 *Bhambhani YN*. Muscle oxygen trends during dynamic exercise measured by near infrared spectroscopy. Can J Appl Physiol 2004; 29: 504–523

5 *Bobbert MF*, *Van Soest AJ*. Why do people jump the way they do? Exerc Sport Sci Rev 2001; 29: 95–102

6 *Bompa TO*. Periodization: Theory and Methodology of Training. London, UK: Blackwell Scientific; 1999

7 *Borg G*, *Hassmen P*, *Lagerstrom M*. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. Eur J Appl Physiol 1987; 56: 679–685

8 *Borg G*. Borg's Perceived Exertion and Pain Scales. Champaign, IL: Human Kinetics; 1998; 29–43

9 *Boushel R*, *Piantadosi CA*. Near-infrared spectroscopy for monitoring muscle oxygenation. Acta Physiol Scand 2000; 168: 615–622

10 *Brooks GA*. Current concepts in lactate exchange. Med Sci Sports Exerc 1991; 23: 895–906

11 *Buchheit M*, *Cormie P*, *Abbiss CR*, *Ahmaidi S*, *Nosaka KK*, *Laursen PB*. Muscle deoxygenation during repeated sprint running: Effect of active vs. passive recovery. Int J Sports Med 2009; 30: 418–425

12 *Cappaert TA*. Time of day effect on athletic performance: An update. J Strength Cond Res 1999; 13: 412–421

13 *Coffey V*, *Leveritt M*, *Gill N*. Effect of recovery modality on 4 h repeated treadmill running performance and changes in physiological variables. J Sci Med Sport 2004; 71: 1–10

14 *Costes F*, *Prieur F*, *Féasson L*, *Geyssant A*, *Barthélémy JC*, *Denis C*. Influence of training on NIRS muscle oxygen saturation during submaximal exercise. Med Sci Sports Exerc 2001; 33: 1484–1489

15 *Dowzer CN*, *Reilly T*, *Cable NT*. Effects of deep shallow water running on spinal shrinkage. Br J Sports Med 1998; 32: 44–48

16 *Dowzer CN*, *Reilly T*. Deep-water running. Sport Exerc Inj 1998; 4: 50–61

17 *Dupont G*, *Moalla W*, *Guinhouya C*, *Ahmaidi S*, *Berthoin S*. Passive versus active recovery during high-intensity intermittent exercises. Med Sci Sports Exerc 2004; 36: 302–308

18 *Foster C*. Monitoring training in athletes with reference to overtraining syndrome/Enregistrement de l'entrainement d'athletes avec reference au syndrome de surentrainement. Med Sci Sports Exerc 1998; 30: 1164–1168

19 *Graham JE*, *Boatwright JD*, *Hunskor MJ*, *Howell DC*. Effect of active vs. passive recovery on repeat suicide run time. J Strength Cond Res 2003; 17: 338–341

20 *Harris DJ*, *Atkinson G*. International Journal of Sports Medicine – Ethical Standards in Sport and Exercise Science Research. Int J Sports Med 2009; 30: 701–702

21 *Hemmings B*, *Smith M*, *Graydon J*, *Dyson R*. Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. Br J Sports Med 2000; 34: 109–114

22 *Heyman E*, *De Geus B*, *Mertens I*, *Meeusen R*. Effects of four recovery methods on repeated maximal rock climbing performance. Med Sci Sports Exerc 2009; 41: 1303–1310

23 *Hopkins W*, *Batterham AM*. Making meaningful inferences about magnitudes. Int J Sports Physiol Perform 2006; 1: 50–57

24 *Hunter AM*, *Watt JM*, *Watt V*, *Galloway SDR*. Effect of lower limb massage on electromyography and force production of the knee extensors. Br J Sports Med 2006; 40: 114–118

25 *Jackson AS*, *Pollock ML*. Practical assessment of body composition. Phys Sportsmed 1985; 13: 76–90

26 *Jougla A*, *Micallef JP*, *Mottet D*. Effects of active vs. passive recovery on repeated rugby-specific exercises. J Sci Med Sport 2009, Jun 26 [Epub ahead of print], doi:10.1016/j.jsams.2009.04.004

27 *Judelson DA*, *Maresh CM*, *Farrell MJ*, *Yamamoto LM*, *Armstrong LE*, *Kraemer WJ*, *Volek JS*, *Spiering BA*, *Casa DJ*, *Anderson JM*. Effect of hydration state on strength, power, and resistance exercise performance. Med Sci Sports Exerc 2007; 39: 1817–1824

28 *Kellmann M*. Enhancing recovery: Preventing Underperformance in Athletes. Champaign, IL: Human Kinetics; 2002; 3–19

29 *Kerksick C*, *Harvey T*, *Stout J*, *Campbell B*, *Wilborn C*, *Kreider R*, *Kalman D*, *Ziegenfuss T*, *Lopez H*, *Landis J*, *Ivy JL*, *Antonio J*. International Society of Sports Nutrition position stand: Nutrient timing. J Int Soc Sports Nutr 2008; 5, Published online 2008 October 3. doi: 10.1186/1550-2783-5-17

30 *Lattier G*, *Millet GY*, *Martin A*, *Martin V*. Fatigue and recovery after high-intensity exercise. Part II: Recovery interventions. Int J Sports Med 2004; 25: 509–515

31 *Mancini DM*, *Bolinger L*, *Li H*, *Kendrick K*, *Chance B*, *Wilson JR*. Validation of near-infrared spectroscopy in humans. J Appl Physiol 1994; 77: 2740–2747

32 *McAinch AJ*, *Febbraio MS*, *Parkin JM*, *Zhao S*, *Tangalakis K*, *Stojanovska L*, *Carey MF*. Effect of active versus passive recovery on metabolism and performance during subsequent exercise. Int J Sport Nutr Exerc Metab 2004; 14: 185–196

33 *McCully KK*, *Hamaoka T*. Near-infrared spectroscopy: what can it tell us about oxygen saturation in skeletal muscle? Exerc Sport Sci Rev 2000; 28: 123–127

34 *Meeusen R*, *Nederhof E*, *Buyse L*, *Roelands B*, *De Schutter G*, *Piacentini MF*. Diagnosing overtraining in athletes using the two bout exercise protocol. Br J Sports Med 2008, published online on Aug 14 2008; doi:10.1136/bjsm.2008.049981

35 *Meeusen R*, *Piacentini MF*, *Busschaert B*, *Buyse L*, *De Schutter G*, *Stray-Gundersen J*. Hormonal responses in athletes: the use of a two bout exercise protocol to detect subtle differences in (over) training status. Eur J Appl Physiol 2004; 91: 140–146

36 *Neary JP*. Application of near infrared spectroscopy to exercise sports science. Can J Appl Physiol 2004; 29: 488–503

37 *Oda S*, *Matsumoto T*, *Nakagawa K*, *Moriya K*. Relaxation effects in humans of underwater exercise of moderate intensity. Eur J Appl Physiol 1999; 80: 253–259

38 *Pereira MIR*, *Gomes PSC*, *Bhambhani YN*. A brief review of the use of near infrared spectroscopy with particular interest in resistance exercise. Sports Med 2007; 37: 615–624

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.

39 *Quaresima V*, *Lepanto R*, *Ferrari M*. The use of near infrared spectroscopy in sports medicine. J Sports Med Phys Fitness 2003; 43: 1–13
40 *Ratel S*, *Bedu M*, *Hennegrave A*, *Dore E*, *Duche P*. Effects of age and recovery duration on peak power output during repeated cycling sprints. Int J Sports Med 2002; 23: 397–402
41 *Reilly T*, *Ekblom B*. The use of recovery methods post-exercise. J Sports Sci 2005; 23: 619–627
42 *Richmond L*, *Dawson B*, *Hillman DH*, *Eastwood PR*. The effect of interstate travel on sleep patterns of elite Australian Rules footballers. J Sci Med Sport 2004; 7: 186–196
43 *Robertson A*, *Watt JM*, *Galloway SDR*. Effects of leg massage on recovery from high intensity cycling exercise. Br J Sports Med 2004; 38: 173–176
44 *Snyder AC*, *Parmenter MA*. Using near-infrared spectroscopy to determine maximal steady state exercise intensity. J Strength Cond Res 2009; 23: 1833–1840
45 *Spencer M*, *Bishop D*, *Dawson B*, *Goodman C*, *Duffield R*. Metabolism and performance in repeated cycle sprints: Active versus passive recovery. Med Sci Sports Exerc 2006; 38: 1492–1499
46 *Spierer DK*, *Goldsmith R*, *Baran DA*, *Hryniewicz K*, *Katz SD*. Effects of active vs. passive recovery on work performed during serial supramaximal exercise tests. Int J Sports Med 2004; 25: 109–114
47 *Suzuki M*, *Umeda T*, *Nakaji S*, *Shimoyama T*, *Mashiko T*, *Sugawara K*. Effect of incorporating low intensity exercise into the recovery period after a rugby match. Br J Sports Med 2004; 38: 436–440
48 *Tessitore A*, *Meeusen R*, *Cortis C*, *Capranica L*. Effects of different recovery interventions on anaerobic performances following preseason soccer training. J Strength Cond Res 2007; 21: 745–750
49 *Tessitore A*, *Meeusen R*, *Pagano R*, *Benvenuti C*, *Tiberi M*, *Capranica L*. Effectiveness of active versus passive recovery strategies after futsal games. J Strength Cond Res 2008; 22: 1402–1412
50 *Vetter RE*. Effects of six warm-up protocols on sprint and jump performance. J Strength Cond Res 2007; 21: 819–823

Downloaded by: ISTITUTO UNIVERSITARIO SCIENZE MOTORIE. Copyrighted material.