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Effects of cold-water immersion and contrast-water therapy after training in young soccer players

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Aim. **Recent studies have investigated the importance of recovery strategies after training session, including hydrotherapy and cryotherapy. However, only a few studies have focused on cold-water immersion (CWI) treatments in team sport disciplines. The present study investigates the effects of CWI and contrast-water therapy (CWT) on the performance of young male soccer players during a week of training.**

Methods. **Eighteen young soccer players participated in the present study (age 15.5±1.0 years, weight 61.8±3.0 Kg, height 175.5±4.0 cm and training experience 8.1±1.0 years). They were involved in a four-day study with recovery using CWI or with CWT after each training session by using performance tests and small-sided games. We measured uric acid concentration, leukocytes, haemoglobin, reticulocytes and creatine kinase changes in the blood, axillary temperature, rating of perceived exertion after a training session, heart rate during exercise, performance tests (counter movement jump, repeated sprint ability and 5' shuttle run).**

Results. **No significant difference were reported between groups when different physiological tests were used; CWI and CWT did not negatively influence the performances of the athletes. The principal effect of CWI was a reduced perception of fatigue after the training session. The use of active recovery protocols based on cold water or cold/thermoneutral water did not induce modifications of inflammatory and haematological markers in young soccer players.**

Conclusion. **The beneficial effect of a reduced perception of fatigue can improve training and competitions in young soccer players.**

Key words: Hydrotherapy - Soccer - Exercise test.

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Often athletes undertake high training loads with the aim of improving their physical performance. One of the principles of the training adaptation theory is progression, usually with an increase in the athlete's exercise load during the season. However, a continuous raise in the number of competitions can reduce the time available for the training interventions. In addition to this, individual athletes and teams need to devote a portion of the training time to injury prevention and recovery strategies, and the time required to recover from a training session or a competition is not always sufficient to avoid the negative effects of an extremely-high exercise volume.[1] This, in turn, is believed to contribute to the aetiology of the overtraining syndrome or to a decrease of the performance levels in individual and team sports. For example, an impairment in performance during the season (élite female handball players) was reported for matches performed over successive days.[2] Thus, it is crucial for athletes to improve their recovery strategies, as the fatigue accumulated in the crucial periods of the season or, in the short term during tournaments, can negatively affect performance.[2, 3]

Recently, active recovery procedures based on cold-water immersion (CWI) or on contrast water therapy (CWT) with an alternation of immersion in thermoneutral and cold water, have been proposed.[1, 4] The beneficial effects of CWI and CWT as a recovery strategy after exercise are associated with different physiological and performance mechanisms. Firstly, the washout of muscle creatine kinase and its systemic concentration,[5-7] as well as an acceleration of the decrease in plasma lactate concentration after intense aerobic exercise have been described in response to CWT.[7] The perception of general fatigue in athletes involved [8] in these active recovery procedures is reduced, and it possibly outlines the decrease of peripheral fatigue, muscle soreness, and the increase of general fitness.[8] However, only few studies were published on the effectiveness of CWI [9, 10] on performance. CWI improved isometric voluntary contractions of knee extensors after prolonged intermittent shuttle running. Only two studies reported the use of CWI treatment in team sport disciplines, *i.e.*, in professional rugby [6] and junior soccer.[11] In soccer players, immediate post-match CWI did not affect physical test performance or parameters of muscle damage, but it did reduce the perception of general fatigue and leg soreness between matches, during a 4-day simulated soccer tournament.[11]

Therefore, the aim of the present study was to investigate the effects of CWI and CWT on the performance during a week of training in junior male soccer players and to compare them to passive recovery.

The study was designed to particularly evaluate eventual detrimental or beneficial effects on physical performances of young soccer players.

Materials and methods

Participants

Eighteen young soccer players participated in the present study. They were competing in the Junior Regional league Championship, which they had won in the previous season. The characteristics (mean [SD]) of the subjects were: age 15.5 (1.0) years, weight 61.8 (3.0) kg, height 175.5 (4.0) cm and a training experience of 8.1 (1.0) years. Written informed consent was given by the parents of these athletes, which were constantly supervised during training and testing sessions by the team's strength and conditioning coach.

Study design

The tests performed on the young athletes were physiological tests, which were selected to evaluate the physical performance during a week of training, and biochemical and haematological tests, which were selected to evaluate the possible systemic modifications due to the training and different recovery treatments.

The players were randomly divided in three groups of 6 subjects each, and assigned to either passive recovery (PAS), CWT, or CWI, respectively. The study was conducted during the training camp before the start of the league season. The four training sessions (from Tuesday to Friday) were all completed from 2 pm to 6 pm. The average temperature during the training sessions was 31.9 (1.7) °C, and the relative humidity was 87.5 (2.9) %.

Two blood samples were taken, before (Monday) and after (Saturday) training. Two samples were drawn, the first was anti-coagulated with EDTA to measure hematological parameters (haemoglobin, leukocytes, platelets, and reticulocytes), the second was used to obtain serum for clinical chemistry parameters (uric acid). The analyses were performed on a Sysmex KX2100 and on a Abbott Architect, daily controlled and appropriately calibrated.

Daily training included : standardized warm-up that including soccer specific running drills and dynamic stretching, performance tests as counter movement jump, repeated sprint ability and 5 min shuttle run test, 30 minutes of training at low intensity that comprised football technical and tactical improvement schemes, small sided games (4x4 min), for a total time of 140 min per day. Tests were performed in the same soccer field and with the same experimental conditions.

Before daily training session, the athletic trainer measured the external (axillary) body temperature.

After daily training session, the athletes followed recovery protocols. Athletes who performed passive recovery (PAS) simply rested in the shadow for 8 minutes. Athletes who performed CWI recovery sat for 8 minutes immersed to the iliac spine level in a portable pool containing water at 15 (0.5) °C. The temperature was chosen according to previous experience.[12] The water temperature was constantly monitored and maintained constant by addition of ice. Water was continuously stirred to avoid the formation of higher temperature regions near the body.[11] The time of eight minutes is near to those described in literature.[4, 8, 10] The time of exposure is not standardized and it is a variable to be defined appropriately in a specific study.

Finally, athletes who performed CWT rested alternatively for 2 minutes in cold water (15 [0.5] °C) and in thermoneutral water (28 [0.5] °C) spending a total of 8 minutes in the two different pools.

We analyzed the rating of perceived exertion three times a day using the Borg Scale 1-10[13]: before each daily session, with the exception of the first day, at the end of the 5 min shuttle run test and after recovery.

Performance tests

Before each physical testing session, a standardized pre-training warm-up was undertaken. Warm-up included soccer-specific running drills and stretching. Then, the athletes performed a countermovement jump, 12x20-m sprints with 20 s between sprints, and 5 min steady-state submaximal running at 12 $km \cdot h^{-1}$. The tests were proposed by Rowsell *et al.*[11] to assess the role of active recovery protocols in restoring performance capacities.

Countermovement jump: maximum countermovement jump height in cm was measured using Ergo-Jump Bosco System (Globus, Treviso, Italy). Vertical standing height was defined by the upper limb being completely extended (flexed at the shoulder with an extended elbow). Each subject performed three jumps with intervals of 30 s. After recovery of 1 min 30 s each subject performed two jumps with intervals of 30 s. Results were calculated as the average of the three highest jumps and are reported in cm. Repeated sprint ability test: the test included 12 maximal-effort 20 meter sprints. The subjects sprinted for 20 meters, then walked back and sprinted again. Sprints were performed at intervals of 20 s. The sprint times were measured by four trainers; the pairing of trainer/athlete was fixed to assure a maximal effort by participants. The average sprint time was calculated by dividing the sum of times by the number of sprints. After the tests, the athletes performed low-intensity running for 10 min.

Submaximal shuttle run test: athletes wore a Polar Team System heart rate monitor (Polar Electro Oy, Kempele, Finland). The test was performed on the field: the environmental conditions did not change between days. The athletes run out and back between two 20 meter lines for 5 min at constant speed (12 $km \cdot h^{-1}$). Each 12 s heart rate was measured by the trainers who also controlled the speed constancy. The average heart rate of each subject was reported. At the end of test, the athletes were asked to provide their rating of perceived exertion on the Borg scale.

Then the athletes were committed in small sided games (4x4min with 3min of passive recovery between each match). In these small sided games the subjects played 3v3 without goalkeepers, with reduced goal size and limitation in the number of the strokes. The size of the pitch was 18x36 m [14] and the intensity of each match was high (180-190 $Beats \cdot min^{-1}$), whilst during a regular soccer game is about 170-180 $Beats \cdot min^{-1}$.[15]

Statistical analysis

Statistical analysis was performed by means of non parametric paired U test (Mann Whitney) among groups. Covariance analysis was used for evaluating day-by-day possible modifications of physiological tests. χ-square (Kruskall Wallis test) was applied for group comparisons.

The level of significance was held at $P<0.05$.

Results

The results of the physical performance tests are listed in Table I. The results of the percent change in physical tests and in perceived exertion are shown in Figures 1, 2.

Repeated Sprint Ability (RSA) test shows a constant decrease in the passive recovery group (PAS) while the differences for CWI and CWT were not significant ($P>0.05$). In the countermovement jump test a non significant decrease of performances is reported for PAS while the decrease is lower in the CWT and CWI groups. In CWI group after an initial decrease of performance in the counter movement jump on the second day (from 39.9 to 38 cm), a constant, but not statistically significant increase was shown until 38.6 cm. In the CWI group the behavior is similar: the performance decreases from day 1 to day 3.

There were not observed significant differences on uric acid concentration after training days in any of the

TABLE 1.—*Physical and performance results for the three groups across successive days of the study (mean±(std dev).*

Cold-Water immersion group (N=6)	Day 1	Day 2	Day 3	Day 4
Repeated sprint mean (s)	3.48±(0.15)	3.58±(0.14)	3.60±(0.13)	3.52±(0.12)
Countermovement jump (cm)	39.9±(2.2)	38.08±(3.34)	38.62±(2.70)	38.65±(2.79)
Average heart rate 5'shuttle running test (Bpm)	179.25±(2.87)	181±(2.94)	178.5±(2.65)	178.75±(2.63)
Rating of perceived exertion before training (1-10)	-	0.48±(0.76)	0.32±(0.18)	0.27±(0.39)
Rating of perceived exertion post 5 min shuttle running test (1-10)	7.17±(0.98)	6.83±(0.75)	6.17±(1.17)	6.5±(0.55)
Rating of perceived exertion after recovery (1-10)	6.17±(0.75)	5.67±(1.03)	5.5±(1.05)	5.67±(0.52)
Temperature difference (post training recovery - pre training) (°C)	-0.2±(0.48)	-0.17±(0.42)	-0.07±(0.55)	-0.23±(0.57)
Contrast-Water Therapy group (N=6)	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Repeated sprint mean (s)	3.56±(0.26)	3.62±(0.19)	3.62±(0.22)	3.57±(0.19)
Countermovement jump (cm)	38.78±(3.49)	37.98±(3.92)	37.47±(3.31)	37.72±(2.95)
Average heart rate 5'shuttle running test (Bpm)	184±(1.73)	186±(1.73)	183.67±(3.21)	182.33±(2.52)
Rating of perceived exertion before training (1-10)	-	0.36±(0.22)	0.52±(0.29)	0.52±(0.29)
Rating of perceived exertion post 5 min shuttle running test (1-10)	7±(0.63)	7±(0)	6.6±(0.55)	6.5±(0.55)
Rating of perceived exertion after recovery (1-10)	6.17±(0.75)	6.2±(0.45)	6.4±(0.55)	6.33±(0.52)
Temperature difference (post training recovery - pre training) (°C)	-0.6±(0.32)	-0.5±(0.23)	-0.36±(0.66)	-0.32±(0.40)
Passive Recovery group (N=6)	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Repeated sprint mean (s)	3.44±(0.15)	3.52±(0.12)	3.56±(0.15)	3.61±(0.15)
Countermovement jump (cm)	38.76±(2.74)	38.23±(3.12)	37.77±(3.11)	36.84±(3.29)
Average heart rate 5'shuttle running test (Bpm)	183.43±(3.87)	186.57±(3.55)	184.29±(2.75)	184.14±(3.13)
Rating of perceived exertion before training (1-10)	-	0.47±(0.71)	0.45±(0.39)	0.33±(0.35)
Rating of perceived exertion post 5 min shuttle running test (1-10)	7±(0)	7.13±(0.64)	6.63±(0.52)	6.75±(0.46)
Rating of perceived exertion after recovery (1-10)	6.57±(0.53)	6.63±(0.74)	6.5±(0.53)	6.63±(0.52)
Temperature difference (post training recovery - pre training) (°C)	-0.16±(0.29)	-0.09±(0.32)	0.06±(0.36)	-0.03±(0.49)

groups. Uric acid is the major circulating antioxidant: the training workload did not increase the parameter and the different protocols did not modify its levels. The concentrations before training were 5.49 $mg{\cdot}dL^{-1}$ in PAS group, 6.00 $mg{\cdot}dL^{-1}$ in CWT, and 4.74 $mg{\cdot}dL^{-1}$ in CWI, and, after training week, 5.55 $mg{\cdot}dL^{-1}$, 6.33 $mg{\cdot}dL^{-1}$, and 4.79 $mg{\cdot}dL^{-1}$, respectively.

No significant changes were reported for leukocytes (5.93 $x10^9$/L before, 5.55 after training in PAS; 6.25 $x10^9$/L before, 5.62 after training in CWT; 5.22 $x10^9$/L before, 5.25 after training in CWI) suggesting that the active protocols do not stimulate proinflammatory pathways.

No statistical difference was reported for haemoglobin (Hb) and reticulocytes (Ret) suggesting that the active protocols do not reduce bone marrow activity. Hb was 14.8 $g{\cdot}dL^{-1}$ before and also after training in PAS group, 14.6 $g{\cdot}dL^{-1}$ before and 14.9 $g{\cdot}dL^{-1}$ after training in CWT, and 13.4 $g{\cdot}dL^{-1}$ before and 13.3 $g{\cdot}dL^{-1}$ after training in CWI. Ret were 1.08 % before and 1.02 after training in PAS, 0.70 % before and after training in CWT, and 0.74% before and 0.66% after training in CWI.

As expected, Creatine kinase (CK) activity increased in all the three groups, but the increase was significantly lower ($P<0.05$) in the two immersion

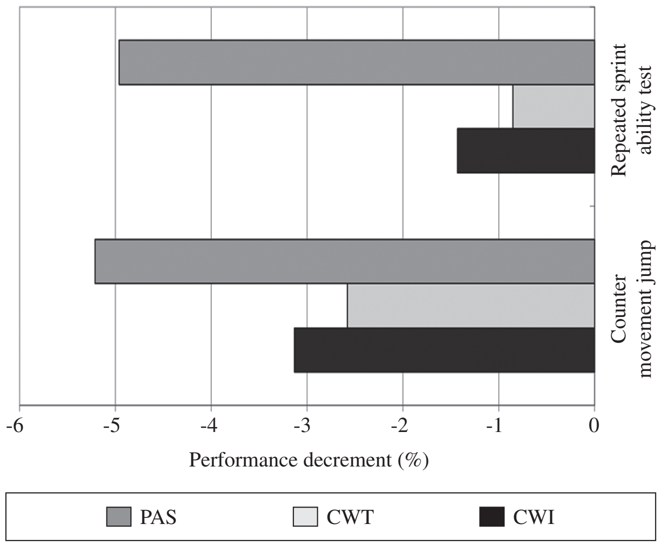

Figure 1.—Change (%) in physical tests performance with cold-water immersion, contrast-water therapy and passive recovery from day 1 to 4 of the study.

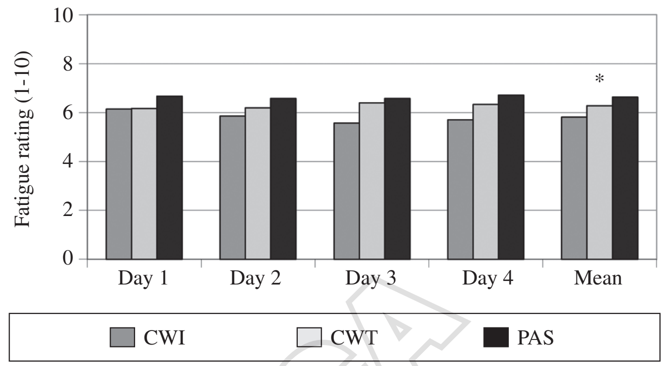

Figure 2.—Rating of perceived exertion for cold-water immersion, compared with contrast-water therapy and passive recovery from day 1 to 4 of the study and the mean. *Significant effect for time (P<0.05).

recovery groups. Mean CK levels in PAS were 120 U/L before and 340 U/L after training program in PAS, 107 U/L before and 270 U/L in CWT, and 112 U/L before and 255 after training in CWI.

Discussion

The evaluation of different recovery protocols in young athletes involved in a standardized training procedure demonstrated that there were no differences between groups by using different recovery protocols. This result confirmed previous reports on the effects of recovery protocols based on water immersion during a simulated soccer tournament[11] and after a 90-min shuttle run.[8] The N.=6 per group, as already reported in literature[7,11], could be a possible limitation of the study.

During the training period, a decrease in performance of all the subjects was reported for countermovement jump and for a repeated ability test. The expected decrease was lower, but not significant, in the two groups submitted to water immersion than in the passive recovery group. Therefore we can confirm the results found by Vaile et al.[16] for twelve cyclists and by Rowsell *et al.*[11] although the extent of the decrease here reported is smaller than previously described.

One can assume that different water temperatures and/or different times of immersion can influence the performance tests. The standardization of active recovery procedures based on cold water immersion is necessary to quantitatively evaluate their effects. In fact, positive effects can be described, confirming data of previous researchers [8, 11, 17] but at least in one case other authors found negligible effects.[18]

One of the specific effect of hydrotherapy, as already described in cyclists between exercise bouts separated by 24 hours,[19] is the improvement of recovery between training sessions, testified by using physiological tests: in fact the use of CWI and CWT did not negatively influence the performances in the athletes of these two groups.

The principal effect of CWI and CWT was the reduction of fatigue perception after the training session. It is noteworthy that the CWI group showed a significantly lower level of fatigue perception in comparison with the passive recovery group (P=0.0225), whilst CWT did not. The reduction of fatigue perception is important for athletes, because it improves training compliance and performance of competition.[20] These results are concordant with those of previous studies performed in soccer players [11] and in cyclists.[21]

Skin temperature was not significantly affected, consistently to what reported in a previous study using cold pack therapy,[22] although contentious data are also reported in literature.[23] High environmental temperatures could have influenced our measurements.

The comparison between the two different patterns of hydrotherapy is particularly interesting. For the two different hydrotherapy treatments here administrated similar results are reported. Performance test are not significantly different, although the absolute values of decrease in performance decrement were lower for CWT. In a previous study the comparison among different hydrotherapy treatments showed that CWI and CWT similarly improved recovery in cyclists where compared with hot water immersion and passive recovery.[16]

The principal merit of hydrotherapy, as reported in literature,[11, 16] is the decrement of fatigue perception. In this field, CWI showed better results than CWT in the athletes involved in this study. It is not possible to supply definitive data from this study to justify where to prefer CWT or CWI. Thus, hydrotherapy treatments could be tuned following athletes and coaches suggestions. In literature CWT was suggested as first choice by some authors.[17, 24, 25] However, also for rating of perceived exertion a standardization of treatment protocols is suggested. Some authors did not find an improvement of RPE in cyclists where performance tests were clearly improved by CWI and CWT during one month experimental design[16] and during an 8 months/study in 38 athletes delayed onset muscle soreness was significantly reduced by hydrotherapy.[17]

The use of recovery protocols based on cold water or cold/thermoneutral water does not induce modifications of inflammatory and haematological markers in young soccer players. The active recovery protocols based on cold water immersion are not detrimental for haematological parameters, do not boost bone marrow production and release of new erythrocytes. Moreover, they do not stimulate production of oxidant species and they limit the increase of muscular damage biochemical parameters, as already demonstrated[5,6] ; although this effect is not always statistically significant, as it was previously reported[11]. The beneficial effect on the wash-out or on a reduced release of markers for muscular damage depends on the athletes level, professional or non professional status, and also on the initial levels of CK. In professional athletes and when circulating concentrations of CK are very high the effects of cold water are more pronounced and evident.

Conclusions

In conclusion, this study suggests there is no statistical evidence that recovery based on cold water immersion protocols attenuate the decrease of performance typical of periods of training or competitions in young soccer players . Immersion recovery has no effects on haematological parameters and does not induce detrimental effects in young non professional athletes. The beneficial effect of a reduced fatigue perception obtained with cold water immersion can improve training and competitions.

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