THE EFFECT OF ACTIVE RECOVERY, COLD WATER IMMERSION AND PASSIVE RECOVERY ON SUBSEQUENT KNEE EXTENSION AND FLEXION STRENGTH

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BACKGROUND: Recovery is an important aspect of every physical activity. Many athletes train hard without giving their body time to recover which can lead to overreaching, burnout or poor performance. Currently cold-water immersion recovery and active recovery have emerged as some of the most popular interventions enabling faster recovery.

OBJECTIVE: To assess the effect of three kinds of recovery (active recovery, cold water immersion, passive recovery) on medium-term knee strength in the extension and flexion.

METHODS: Fourteen athletes at the age of 26.6 ± 4.4 years performed, in a random cross-over design, 3 sessions with 3 repeated medium-term isokinetic tests. The effect of active recovery, passive rest and cold water immersion were assessed by 3 × 3 (time × recovery) repeated-measure ANOVA, respectively. The dependent variables were – peak torque, total work and average power.

RESULTS: We found significantly lower absolute differences between the first and third trial in knee extension for peak torque after the active recovery (↑ 0.9 N × m) than after the cold water immersion (↓ 14.6 N × m) or the passive recovery (↓ 13.9 N × m). The decrease of the average power was significantly lower differences after the active recovery (↓ 5 W) than after the cold water immersion (↓ 23.7 W) or passive recovery (↓ 25.9 W). The changes in total work were not significant. We did not found any changes in the isokinetic strength for the knee flexors after different kinds of recovery. Maximal heart rate (HR_{max}) was significantly higher during the active recovery than during the cold water immersion and the passive recovery (173 ± 14, 166 ± 14 and 167 ± 14 rpm). We have found significant differences in the average heart rates (HR_{avg}) during active recovery, cold water immersion and passive recovery (124 ± 8, 97 ± 9 and 107 ± 12 rpm).

CONCLUSION: We found the positive effect of the active recovery on the subsequent medium-term performance for knee extension. That was the only method which showed lower decrease of knee strength in extension in comparison with passive recovery and cold water immersion. We have found the significant differences of heart rate which was recovery dependent.

Keywords: Recovery, cold water immersion, passive and active recovery, isokinetic strength, heart rate.

INTRODUCTION

It is generally accepted that good recovery enables better performance and decreases the number of injuries in athletes. Recovery is an important aspect of any physical activity. Many athletes train extremely hard without giving their body time to recover which can lead to overreaching, burnout or poor performance (Cochrane, 2004). According to Hargreaves and Spriet (2006) recovery is simply defined as a biological process of removing fatigue. Astrand, Rodahl, Dahl, and Stromme (2003) defined fatigue as a complex of physiological and psychological process that leads to pre-load condition. It is a routine for athletes to employ post exercise strategies or practices in a bid to speed up recovery (Bleakley & Davison, 2010).

Recently, cold-water immersion recovery has emerged as one of the most popular interventions. Despite its popularity, the evidence from clinical trials remains ambiguous, and there is also little evidence to design an optimal treatment protocol (Cochrane, 2004). Anecdotal reports from coaches, medical personnel and athletes suggest that this method has positive effects on subsequent performance (Enwemeka et al., 2002; Myrer, Draper, & Durrant, 1994). There is general consensus that the application of cold water immersion decreases skin, subcutaneous and muscle temperature. Subsequently, the decrease in tissue temperature is thought to stimulate the cutaneous receptors causing vasoconstriction which decreases the swelling and possible inflammatory processes by slowing the metabolism and production of metabolites and thereby limiting the degree of the injury (Enwemeka et al., 2002). We can quantify the degree of the recovery by such indicators as reduction of HR, respiratory rate and ventilation parameters, restoration of energy reserves and ion balance, removal of waste products of metabolism, decrease of muscle tension and reduction of the activity of the central nervous system (Bleakley & Davison, 2010). Various processes of recovery improve and accelerate these indicators and decrease fatigue. In our study, we focused on the application of cold water immersion and passive and active recovery.

Especially active recovery and cold water immersion offer very useful and low-cost recovery procedure. All the activities such as walking, running or cycling can be used as active recovery. The start of recovery processes while using active procedures needs to be kept at a moderate intensity of the selected exercises (50–65% maximum HR or 35% VO_2max) which usually takes around 20 min. (Cochrane, 2004; McArdle, Katch, & Katch, 2001). The idea of this kind of recovery is to accelerate the supply of oxygen into the tissue and lactate and other muscle metabolites removal (Barnett, 2006; Draper, Bird, Coleman, & Hodgson, 2006). Therefore the intensity of the exercise has to be set at certain threshold level.

Hydrotherapy belongs to the popular and widely used recovery methods. Water immersion reduces muscle oedema and increases heart rate. It also increases blood flow which further speeds up the removal of waste products after muscle work (Bleakley & Davison, 2010; Ingram, Dawson, Goodman, Wallman, & Beilby, 2009). Interestingly, there is not such decrease of performance after cold water immersion application in combination with warm water bath compared to passive recovery (Viitasalo, Niemela, & Kaappola, 1995).

Finally passive recovery in the sitting or lying position without any other activities and any other aids belongs to one of the most easily performed recovery.

By all means, different types of recovery are dependent on the sport's loads. Therefore the aim of the study was to clarify the influence of different recovery process (active and passive recovery, cold water immersion) on the subsequent medium-term knee strength during extension and flexion.

METHODS

Participants

The group of participants consisted of 14 men (mean ± standard deviation) in the age of 26.6 ± 4.4 years, body height of 1.80 ± 0.06 m and body weight 74.6 ± 5.2 kg (fat 11.5 ± 1.9 %, lean body mass 65.9 ± 4.5 kg), determined by bioimpedance method (Bunc, 1995). We chose students of physical education who were somehow active in sports. None of the participants stated anything that could influence the results. During the last two years, none of the students suffered from any injuries or other pathologies of the lower limbs. Measurements were performed only on the dominant lower extremity. The dominant leg was defined as the leg that the participant uses as a take off leg for the long jump (Miyaguchi & Demura, 2010). Twelve of the 14 participants identified right leg as their dominant leg.

The study received approval from the institutions Ethics Advisory Committee of Charles University.

Experimental procedure

Isokinetic knee strength measurement

The measurements were performed under constant laboratory conditions. Measurement of the concentric strength in knee extension and flexion was realized on the isokinetic dynamometer Cybex Humac Norm (Cybex NORM ®, Humac, CA, USA).

We measured isokinetic knee strength in extension and flexion with three trials in one day defined by constant angular velocity of 150° × s^{-1} (50 repetitions) with a duration of 70–80 s. Between the trials (15 min. rest with recoveries) of the isokinetic strength measurement we applied the recoveries (passive recovery, active recovery and cold water immersion). The strength parameters were peak torque, total work and average power.

The loaded limb was fixed above the knee strap to stabilize it. The chair and dynamometer were set to the settings of dynamometer for knee extension and flexion measurement. The knee axis was parallel with the dynamometer arm. Range of the knee motion was approximately 90°.

During the isokinetic strength measurements we motivated the students verbally by audible instructions. The subjects were also motivated visually by seeing their immediate results.

Recovery strategies

Immediately after isokinetic knee strength we applied passive recovery in one group, active recovery in the second group and cold water immersion in the third group. The other day, the groups were exchanged so that everyone would undergo all the kinds of recovery. The schedule and times were as follows:

1. The passive recovery was performed in the sitting position on the chair of dynamometer for 15 min. at room's temperature 22 ± 1° C.
2. As active recovery we used walking for 10 minutes on the treadmill of 5.5 km × h^{-1} speed and a gradient – was depended on the HR to achieve 60–65% of individual HR_{max}. HR_{max} was determined during the vita maxima test on a treadmill ergometer. Individuals HR_{max} reached 194 ± 10 rpm.
3. As cold water therapy the participants were immersed up to their hips in the cold bath (13 ± 1° C) for 3 × 2, 5 min. with 2 min. out of the bath, repeated twice as intermittent protocol. In the room there was average air temperature 22 ± 1° C while the par-

ticipants were in the sitting position (Vaile, Halson, Gill, & Dawson, 2008a). The water temperature was determined according to the protocol of Malkinson, Martin, Simper, and Cooper (1981).

Experimental design

This was a randomized cross-over experiment design study. Each individual was at the same time in the group with the experimental factors (active recovery, cold water) in the control group (passive recovery). The dependent variables were peak torque, total work and average power.

The significance of the results was verified by 3 × 3 (time × recovery) analysis of variance with repeated measures. The significance of the results was assessed by the coefficient partial η^2, which represents percentage of the total variance explained as independent variable. Statistical significance of differences was in the level $p \leq 0.05$. The SPSS Statistical program for Windows (version 18.0) was used to evaluate the results of the study.

RESULTS

We observed significantly smaller absolute changes between first and third trial for knee extension, for peak torque after active recovery (↑ 0.9 N × m) compared with cold water (↓ 14.6 N × m) and passive recovery (↓ 13.9N × m). We assessed significant decreases of average power after cold water immersion (↓ 23.7 W) and after passive recovery (↓ 25.9 W). After active recovery (↓ 5 W) we did not notice a significant difference of average power. The changes of total work for knee extension and flexion were insignificant. The percentage changes of peak torque, total work and average power between first and third trial are in the TABLE 1.

TABLE 1

Percentage changes (%) (↓ decrease, ↑ increase) of peak torque (PT), total work (TW) and average power (AP) after passive recovery (PAS), active recovery (ACT) and after cold water immersion (CWI)

% changes between 1st and 3rd trials		Extension	Flexion
Peak torque	PAS	↓ 8.7	↓ 2.1
	ACT	↑ 0.5	↓ 5.2
	CWI	↓ 8.7	↓ 4.1
Total work	PAS	↓ 6.8	↑ 1.4
	ACT	↓ 1.3	↓ 1.1
	CWI	↓ 1.0	↑ 3.6
Average power	PAS	↓ 10.3	↓ 8.7
	ACT	↓ 2.0	↓ 5.6
	CWI	↓ 9.0	↓ 3.1

The decrease of strength performance for knee extension is shown in Fig. 1–3 and for knee flexion in Fig. 4–6. The decrease of dependent variables was recorded (Fig. 1–6) after recoveries. After active recovery and cold water immersion we found no significant differences in strength performance (peak torque, total work, average power). The significant differences of knee extension was assessed for peak torque $F_{2, 26} = 9.0$ ($p = 0.00$), $\eta^2 = 0.41$ for both recovery $F_{2, 26} = 3.5$ ($p = 0.04$), $\eta^2 = 0.21$ and for average power $F_{2, 26} = 6.8$ ($p = 0.00$), $\eta^2 = 0.34$ for time factor.

For knee extension recovery was in the interaction with the order of measurements statistically and substantively significant for peak torque, where was $F_{2, 52} = 5.9$ ($p = 0.00$), $\eta^2 = 0.31$ and the average power was $F_{2, 52} = 2.7$ ($p = 0.04$), $\eta^2 = 0.10$. Recovery in the interaction with the time had no significant effects on the overall work of knee extension, where $F_{2, 52} = 1.4$ ($p = 0.25$), $\eta^2 = 0.10$.

Fig. 1–3 for knee flexion there is not obvious decrease of the peak torque, total work or average power after three types of recovery. The three types of recovery did not have any effect on strength indicators. The strength differences for knee flexion occurred in the interval of the standard error of measurement (SEM). We did not find significant differences of knee flexion measurement after recovery.

The time did have not significant effect on knee flexion especially of peak torque $F_{2, 26} = 4.3$ ($p = 0.02$), $\eta^2 = 0.25$ and the average power $F_{2, 26} = 5.3$ ($p = 0.01$), $\eta^2 = 0.29$). The time was statistically insignificant ($F_{2, 26} = 0.4$ /$p = 0.68$/, $\eta^2 = 0.03$).

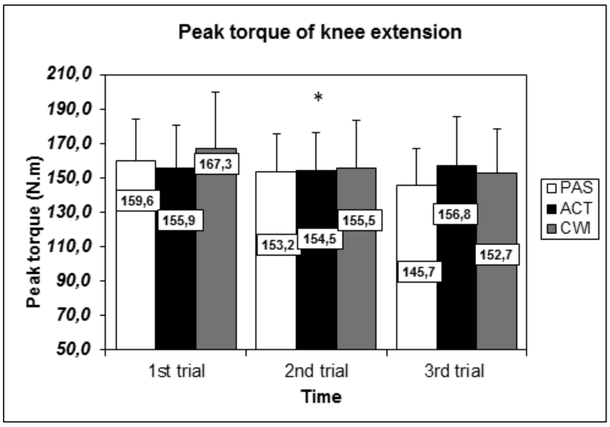
The recovery in the interaction with time had no significant effect on the peak torque $F_{2, 52} = 0.1$ ($p = 0.10$), $\eta^2 = 0.06$, the total work of $F_{2, 52} = 0.8$ ($p = 0.55$), $\eta^2 = 0.06$ and the average power ($F_{2, 52} = 0.2$ /$p = 0.92$/, $\eta^2 = 0.02$).

HR_{max} during active recovery was significantly higher in comparison with passive recovery (173 ± 14 vs. 167 ± 14 rpm, $t_{2, 13} = 2.7$, $p = 0.02$). We found similar values of HR_{max} during the application of passive species recovery and cold water (167 ± 14 vs. 166 ± 14 rpm) and that was dependent on the recovery process. HR_{avg} was significantly higher from active recovery than passive recovery 124 ± 8 vs. 107 ± 12 rpm ($t_{2, 13} = 4.5$, $p = 0.00$). HR_{avg} during passive recovery was 107 ± 12 rpm and during using cold water immersion was 97 ± 9 rpm. The differences were significant ($t_{2, 13} = 2.5$, $p = 0.03$) (Fig. 7).

DISCUSSION

We found only minimal changes in repeated strength performance after active recovery and cold water immersion compared to passive recovery. A significant effect of active recovery was observed only in case of repeated

Fig. 1
Means and standard deviation of peak torque for knee extension for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)



Legend: *significant interaction of recovery and time p = 0.00, $\eta^2 = 0.31$

Fig. 2
Means and standard deviation of total work for knee extension for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)

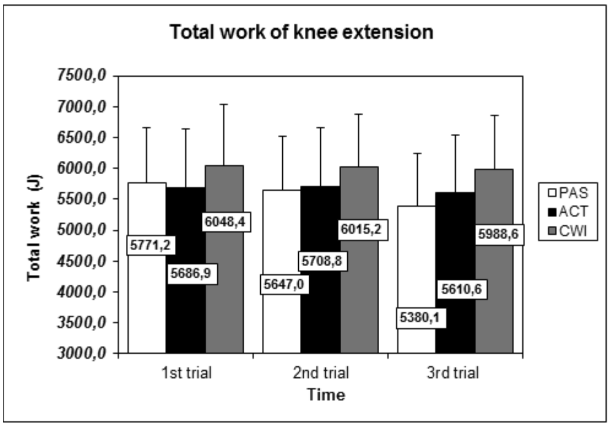
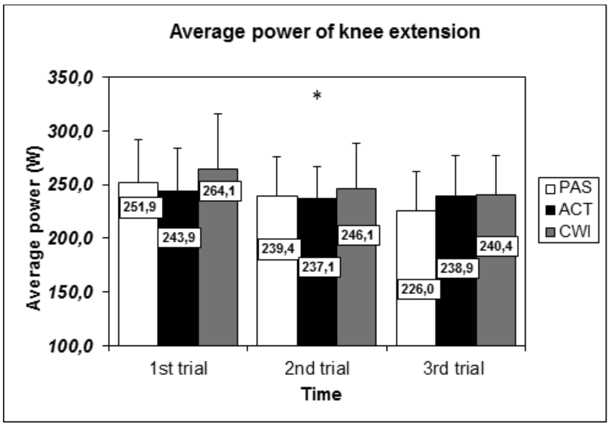
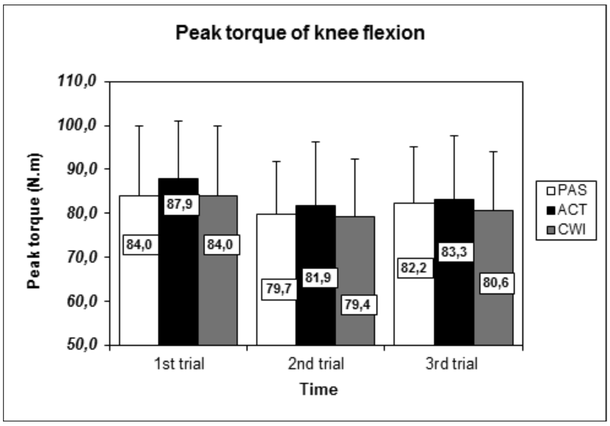


Fig. 3
Means and standard deviation of average power for knee extension for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)



Legend: *significant interaction of recovery and time p = 0.04, $\eta^2 = 0.10$

Fig. 4
Means and standard deviation of peak torque for knee flexion for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)



knee extension for peak torque and average power. For total work, the effect of recovery was not significant. For knee flexion we found significant changes for repeated measurements in active recovery and cold water immersion compared to passive recovery. Significant effect of active recovery and cold water immersion was observed only for knee extension for repeated measurement on peak torque and average power.

However, no significant differences in knee strength during flexion were observed among any of the cold water immersion and active recovery protocols.

Walking (65% intensity of maximal HR) as active recovery was chosen because it doesn't require such complex coordination and it is a widely accessible activity. Active recovery, for example running or cycling, could have similar effects as walking. The intensity of certain

Fig. 5
Means and standard deviation of total work for knee extension for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)

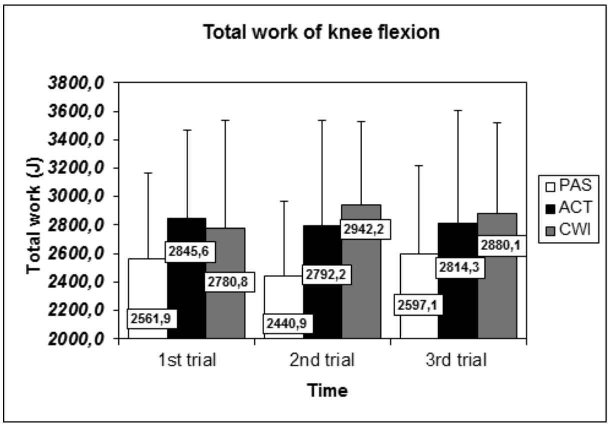


Fig. 6
Means and standard deviation of average power for knee flexion for subsequent measurement for three types of recovery (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)

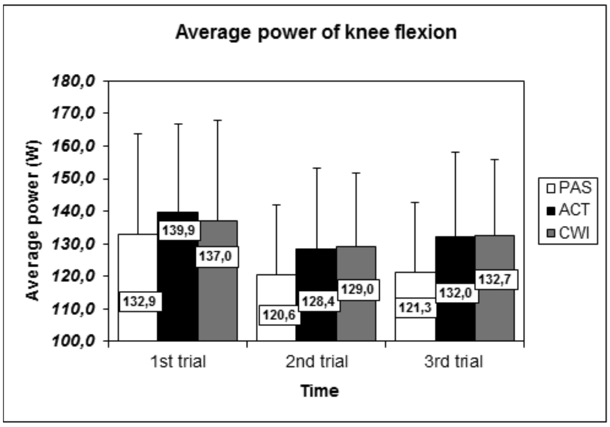
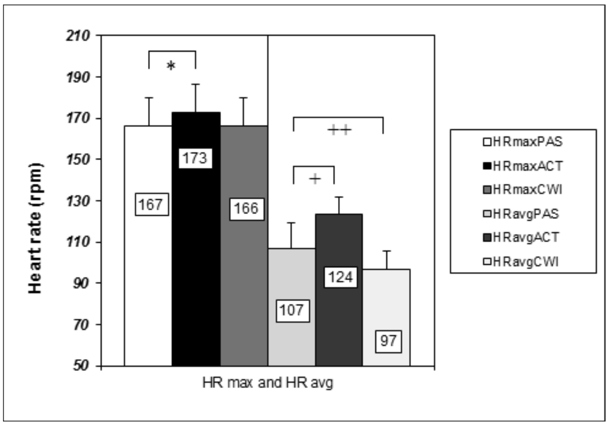


Fig. 7
Means and standard deviation of maximal (HR_{max}) and average heart rates (HR_{avg}) during knee strength measurement and recovery application (PAS – passive recovery, ACT – active recovery, CWI – cold water immersion)



Legend:
* Significant difference of HR_{max} PAS and HR_{max}ACT, p = 0.02
\+ Significant difference of HR_{avg}PAS and HR_{avg}ACT, p = 0.00
++ Significant difference of HR_{avg} PAS and HR_{avg}CWI, p = 0.03

activity is more important than the kind of this activity itself (Cochrane, 2004). Walking (maximum intensity of 65% HR_{max}) has been already used in the study of Baláš, Chovan, and Martin (2010). The authors used active recovery after repeated climbing until exhaustion and stated 14% decrease of performance in comparison with 41% after passive recovery. However, the study was focused only on the upper extremities after the climbing performance. In our case while focusing on lower extremities, we noticed decreased peak torque (0.5%) after walking about the same intensity and the decrease of the total work and the average power (by 1.3% and 2.0%). We found that walking is an adequate type of recovery for repeated isokinetic strength activity of the lower limbs. In the other studies (Heyman, De Geus, Mertens, & Meeusen, 2009; Watts, Daggett, Gallagher, & Wilkins, 2000) the bicycle ergometer seems to provide the activity for acceleration the recovery process compared to the passive one. Active recovery plays an important role when we want to get the optimal decrease of fatigue symptoms. We have to keep in mind that the recovery we chose should match with the intensity of loading processes (Bielik, 2010; Vanderthommen, Makrof, & Demoulin, 2010).

Vanderthommen, Makrof, and Demoulin (2010) reported the insignificant increase of maximal power after active recovery (intensity was 50% HR_{max}, for 25 min.) on bicycle ergometer then after passive rest (105.3 ± 12.2 vs. 99.1 ± 10.7%). Nevertheless, we could not compare specific cycling performance because we evaluated the extension and flexion separately. All the same Bielik (2010) applied longer recovery time (20 min.), after which he recorded smaller decline in maximal and average power after active recovery process than after passive rest (970.2 ± 68.9 vs. 875.5 ± 56.2 W, $p < 0.05$ and 746.1 ± 47.0 vs. 678.4 ± 45.2 W). The effect of recovery on the fatigue (active vs. passive recovery) was not significant (35.2 ± 7.7 vs. 33.6 ± 8.4%). The concentration of blood lactate was significantly lower after active recovery than the passive rest (7.4 ± 3.9 vs. 13.3 ± 2.9 mmol × l^{-1}, $p < 0.01$) (Bielik, 2010). In our case we confirmed the significant effect of recovery on peak torque and average power for extensors ($p = 0.001$). We found significant changes for the repeated measurements of knee strength flexor that was not influenced by recovery. The training process is very often neglected and knee flexors are often injured due to inadequate muscle preparation (Greig & Siegler, 2009). The effect of active recovery on blood lactate after exercise is well documented but the exact mechanism of lactate fatigue in a repeated performance needs to be discussed further (Barnett, 2006; Dodd & Alvar, 2007; Watts et al., 2000).

Mechanisms of performance limitation in relation to the type of recovery was described by many authors (Astrand et al., 2003; Bielik, 2010; Heyman et al., 2009; Watts et al., 2000). Several authors (Allen, Lamb, & Westerblad, 2008; Chin & Allen, 1997; Place, Yamada, Bruton, & Westerblad, 2010; Westerblad, Bruton, Allen, & Lannergren, 2000) agree on the inability of contraction which caused by insufficiency of ion intake such as calcium.

Cold water immersion has the potential to minimize performance reduction of knee extension and flexion. The effect of cold water immersion showed the smallest decrease by % of peak torque, total work and average power of knee flexion strength. Cold water immersion was changed into higher room temperature repeatedly not to hold up the recovery processes. In our case cold water immersion was only partial diving (to the hip) for the lower extremities to avoid the negative effects of the whole body cold bathing to the urinary tract. The individuals had to stand in a barrel submereged to their hips. The water temperature was increased up to 15° C after one submersion procedure. In the other studies (Parouty et al., 2010; Peiffer et al., 2010), they used a water temperature of 14° C and the subjects were to the neck in cold water for 5 min. and 5 min. in room temperature in a sitting position, there was a significant effect on repetitive strength performance in the group of sprint swimmers. Water temperature and the duration of submersion seemed to be optimal in our study too. Similar positive effect of water temperature and duration of cold water immersion was confirmed in a group of climbers when applied only on the forearm (Baláš et al., 2010).

There are certain recovering processes occurring after the application of such cold water – local vasoconstriction of blood vessels, increase local blood flow avoiding cell necrosis, swelling, slowing of cellular metabolism, slowing of nerve transmission and means of reducing pain by proprioceptors of loaded muscles. Whether performance recovery after cold water immersion is primarily linked to the return of fluid from muscles to the blood requires further investigation (Wilcock, Cronin, & Hing, 2006). The positive effect of hydrotherapy can be also caused by hydrostatic pressure, which affects blood circulation. Hydrostatic pressure during water immersion might be the other mechanism linked to performance recovery (Ingram et al., 2009; Vaile, Halson, Gill, & Dawson, 2008b). Barnett (2006) noted that some applications of cold water immersion have a contradictory effect of deceleration the recovery processes. This may explain the insignificant effect of cold water on total work of knee extension and all variables of knee flexion in our study. The temperature of water and the duration of the water immersion should be discussed in this case.

In our work we observed significantly higher HR_{max} (173 ± 14 rpm, $p = 0.02$) during active recovery than during passive recovery (167 ± 14 rpm). Active recovery also led to significantly higher values of HR_{avg} (124 ± 8 rpm, $p = 0.00$) than passive recovery (107 ± 12 rpm). Bielik (2010) recorded significantly increase of HR_{avg} (125 ± 12.4 rpm, $p < 0.01$) after active recovery on bicycle ergometer than in passive rest (105.1 ± 8.2 rpm). We agree with the work of Draper, Bird, Coleman, and Hodgson (2006), who applied walking recovery after climbing performance. HR_{avg} was increased after active recovery between maximal climbing performance tests. Authors Draper, Bird, Coleman, and Hodgson (2006) found steeper increase of HR_{avg} than with passive recovery but the differences were not statistically significant.

HR_{avg} during passive recovery was 107 ± 12 rpm and during using cold water immersion was 97 ± 9 rpm. The differences were significant. Klugar et al. (2009) reported significant decrease of HR_{avg} after scuba diving (on average from 63.2 to 58.8 rpm) where the temperature of the water reached an average of 29° C.

We can find different opinion on this problem in the current literature, which is caused mainly by the different load localization and its effect on the blood circulation (Baláš et al., 2010; Draper, Bird, Coleman, & Hodgson, 2006).

CONCLUSIONS

We found significantly smaller changes of the peak torque after active recovery (↑ 0.9 N × m) compared with cold water immersion (↓ 14.6 N × m) and passive recovery (↓ 13.9 N × m) in subsequent knee medium-term muscular performance. We noticed a significant decrease of average power after active recovery (↓ 5 W) and after cold water immersion (↓ 23.7 W) and after passive recovery (↓ 25.9 W). There was no significant difference in total work by using the other recoveries. Active recovery and cold water immersion had a significant effect on total work of knee extension and flexion.

HR_{max} significantly increased during active recovery than passive recovery (173 ± 14 vs. 167 ± 14 rpm) and HR_{avg} (124 ± 8 vs. 107 ± 12 rpm). The cold water immersion did not have any effect on HR_{max} compared to passive and active recovery on the contrary there were significant changes in HR_{avg} during passive recovery and active recovery (97 ± 9 vs. 107 ± 12 rpm).

In our study we found a positive effect of walking recovery on lower limbs strength performance. After passive recovery we found larger decline of muscle performance in medium term activities.

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VLIV AKTIVNÍHO ODPOČINKU A STUDENÉ VODY NA OPAKOVANÝ VÝKON EXTENZORŮ A FLEXORŮ KOLENNÍHO KLOUBU

(Souhrn anglického textu)

VÝCHODISKA: Zotavení patří mezi důležité komponenty fyzické aktivity. Není výjimkou, že mnoho sportovců trénuje ve vysokých dávkách, aniž by tělo mělo čas na adekvátní odpočinek. Vede to k tomu, že dochází k přetrénování, vyhoření a snížení výkonnosti sportovce. V poslední době se jeví studená voda a aktivní odpočinek jako jedny z nejpopulárnějších druhů zotavení.

CÍLE: Cílem předložené studie bylo zjistit vliv tří různých druhů zotavení (aktivní odpočinek, studená voda a pasivní odpočinek) na opakovaný střednědobý svalový výkon extenzorů a flexorů kolenního kloubu.

METODIKA: Studie se zúčastnilo 14 sportovců ve věku 26,6 ± 4,4 let. Jednalo se o randomizovaný křížený plán studie. Měření izokinetické síly bylo prováděno ve třech dnech, kdy v jeden den došlo ke třem pokusům. Mezi jednotlivými pokusy byly aplikovány různé druhy zotavení. Vliv aktivního odpočinku, studené vody a pasivního odpočinku byl zjišťován pomocí 3 × 3 (čas × zotavení) analýzou rozptylu s opakováním měření. Jednalo se o tyto závisle proměnné – maximální moment síly, celkovou práci a průměrný výkon.

VÝSLEDKY: Zjistili jsme významně nižší pokles maximálního momentu síly extenzorů po aktivním odpočinku (↑ 0,9 N × m) než po studené vodě (↓ 14,6 N × m) a pasivním odpočinku (↓ 13,9 N × m). Pokles průměrného výkonu byl významně menší po aktivním odpočinku (↓ 5 W) než po studené vodě (↓ 23,7 W) a pasivním odpočinku (↓ 25,9 W). Nezjistili jsme významné změny izokinetické síly flexorů při aplikaci vybraných druhů zotavení. Maximální srdeční frekvence byla významně vyšší při aktivním odpočinku než při použití studené vody a při pasivním odpočinku (173 ± 14, 166 ± 14 a 167 ± 14 tepů × min^{-1}). Našli jsme významné rozdíly v průměrné srdeční frekvenci při aktivním odpočinku, studené vodě a pasivním odpočinku (124 ± 8, 97 ± 9 and 107 ± 12 tepů × min^{-1}).

ZÁVĚRY: Zjistili jsme pozitivní efekt aktivního odpočinku na opakovaný střednědobý svalový výkon extenzorů kolenního kloubu. Byla to jediná metoda, po které byl pokles ukazatelů svalového výkonu nejmenší. Zaznamenali jsme také významné změny srdeční frekvence vlivem různých druhů zotavení.

Klíčová slova: zotavení, ochlazování, pasivní a aktivní odpočinek, izokinetická síla.

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