EFFECTS OF FAR INFRARED WARM ON RECOVERY IN POWER ATHLETES DURING A 5- DAY TRAINING PERIOD

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ABSTRACT

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Purpose. Scientific evidences of thermal therapy on performance recovery are limited and also controversial. It has been shown recently by Hausswirth et al. (2011) that far infrared (FIR) therapy accelerates recovery, while it is also documented that temperate water immersion does not improve performance recovery (Pournot et al. 2011). The purpose of the present study was to find more concrete information about the effects of the thermal therapy and especially the FIR warm on the recovery of the athletes.
Methods. The experimental group consisted of ten national level male athletes (22.3 ± 4.5 years) from the power events in track and field, gymnastics and Finnish baseball. The experimental group was its own control group. Starting order of the subjects in the groups was randomized. Training and nutrition were standardized during the 5-day training period. The experimental design consisted of performance tests (isometric strength tests, countermovement jump and Wingate 30 s test), questionnaires and the fasting blood samples (testosterone, cortisol, SHBG, hsCRP and creatinekinase [CK]). In contrast to the control period, during the experimental period the subjects used infrared bag (FIR65º, U2i / Oy You Two Import Ltd, Oulu, Finland, 40 min / 50 ºC) every evening from Monday to Thursday. Statistical analyses included ANOVA and paired samples t-test. Level of significance was set at $p<0.05$.
Results. Average power in Wingate 30 s test increased significantly ($p = 0.015$) during the experimental condition, while during the control condition no significant changes were observed. There were no significant differences in the blood variables between the measurement periods. However, there was a significant increase in the blood SHBG level ($p = 0.032$) between the first and the third day and in the testosterone level ($p = 0.023$) between the third and the fifth day during the experimental condition. The level of CK was significantly higher in the second day than in the first day ($p = 0.023$) during the control condition and in the third day than in the first day during the control ($p = 0.007$) and the experimental conditions (0.030). The relative change in the testosterone/cortisol ratio between the day one and the day five increased significantly more ($p = 0.026$) during the experimental condition than during the control condition. The sensations in the muscle soreness were milder during the experimental condition when compared to the control condition.
Discussion and conclusions. The present study indicates that FIR warm improves recovery of the anaerobic performance during the 5- day training period. The subjective sensations support the positive effects of the FIR warm on recovery. The changes in the testosterone/cortisol ratio, CK response, and serum testosterone and SHBG levels indicate probability to the improved anabolic state and accelerated recovery due to the FIR warm. However, because there were no significant changes in blood variables between the two conditions, additional studies are needed considering the effects of the FIR warm on them. According to this study FIR warm therapy enhances the recovery after a short 5- day training period when compared to the passive recovery modality.

Keywords: Far infrared warm, recovery, performance, blood variables, subjective sensations

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1 INTRODUCTION

Around the world, athletes in different events train for developing themselves faster, stronger and more technical than their rivals. For that they need commitment to the hard and optimal training from themselves as well as support from their coaches and the others involved in their lives. Hard training exposes athletes to the physical and mental stress that are essential for improvement, but can further induce overtraining and even severe injuries. This may occur if recovery is not sufficiently involved in the training programs.

For accelerating recovery and to enable harder training, athletes and coaches have tried to found different recovery modalities. Water immersions, cryotherapy, thermal therapy and active recovery modalities, just to mention a few have become a daily or at least a weekly part of the training and rehabilitation programs. However, scientific evidence that supports their use is somehow limited, especially when considering the use of thermal therapy.

Infrared radiation has warming effect, which has been used in infrared sauna or with infrared bag. Only a few studies have examined the effects of the infrared therapy on health factors or recovery from training. Beneficial effects of it have been observed on chronic low back pain (Gale et al. 2006), on the vascular endothelial inflammation (Lin et al. 2008) and heart and coronary diseases (Beever 2009). Using of the infrared sauna has been also noticed to decrease cortisol levels and blood pressure and to increase growth hormone and heart rate acutely (Tornberg 2010; Mäntykoski 2010). Thus, infrared warm could potentially improve the recovery from sports training via increased blood circulation and a decreased stress state of the body.

The purpose of this study was to examine effects of the far infrared warm on the selected physiological variables such as hormones, creatinekinase and C-reactive protein as well as sensations and performance of power athletes during a 5- day training period. By this design we tried to define effects of the far infrared warm on power athlete’s recovery from the sport training. We hypothesized based on previous investigations that the far

infrared warm accelerates the recovery in maximal strength (Hausswirth et al. 2011) and in speed strength (Mäntykoski 2010), but it does not have effects on anaerobic performance (Pournot et al. 2011). We hypothesized also no changes in fasting serum concentrations of testosterone, cortisol, SHBG, creatinekinase or hsCRP (Ahtiainen et al. 2005), but improvements in the perceived sensations of athletes (Gale et al 2008; Hausswirth et al. 2011; Oosterveld 2008).

2 RECOVERY AFTER PHYSICAL TRAINING

2.1 Performance

Training induces fatigue and because of that muscles voluntary activation and able to contract decreases. Häkkinen and Pakarinen (1993) and Ahtiainen et al. (2005) observed that isometric force production can decrease for two or even three days after the single strenuous hypertrophic strength training. According to Zainuddin et al. (2005) isometric torque was still significantly lower seven days after hypertrophic strength training and recovered to the pre-exercise values in ten days (Figure 1). The reason can be found from decreased instant energy source levels of the muscle, changes in anabolic hormone concentrations, increased muscle lactate concentration and breakdown of the muscle structures, that induces muscle soreness and great fall in the performance temporarily. (Ahtiainen et al. 2005; Häkkinen 1990, 45 – 47; Nosaka et al. 2002.)

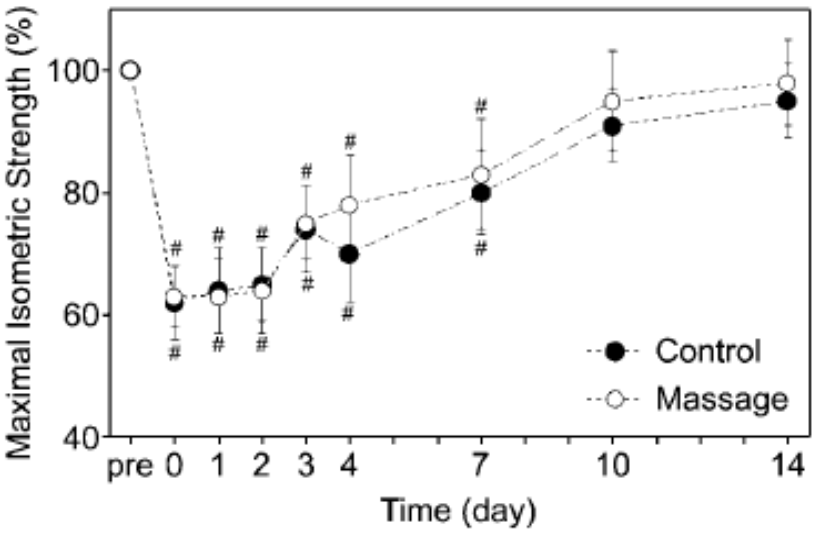

Figure 1. Changes in maximal voluntary isometric torque from baseline (pre), immediately after (0) and for 1 to 14 days post-exercise in massaged and control arms (Zainuddin et al. 2005).

Training with high movement velocities (eg. speed- and speed strength training) seems to increase initial firing rates of the fast motor units and decrease their activation thresholds (Van Cutsem et al. 1998). Because of these neural adaptations athletes and coaches should take into account the effects of speed training and speed strength training to the

neural system when considering the recovery after the trainings. Fatigue can be also result of decreased muscle- and liver glycogen stores. According to Fairchild et al. (2003) high-intensity exercise of three minutes induce significant decrements (46 %) in muscle glycogen stores. However, it was observed that muscle glycogen contents was replenished significantly already during 90 minutes recovery.

2.2 Muscle soreness

Muscle soreness has been observed to be greatest between 1 – 3 days after hypertrophic strength training and it may not be fully recovered until 7 – 10 days after the work-out (Nosaka et al. 2002). Uchida et al. (2009) investigated effects of different intensities strength work-outs on the muscle soreness and noticed that muscle soreness was greatest 48 hours after the work-outs. It was also observed that concentration of the creatinekinase enzyme and prostaglandin (tissue hormone) increased during the next few days after the training. Because there were no significant differences in creatinekinase, prostaglandin and muscle soreness between the different intensities training groups, the authors suggested that more prescriptive factors may be the training volume rather than the intensity.

In addition to the training volume also the type of the training affects to the muscle soreness. Willoughby et al. (2003) observed greater increases in muscle soreness after eccentric strength training than after concentric strength training. Muscle soreness recovered to the baseline levels in 48 hours after the concentric training, while it was still significantly elevated 48 hours after the eccentric training. In addition to strength training muscle soreness occurs also in the other exercises, especially in those that contains large eccentric component. Eston et al. (1996) observed significant increases in muscle soreness after downhill running, that achieved its peak values 48 hours after the training session and recovered to the baseline values during four days.

2.3 Hormones

Concentrations of the serum growth hormone, testosterone and cortisol have been observed to increase acutely after the hypertrophic strength training protocol. (Ahtiainen et al. 2005; Häkkinen & Pakarinen 1993; Kraemer et al. 1998.) Also after the endurance training serum testosterone and cortisol concentrations have been observed to elevate significantly (Vuorimaa et al. 2008). After hypertrophic strength training blood testosterone, cortisol and growth hormone levels have been observed to decrease back to the pre-exercise values in 60 – 90 minutes (Kraemer et al. 1998). The same is observed with testosterone and cortisol after the endurance training session (Vuorimaa et al. 2008), and cortisol and prolactin after the interval training (Gray et al. 1993). Further, after the endurance training session cortisol and testosterone seem to decrease even below the resting values after 24 hours recovery (Daly et al. 2005).

Häkkinen et. al. (1985) observed that during twenty weeks of heavy resistance training cortisol concentrations decreased and testosterone/cortisol ratio increased significantly indicating more anabolic-androgenic activity at the end of the training period. When training was continued four weeks further testosterone/cortisol ratio reached a plateau that could have been consequence of overtraining. At the same time isometric strength between the weeks 20 – 24 did not increase. Also long-term (20 weeks) speed strength training induced significant increases in testosterone concentration and testosterone/cortisol ratio. However, it is also very common that serum testosterone –and cortisol concentrations do not change during strength training period, if the volume of the training is constant (Häkkinen 1990, 74 – 82).

3 RECOVERY MODALITIES IN SPORT

Adequate passive rest and sufficient sleep are the most obvious methods to enhance recovery and avoid fatigue. The amount of required sleep varies between individuals, but general advice is to sleep the amount of time that is needed to feel wakeful during the day. Persistent sleep loss can have negative impact on the general well-being and quality of training. (Meeusen et al. 2013.) However, it seems that even a total sleep deprivation (30 h) does not affect on anaerobic performance of the athletes in a short-term, although it induces anxiety (Vardar et al. 2007).

In addition to passive recovery (rest between the training sessions and sleep) different recovery modalities have been developed to accelerate recovery after training. If they are in use, a recovery period between the training sessions consists of chosen recovery modality/modalities and passive rest. According to Pournot et al. (2011) recovery modalities such as cold water immersion and contrast temperate water improved the recovery of the performances significantly more than passive recovery modality alone (Figure 4). This is supported also by Versey et al. (2011).

In addition to sufficient rest between the training sessions nutrition is a basic element considering the recovery. For example, replenishment of muscle glycogen stores can be enhanced with nutrition. It is recommended to take carbohydrate immediately after the exercise (1.2 g / kg body weight / hour) to assist in muscle glycogen synthesis. Further, additional protein or amino acids does not increase muscle glycogensynthesis rates when carbohydrate intake exceeds the recommended amount. However, protein ingestion (0.2 – 0.4 g / kg body weight / hour) and carbohydrate intake (0.8 g /kg body weight / hour) seems to result in similar glycogen repletion as recommended carbohydrate intake after the exercise. In addition, protein is recommended to take after the exercise to stimulate protein synthesis, inhibit protein breakdown and allow net muscle accretion. To maximize muscle protein-synthesis rates during first hours after the exercise 20 g protein is recommended to consume immediately after the exercise. (Beelen et al 2010.) As it can be seen from Figure 2, nutrition has also effects to the recovery of serum testosterone levels after the hypertrophic strength training (Kraemer et al. 1998).

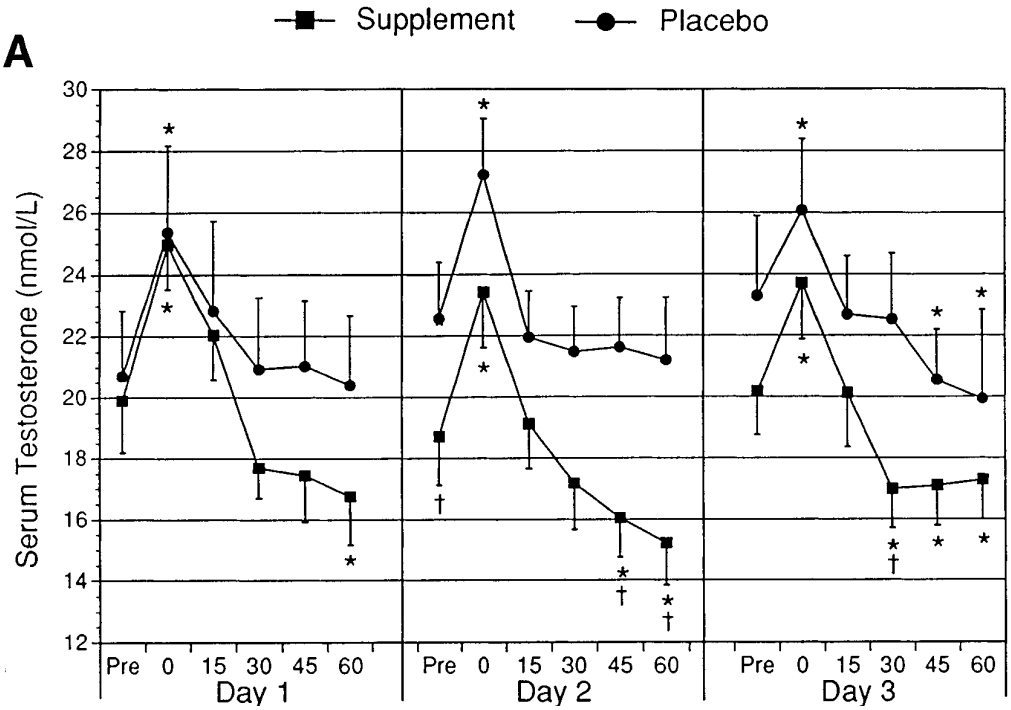

Figure 2. Serum testosterone concentrations during the three days hypertrophic training period in the nutrition supplement group and placebo group. Testosterone levels declined to the resting values or below them during 60 minutes recovery. (Kraemer et al. 1998.)

3.1 Active recovery

Active recovery with light exercise is a more effective post-exercise recovery modality than passive recovery. It has been showed recently that after treadmill running at 90 % of VO2max the decrease in accumulated blood lactate is more effective when the intensity of the active recovery is between 80 – 100 % of the individual lactate threshold than at lower exercise intensities or in passive recovery. (Menzies et al. 2010.) Also other researches support the finding of the benefits of the active recovery. Vaile et al. (2008) demonstrated that five minutes cycling at the intensity of 40 % of VO2peak is more effective than cold water immersion strategies when considering the lactate clearance after the intensive 30 minutes cycling performance. In addition, Monedero and Donne (2000) noticed active recovery to be more effective than massage to remove blood lactate after 5 km cycling. The duration of the optimal active recovery after the performances needs some further investigation.

Despite the positive effects of the active recovery on the lactate clearance rate, it has been noticed (Vaile et al. 2008) that cold water immersion after the 30 minutes intensive cycling performance maintains performance better than active recovery. This observation is based on the finding that cold water immersion induced a significantly lower percentage decline in work between the first and the second cycling bout. In addition, active recovery impairs muscle glycogen resynthesis that can further moderate recovery (Fairchild et al. 2003).

3.2 Massage

Massage has been observed to increase clearance of creatinekinase and decrease muscle soreness and swelling after the eccentric exercise (Zainuddin et al. 2005). There are also evidences that muscle tone decreases immediately after massage (Callaghan 1993). Muscle tone is defined as the stiffness or resistance of the muscle to passive movement (Knutson & Owens 2003). However, changes in both muscle architecture and muscle tone need some further work.

Despite the possible benefits athletes should take into consideration that massage affects to the following performance. Hunter et al. (2006) found out that acutely after the massage force production of knee extensors decreased. It has also been shown that lower limb massage impaired explosive and high speed motor capacities acutely. Impairments were significant in 10 meter acceleration, 30 meter acceleration and vertical jump and they were similar as after a stretching protocol. (Arabaci 2008.) Hunter et al. (2006) did not find significant changes in electromyography after massage and concluded that decrease in force production after massage is maybe due to changes in muscle architecture affecting the length-tension relationship. Also Barlow et al. (2007) found no differences in electromyography in submaximal isometric knee extension after massage.

3.3 Temperature based modalities

3.3.1 Cryotherapy

Pournot et al. (2011) investigated the effects of the different temperature water treatments on the recovery from the exhaustive intermittent anaerobic exercise. Recovery modalities they used were cold water immersion in the water temperature of 10 ºC (CWI), temperate water immersion (TWI) in the water temperature of 36 ºC, contrast water immersion (CWT) and passive recovery without the water immersion. The length of all recovery modalities was 15 minutes. Maximal voluntary isokinetic strength (MVC), countermovement jump (CMJ) and power in the 30-second rowing test (P30) decreased significantly immediately after the exhaustive exercise. However, results indicated that only in the cold water immersion group MVC and CMJ were not lower than the pre-exercise values 1 hour after the exercise. Also after the 24-hours recovery period the values in the CWI and CWT groups in MVC test were not significantly lower when compared to the pre-exercise values. In the other groups the values were still lower after 24 hours recovery. The results of the performance tests are shown in figure 3. During the recovery period the CWI group was the only group where plasma creatinekinase concentration did not increase significantly. The results of this study indicates faster recovery of the performance after using the cold water immersion than after using other recovery modalities, what is supported also by Ascensao et al. (2011) and Vaile et al. (2008).

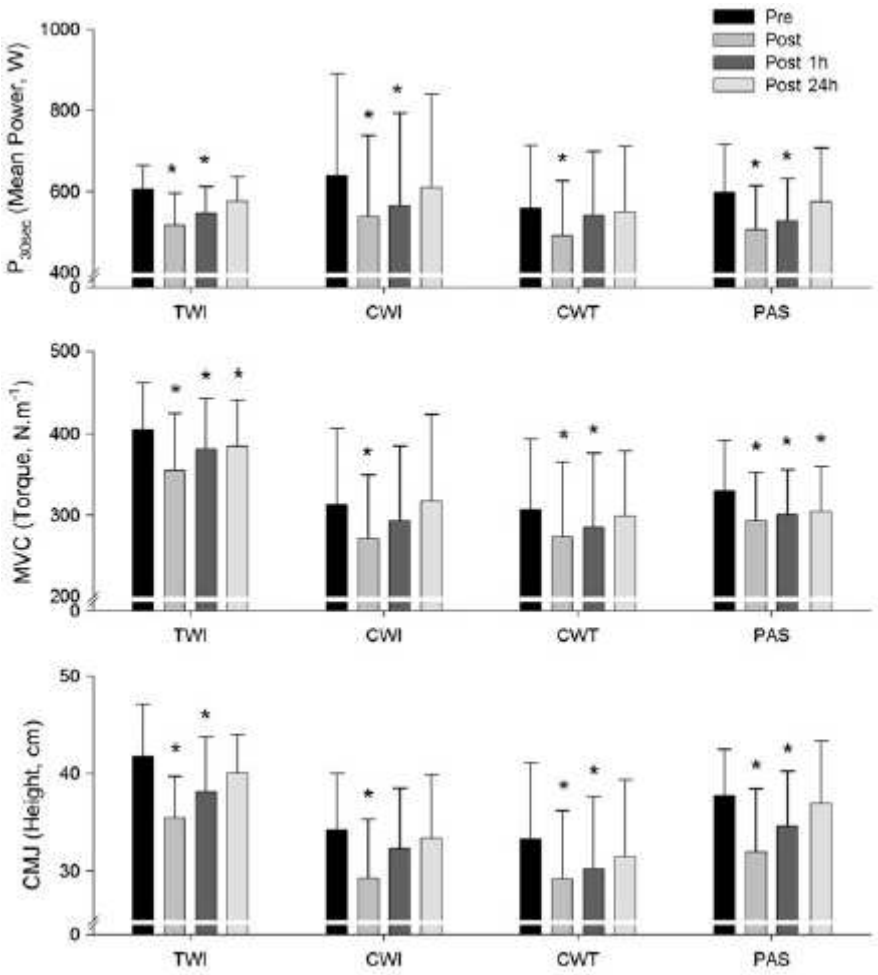

Figure 3. Mean ± S.D. Maximal isometric voluntary contraction (MVC), counter-movement jump (CMJ) and mean power during 30 seconds all-out rowing performance (P 30 s) for temperate water immersion (TWI), cold water immersion (CWI), contrast water temperature (CWT) and passive (PAS) conditions. There were no significant differences between the groups for all values. Asterisks represents significant difference to pre-exercise values ($P<0.05$). (Pournot et al. 2011.)

In contrast to the previous findings Peiffer et al. (2009) observed significantly worse recovery in isometric contraction torque after using 20 minutes of cold water treatment compared to the control condition. This was noticed with and without the superimposed electrical stimulation during the contraction, and the results indicate negative effect on neuromuscular function. Preceding training before the recovery intervention consisted of 90 minutes cycling and 16,1 km time trial in the heat. Anyway, in this research there was only 25 minutes rest before the isometric tests comparing to the previously described research done by Pournot et al. (2011) where the rest length was 45 minutes. Also the cold water immersion length was 5 minutes longer.

Altogether, cryotherapy induced faster performance recovery after the training than thermal therapy or passive recovery modalities do (Pournot et al. 2011). This is supported also by Ascensao et al. (2011) and Vaile et al. (2008), who observed more beneficial effects of the cryotherapy than thermal therapy or the active recovery on the recovery of the performance. Anyway, active recovery is more effective to reduce accumulated lactate after the performance than cryotherapy (Vaile et al. 2008), and use of cryotherapy can not be recommended too near of the following performance (Peiffer et al. 2009). Thus, cryotherapy should be used after the training day or at least there should be a long break between the training sessions when it is used. In the tournaments active recovery should be used instead of cryotherapy if time-period between the games is short.

3.3.2 Thermal therapy

Beneficial effects of the heat treatment appear to affect on the level of the skin (1 – 2 cm deep) and the effects unlikely reach the deeper tissues. However, it seems that infrared warm is exception on that because it penetrates to the deep tissues on the human body (Beever 2009). Infrared warm and its use as a recovery modality are introduced later in the chapter four.

It has been noticed that temperate water immersion (42 ºC) after the exhaustive exercise did not improve recovery when compared with passive recovery intervention. In addition, recovery after the exercise was slower after using temperate water immersion when compared to cold water immersion and contrast temperate water treatment (Figure 3). (Pournot et al. 2011.) However, there are also some evidences that support the use of thermal therapy as a recovery modality. It has been found out that 30 minutes sauna treatment at 90 degrees immediately after training improved endurance performance in 5 km running about 2 percent and in the endurance test running time before the exhaustion rose 32 percent. (Bomba & Haff 2009, 111.)

3.3.3 Contrast warm therapy

Contrast therapy is the combination of the cryotherapy and the thermotherapy that is used alternatively (eg. Pournot et al 2011). Contrast therapy has been suggested to affect blood flow, reduce swelling and decrease inflammation and muscle spasms via the improved "muscle pumping action". Muscle pumping action is the result of vasoconstriction and vasodilation. (Bomba & Haff 2009, 113.)

In the previously mentioned study of Pournot et al. (2011) it was noticed that contrast temperate water immersion was the best recovery modality to improve maximal 30 s rowing performance after the exhaustive exercise. In addition to cold water immersion it was a significantly better recovery modality than passive recovery or temperate water immersion during the 24-hour recovery period (Figure 3). In contrast water immersion there were five cycles of 1 min 30 s in each path and athletes alternated immersions at 10 ºC and 42 ºC degree waters during 15 minutes. Contrast water treatment also increased lactate dehydrogenase 24-hours after the exercise, where the other treatments did not affect during the recovery.

Versey et al. (2011) compared 6 minutes, 12 minutes and 18 minutes contrast water therapy (CWT) with the passive recovery in trained male cyclists. Recovery interventions were used after the intense cycling bout of 75 min duration and cycling was repeated after the treatments. Cycling consisted of six sets of five 15-seconds sprints and three 5-minutes time trials. The authors found out that 6 minutes and 12 minutes CWT improved the recovery of the total work done during the time-trials and sprints as well as peak power during the sprints when compared to the passive recovery intervention. In contrast, they noticed that 18-minutes CWT did not improve recovery and suggested that CWT up to 12-minutes is more effective than longer treatments when considering the recovery.

3.4 Water immersion

Water immersion is usually used in conjunction with cryotherapy and thermotherapy, but it can be also used in thermoneutral (16 – 35 ºC) water (Ascensao et al. 2011). The

mechanism of water immersion to improve recovery is based on the increased hydrostatic pressure, what increases the fluid displacement from the extremities to the central portions of the body. (Bomba & Haff 2009, 108.)

Pournot et al. (2011) did not find significant effects during 24-hours recovery in maximal strength, speed strength and speed endurance performances when using temperate water immersion in 42 ºC degree. Instead they found improved recovery when using contrast temperature water and cold water immersions. This could indicate that the recovery of the performance levels after the exhaustive exercise is based more on temperature than water immersion itself. In addition, temperate water immersion did not improve the recovery more than passive recovery what supports the previous indication.

This finding is supported also by Ascensao et al. (2011) who investigated effects of the thermoneutral water immersion (35 ºC) and cold water immersion (10 ºC) on the recovery after the football match. They demonstrated that creatinekinase activity and concentration of the C-reactive protein increased in both treatment groups at 30 minutes, 24 h and 48 hours after the match, but the increases were greater in the thermoneutral water immersion (TWI) group than in the cold water immersion group (CWI). After the match a significant decrease in squat jump was observed at 24 h, and in the countermovement jump and peak quadriceps strength at 24 h and 48 h in the thermoneutral water immersion group. In contrast, there were significant decreases only in the countermovement jump at 24 h and peak quadriceps strength at 48 hours after the match in the cold water immersion group. Quadriceps strength was significantly greater at 24 h after the match when cold water was used instead of thermoneutral water.

In summary it could be said according to the introduced investigations (Ascensao et al 2011; Pournot et al. 2011;), that probably water immersion itself does not affect on the recovery of the performance after the training. However, when water immersion is used in conjunction with cryotherapy (cold water immersion) and when contrast water immersion is used, water immersion is a useful tool to improve recovery (Ascensao et al. 2011; Pournot et al. 2011; Versey et al 2011). Altogether, benefit of the water immersion is based on the temperature more than the water itself.

3.5 Nonsteroidal anti-inflammatory drugs

It has been observed by Tokmakidis et al. (2003) that use of ibuprofen after eccentric exercise diminish muscle soreness and decrease creatinekinase response after eccentric exercise. However, no significant effects on muscle function was noted despite the conclusions from the other researches. Despite the possible beneficial effects on muscle soreness ibuprofen has been observed to diminish protein synthesis response after resistance training. Therefore, the repeated use of nonsteroidal anti-inflammatory drugs (NSAIDs) over the extended period of time can have negative effects on adaptations to training and muscle repair. Further, these negative effects preclude the use of NSAIDs as a recovery method. (Barnett 2006.)

3.6 Combined strategies

The most rapid recovery after the exercise can be achieved when combining different recovery methods. Di Masi et al. (2007) observed that cycling in water reduced blood lactate more than cycling on land after the exercise bout with intensity above the ventilatory threshold. This indicates that combined active recovery and water immersion is more effective to reduce blood lactate than active recovery alone.

Monedero and Donne (2000) compared effects of combined active recovery and massage with active recovery, massage and passive recovery alone. According to them the combined recovery intervention was significantly better than other recovery modalities to maintain performance during subsequent maximal 5 km cycling. It was also shown that the active and combined interventions were more efficient than the passive intervention or massage for removal blood lactate after exercise. However, it is notable that highest blood lactate clearance rate during the combined recovery intervention was attained during the active phases of it.

4 INFRAREDWARM

4.1 Mechanisms

Electromagnetic radiation can be divided into different parts according to its wavelength. The wavelength of the microwaves is longer than the wavelength of the visible rays from the sun or the ultraviolet rays. Between the microwaves and the visible rays we can differentiate the infrared rays. Further, the infrared rays can be divided in near-, middle- and far infrared rays, that we can also see in figure 4. (Beever 2009.)

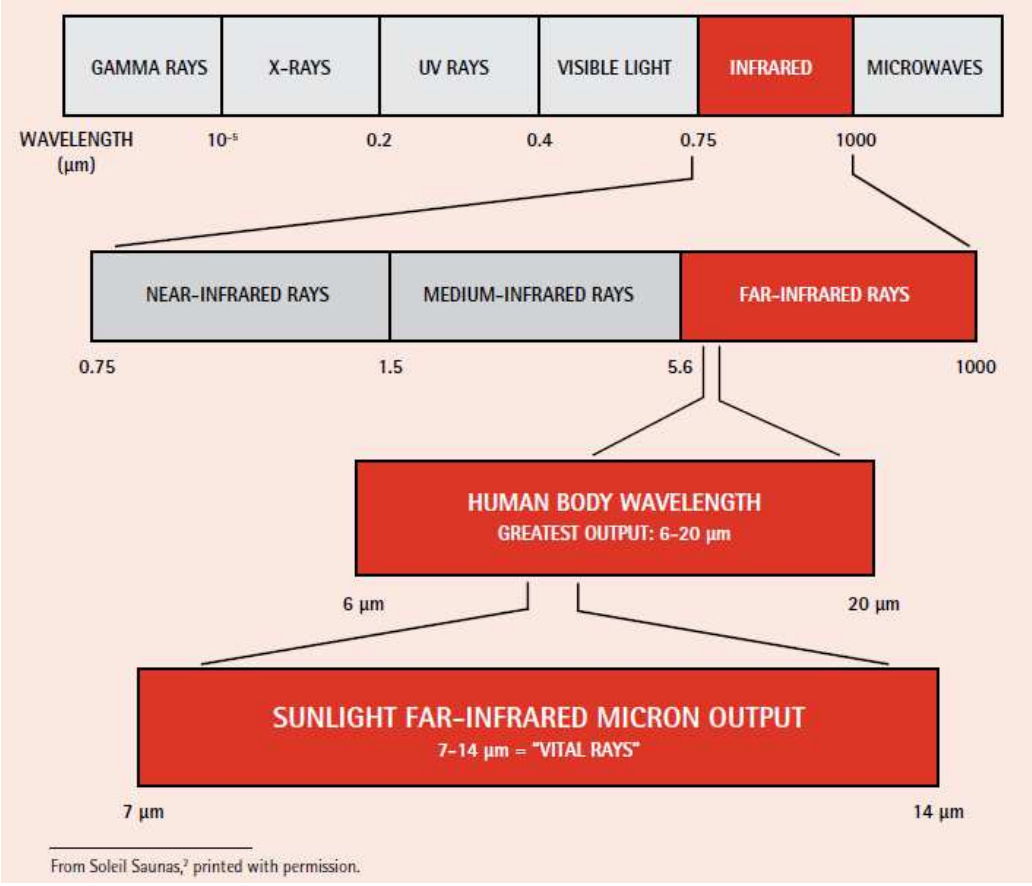

Figure 4. Wavelength range of the infrared rays used in far infrared bags- and saunas (Beever 2009).

Function of the infrared sauna and the infrared bag is based on the warming effect of the infrared radiation. Although infrared radiation comes from the sun, we can not see it. Wavelength of the far infrared (FIR) is between 5,6 and 1000 micrometers. Vibration

frequency characteristic of human body is between 6 – 20 µm and the infrared sauna and the infrared bag are designed so that they radiate these wavelengths. FIR radiation can penetrate deeper to the muscles, blood vessels, lymphatic glands and nerves than warmed air (for example, in traditional saunas) and users develop more sweat at a lower temperature than in traditional saunas. Effects of the far infrared warm on the cardiovascular system are similar as achieved by walking at a moderate pace and they are mediated by increased sweating, vasodilation, increased heart rate, increased cardiac output and decreased afterload. (Beever 2009; Mäntykoski 2010; Tornberg 2010.) The mechanism by which FIR radiation exerts its effects is not known (Lin et al. 2008), but similar wavelength of it and human body can be one possible factor that enables it to penetrate deeper to the body.

4.2 Health effects

Lin et al. (2008) observed in their study that FIR therapy attains inhibition of vascular endothelial inflammation. This anti-inflammatory effect was mediated via the increased HO-1 protein expression attained after FIR treatment. From the products of the HO-1 the bilirubin was the main factor promoting increased monocytes adhesion on the endothelial cells of the human umbilical vein and further the anti-inflammatory effect. According to the authors the ability of the FIR-treatment to inhibit inflammation via the HO-1 mechanism may provide the FIR-therapy an important tool when promoting the survival of the arteriousvenous fistula failure in the hemodialysis (HD) patients. It was also observed in this research, that in hemodialysis patients FIR-therapy exerts an anti-inflammatory effect in vivo. Hemodialysis caused the raising of the inflammation markers of these patients and after the FIR-treatment levels of these markers were significantly lower. This can also be seen in table 1, where three inflammation markers hypersensitive C-reactive protein (hsCRP), soluble intercellular adhesion molecule-1 (sICAM-1) and soluble vascular cell adhesion molecule-1 (sVCAM-1) are shown before hemodialysis (BHD) and after hemodialysis (AHD) with and without FIR-treatment.

Table 1. Serum concentrations of inflammatory markers for 20 HD patients before and after a single HD session with or without FIR therapy (Lin et al. 2008).

	HD session without FIR	HD session with FIR
hsCRP (mg/L)-BHD	4.10±4.07	4.63±4.32
hsCRP (mg/L)-AHD	4.34±4.26*	3.98±2.93
Δ (AHD-BHD) hsCRP (mg/L)	0.24±0.43	−0.65±1.73†
sICAM-1 (ng/mL)-BHD	690±225	728±218
sICAM-1 (ng/mL)-AHD	886±281*	823±320*
Δ (AHD-BHD) sICAM (ng/mL)	196±128	95±190†
sVCAM-1 (ng/mL)-BHD	1135±664	1164±676
sVCAM-1 (ng/mL)-AHD	1461±716*	1243±667*†
Δ (AHD-BHD) sVCAM-1 (ng/mL)	326±249	79±107†

hsCRP, hypersensitive C-reactive protein; BHD, before hemodialysis; AHD, after hemodialysis; sICAM-1, soluble intercellular adhesion molecule-1; sVCAM-1, soluble vascular cell adhesion molecule-1

Values are expressed as the mean ± SD.

*Statistically significant effect of HD.

†Statistically significant effect of FIR therapy.

Kihara et al. (2004) noticed that in patients with chronic heart failure repeated infrared sauna treatment in 60°C degree five times per week during a two-week period improved ventricular arrhytmias. Furthermore, authors found out that in the sauna-treated group plasma concentration of brain natriuretic peptide was significantly lower compared to the control group after a two-week experimental period. Based on this finding authors suggest that lower risk of ventricular arrhytmias may be do to the reduction of ventricular wall stretch caused by decreased brain natriuretic peptide. Also the heart rate variability increased significantly and based on previous researches authors suggested that it could affect to improvements in ventricular arrhytmias. There was also a significant reduction in body weight and a significant improvement in NYHA functional class after the two weeks of the sauna-treatment period when compared to the non-treated period.

Also other researches support the use of the far infrared sauna therapy in those with congestive heart failure (CHF). In one study done by Kihara et al. (2002) there was a significant improvement in patients NYHA-class as well in systolic blood pressure after two weeks of FIR therapy. Also brain natriuretic peptide levels decreased significantly

and endothelial function improved. In conclusion, the authors indicated that FIR treatment improved cardiac function and clinical symptoms associated with congestive heart failure. According to the authors this improvement was a result of improved vascular endothelial function. (Beever 2009.)

It has also been observed, that three weeks use of the FIR sauna at 60°C degree five times per week improved exercise tolerance in 6-minutes walk distance in patients with chronic heart failure. Also the peak VO2 and ventilation efficiency slope in exercise testing improved. Further, there was a significant increase in left ventricular ejection fraction, while neurohumoral activations were inhibited. Supportive finding to improved endothelial function was that the flow mediated dilation of the brachial artery and the number of CD34 leucocytes increased. In addition, there were also significant decrements in plasma norepinephrine and brain natriuretic peptide associated to the use of far-infrared sauna. (Ohori et al. 2012.)

Oosterveld et al. (2009) investigated effects of the infrared sauna in patients with rheumatoid arthritis (RA) and ankylosing spondylitis (AS). According to them a single 30 minutes session in the infrared sauna at an ambient temperature of 55°C decreased sensation of pain and stiffness significantly in both RA and AS patients. Also the fatigue improved, but not significantly. Patients used infrared sauna two times per week during a four-week period and during this period pain and fatigue improved slightly and stiffness almost reached significant changes in RA patients. In the AS patients there was also a slight improvement in stiffness, but no improvements in pain and fatigue.

Gale et al. (2006) investigated effects of the infrared therapy for chronic low back pain (6,5 years in average). Subjects in both experimental and control (placebo) groups had seven weekly sessions over the whole seven weeks experimental period. There was noticed approximately 50 % progressive decline in the pain during the seven weeks treatment period in the experimental group and the decline was greater when approaching the end of the period. Pain values were significantly lower in the experimental group than in the control group and also a significant decline was observed when the start values and the end values of the infrared group were compared. There were also small but not significant decrements (placebo effect) of the pain values in the control group as we can notice from figure 5.

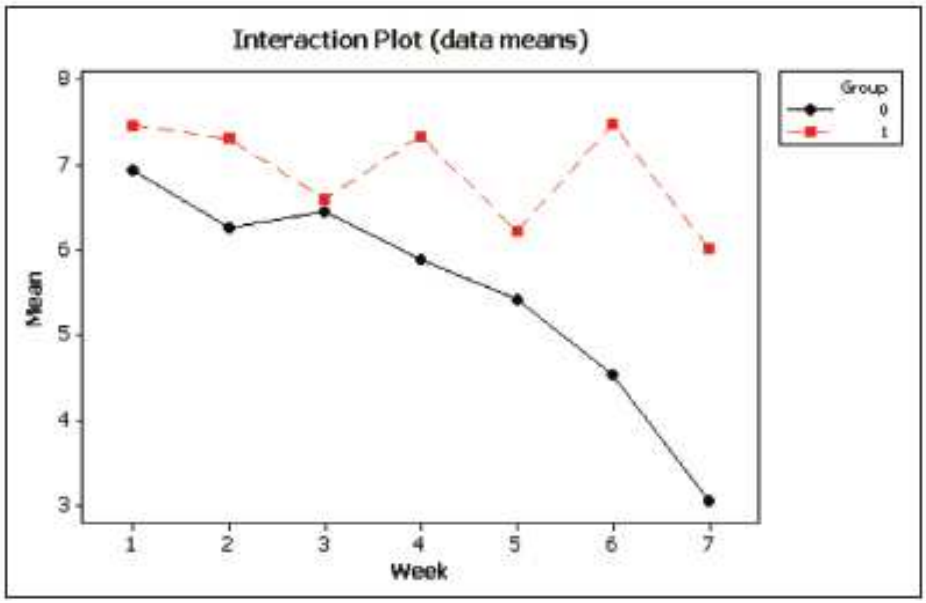

Figure 5. Mean pain scores for both groups during seven weeks period. The infrared group (group 0, black line) and the placebo group (group 1, red line). (Gale et al. 2006.)

4.3 Effects on the athletes recovery

Hausswirth et al. (2011) compared effects of the far infrared therapy (FIR), whole-body cryotherapy (WBC) and passive modalities (PAS) on the recovery after intensive running performance in highly-trained runners. Nine runners performed three identical trail runs on a motorized treadmill in three non-adjoining weeks. All participants tested one of the three recovery modalities in random order after each strenuous running exercise. Indicators of the exercise induced muscle damage such as plasma creatinekinase activity, isometric maximal voluntary torque and perceived sensations of tiredness, well-being and pain were investigated immediately before and after each running trails and within 1 hour, 24 hours and 48 hours during the recovery. The results indicated that maximal voluntary contraction (MVC) was recovered after the first WBC session (1 hour) while it was recovered later after the FIR session (24 hours). However, after the passive condition any recovery did not occur in MVC. Plasma creatinekinase (CK) activity increased significantly after the running trails, but no effect of recovery modalities on CK activity was recorded in all testing periods. Pain and tiredness caused by running trial were reduced already one hour after the first WBC session compared to FIR condition where pain was reduced 48 hours after the performance. Well-being remained lower than pre-

exercise values during 24 hours after the running but attained pre-exercise values in the FIR condition 48 hours after running. However, well-being was higher at post 24 h in the WBC group and post 48 h in the FIR condition when comparing post exercise values. PAS condition neither reduced the pain or tiredness during the 48 recovery period and well-being remained lower than pre-exercise values in all testing periods.

Tornberg (2010) investigated effects of the infrared sauna on the recovery from the hypertrophic strength training. Tornberg didn't find any effects in blood pH, electrolytes, hormones, blood lactate, subject's sensation of the recovery or blood pressure when comparing effects of 30 minutes infrared-sauna and 30 min passive recovery immediately after the strength work-out in young men (25,3 ± 8,4 years) with sporting background. In contrast, in the isometric strength tests and countermovement jump results were better after using infrared-sauna, although not significantly. During the infrared recovery and 30 minutes after that heart rate was significantly higher than during one hour passive recovery after the work-out. Treatment time was 30 minutes and temperature in the sauna changed between 35 – 50 ºC. This was due to the taken blood samples associated with door opening during sauna therapy.

Tornberg (2010) also compared effects of the infrared-sauna and normal Finnish sauna on the rest. He didn't find any effects in blood pressure or weight but there was significantly greater heart rate in the Finnish sauna at the time point 20 and 30 minutes. Also the blood pH was significantly higher in the normal sauna, but there were no differences in hormones and electrolytes between these two sauna treatments. Anyway, cortisol values were significantly lower and growth hormone levels significantly higher after both sauna treatments than before them. Based on that infrared-sauna induces constructive hormone response necessary for growth.

Mäntykoski (2010) compared the effects of the infrared sauna and the passive recovery from the exhausted endurance. The results indicated that the countermovement jump was 2,3 ± 2,4 cm higher after the sauna treatment when comparing to passive recovery, what was a significant difference. During the 30 minutes sauna treatment after the endurance performance the heart rate was also significantly higher than after passive recovery. In contrast, there were no significant differences in blood pressure, blood lactate, VO2-

consumption, blood hormone concentrations or subject’s sensations between these two conditions.

5 RESEARCH PROBLEMS AND HYPOTHESES

The purpose of this study was to examine the effects of far infrared (FIR) warm on selected physiological variables: serum hormones, creatine kinase and C-reactive protein as well as sensations and performance of power athletes during a 5- day training period. By this design we defined effects of the far infrared warm on recovery in power athletes. We assumed that it improves recovery and performance when comparing to recovery without infrared treatment.

Research problems and hypotheses were as follows:

1) Does FIR warm affect to the athlete's recovery from training based on the physical tests?

   Hypothesis: Far infrared warm during the training period improves recovery of maximal strength (Hausswirth et al. 2011) and speed strength (Mäntykoski 2010) after the training work-out more than the passive recovery does. However, it does not improve recovery of the anaerobic performances (Pournot et al. 2011).

2) Does FIR warm affect on the fasting serum concentrations of hormones, creatine kinase and hypersensitive C-reactive protein?

   Hypothesis: Although infrared induces acute decrements in concentrations of cortisol (Tornberg 2010) and hsCRP (Lin et al. 2008), we suggest it does not have any effects on the fasting levels of hormones (Ahtiainen et al. 2005), creatinekinase (Hausswirth et al. 2011) or hsCRP.

3) Does FIR warm improve perceived sensations of the athletes during the training period?

   Hypothesis: Use of the infraredbag affects perceived sensations by inducing better feeling on the muscles as well as makes athletes feel themselves "readier" in the training sessions. (Gale et al 2008; Hausswirth et al. 2011; Oosterveld 2008).

6 RESEARCH METHODS

6.1 Subjects

The experimental group consisted of ten national level male athletes from the track and field, gymnastics and Finnish baseball. Track and field athletes were either jumpers, decathletes or sprinters, thus all of the athletes were from speed strength events. Before participating in the study subjects signed an informed consent, which indicated all procedures and possible risks and benefits of the study. The Ethics Committee of the University of Jyväskylä admitted an ethical permission for the research. The experimental group acted also as its own control group. The mean energy intake was similar during both periods, because nutrition during the second measurement period was based on the nutrition diaries made during the first measurement period. Training during the second measurement period was based on the diaries made during the first measurement period, but little changes between the periods were observed because of minor injuries. Table 2 shows detailed information of the subjects.

Table 2. Description (mean and SD) of the subjects involved in the study. Training hours are summed between days 1 – 4.

	Age (years)	Height (cm)	Pre body mass (kg)	Post body mass (kg)	Energy intake (kcal/d)	Training (h)
Experimental condition	22,3 (4,5)	178,5 (6,62)	75,85 (9,63)	75,71 (9,55)	2814 (623)	7,85 (4,1)
Control condition	Same	Same	75,36 (9,37)	75,39 (9,46)	Same	8,05 (3,9)

6.2 Experimental design

Performance tests were done on the first and the fifth day of the training period. These were countermovement jump, isometric leg press and 30 seconds Wingate test (Table 3). Fasting blood samples were taken every morning except the fourth morning at 8 – 9 a clock after ten hours of fasting. Serum testosterone, cortisol, SHBG, creatinekinase and sensitive C-reactive protein (CRP) were analyzed. Subjects filled a question form of their feelings same mornings when blood samples were taken. The experimental group acted

as its own control group and the starting order of the subjects was randomized. Thus, five athletes performed the first measurement period with using the infrared bag and the second measurement period without using it, and five of them did vice versa. There were 2 – 4 weeks between the measurement periods depending of the athlete, and his training and training camp schedules. Every athlete filled the training and nutrition diary during the first measurement period. During the second measurement period they were instructed to repeat their training programme and nutrition similar as during the first measurement period.

Before the first measurement day one day was rest from training and two days before that training was instructed to be easy. Subjects were instructed to avoid alcohol consumption three days before the period and during the period. They were instructed not to taken massage during the measurement period and four days before it and to use regular sleeping rhythm two days before the measurements and during the actual period. Sleeping time was instructed to be between 11 a clock pm. to 7.30 a clock am. During the experimental period infrared bag was used every evening between Monday and Thursday. Treatment time and temperature was 40 minutes and 50 degrees, respectively. The experimental period lasted five days and the design is shown in table 3. Training is marked to take place 14 – 16 a clock, but in practice athletes did their own training program in each day as described before.

Table 3. The experimental design.

	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
8 - 9 a clock	Blood samples, questionnaires	Blood samples, questionnaires	Blood samples, questionnaires		Blood samples, questionnaires
14 – 16 a clock	Performance tests: CMJ, isometric leg press, Wingate 30s	Training	Training	Training	Performance tests: CMJ, isometric leg press, Wingate 30s
Evening	Infraredbag (40 min/50ºC)	Infraredbag (40 min/50ºC)	Infraredbag (40 min/50ºC)	Infraredbag (40 min/50ºC)	

6.3 Data collection and analysis

Training. Athletes kept training diary during the first measurement period. Training consisted mainly of strength and technique training and loading of the five-day training period was instructed to be hard. Training diaries of the first measurement period were checked by the authors and subjects were supervised to train in a similar way during the second measurement period. Training hours between the first and the fourth day of the measurement periods were analyzed from the training diaries.

Use of the infraredbag. Athletes used the infraredbag every evening during the experimental period besides the fifth evening when the training period ended. They drank four dl water before using the bag and immediately after that. Food was not eaten half an hour before and after using the bag. Temperature and time of the treatment was 50 ºC and 40 minutes, respectively. Athletes used short under wears in the bag and they lay in the bag so that whole body received the treatment. During the control period infrared bag was not used. The far infrared bag (FIR65º, U2i / Oy You Two Import Ltd, Oulu, Finland) consisted of the bag itself, the control unit and the power source. The bag was made of nylon, polyuretan textile and space carbon fiber. Size of the bag was 180cm∗92cm and the weight 7,4 kg. The control unit was one channelled and from that a user switched the apparatus on and off and adjusted the time (5 – 60 min) and the temperature (30ºC – 60ºC). The product took current from the mains and it produced power of 330W (maximum). The infrared bag itself changed the electric current to the wavelengths of the far infrared and when the product was in action it emitted this far infrared warm and induced warming effect to the object.

Nutrition. Athletes kept nutrition diary for five days, one day before the measurements and first four days during the first measurement period. They repeated nutrition similarly during the second measurement period based on their diaries. They marked on their diaries very precisely their food intake, drinking and also possible food supplements they used. Nutrition diaries were analyzed using NutriFlow- internet programme (www.nutriflow.fi).

Performance tests. Maximal isometric strength of the leg extensors and rate of isometric strength developed during the first 200 ms were measured using isometric leg dynamometer (knee angle 107º). Explosive strength of the legs extensors were investigated from the impulse of the countermovement jump (CMJ) on a force platform. Analogical data was changed to digital by using AD- transducer (CED, Power 1401, Cambridge, Englanti). Sampling rate in all tests was 1000 Hz. Signal version 4.04 was used in both CMJ and isometric tests for analyzing the results.

Anaerobic performance was investigated with the Wingate 30 second test using Monark cycle ergometer. Athletes did 30 seconds cycling performance at the maximal power and blood lactate samples were taken before and immediately after the performance and during the recovery at time points 5, 10 and 30 minutes for examining lactate clearance rate. Four seconds acceleration to the maximal speed without the load preceded the test. After subjects attained the maximal speed a load equal of 1/13 of their body weight was dropped and they continued the cycling maximally 30 seconds with that load. Monark Anaerobic Test Software on the computer was used for collecting and calculating the results. Average power during the test was counted also by investigators for verifying correct results. Lactate samples were taken from the finger and the sample volume was 20 µl. Samples were analyzed with Biosen C_line EKF Diagnostic device (Magdeburg, Germany). The measurement principle was enzymatic and whole blood was analyzed. Volume of the reaction vessels used was 1.5 ml and measurement range 0.4 – 40 mmol/l. Accuracy (CV) of the analyze was < 1.5 % at 12 mmol/l and stability < 3 % over ten tests, based on 12 mmol/l. Lactate clearance rate was counted by calculating difference in lactates immediately and 30 minutes after the Wingate test, and dividing this difference by recovery time. Tiredness during the test was counted using the following formula**:**

$$\frac{\text{average power during the first 5 seconds} - \text{average power during the last 5 seconds}}{\text{average power during the first 5 seconds}}$$

Fasting blood samples. During the measurement period fasting blood samples were taken from the antecubital vein every morning except the fourth. They were taken in a sitting position at 8 – 9 a clock after ten hours of fasting. During the second measurement period each individual was instructed to come to the blood measurements exactly at the same time as during the first measurement period. Concentrations of serum total cortisol and

testosterone, sex-hormone binding globulin (SHBG), creatinekinase (CK) and hypersensitive C- reactive protein (hsCRP) were analyzed. Serum samples were handled in sentrifug and were kept frozen at -80 °C until analyzed.

Five milliliters of blood was taken for the determination of serum hormone concentrations. Samples were analyzed by an immunometric chemiluminescence method with Immulite® 1000 (Siemens, Llanberis, UK). The sensitivity of the assay for serum testosterone was 0.5 nmol/l, for SHBG 0.2 nmol/l, for cortisol 5.5 nmol/l and for hsCRP 0.1 mg/l. Coefficient variation (CV) was 13.7 % for serum testosterone, 5.5 % for SHBG, 10.1 % for cortisol and 11.9 % for hsCRP. Creatinekinase was assessed by the spectrophotometric method with Konelab 20 XTi (Thermo Fisher Scientific, Vantaa, Finland). The detection limit of this method for creatinekinase was 7 U/l and CV was 2.6 %.

Questionnaires. Questionnaires were taken every morning except the fourth during the research period and they were analyzed after the research. Questions were related to sleep quality and quantity, sensations in the muscles, general alertness, sensations during the training work-out and sensations after using the infrared bag. The question form used is shown in Appendix 1.

6.4 Statistical analysis

Results are presented as the means ± standard deviations (SD). Statistical analyses were performed with PAWS Statistics version 19.0 for Windows (SPSS, Inc, Chicago, IL). With the hormones day to day differences within and between the measurements periods were analyzed with Analysis of variance (ANOVA). Results were analyzed also with paired samples T-test. With physical tests pre versus post differences within the measurements periods were analyzed with paired samples T-test. The same test was used for analyzing pre measurements between the experimental and control periods as well as post measurements between these periods. Level of significance was set at $p<0.05$.

7 RESULTS

7.1 Performance

7.1.1 Isometric strength and rate of force development

Maximal isometric strength did not change either in the experimental ($p = 0.144$) or the control condition ($p = 0.196$) during the measurement periods (Figure 6). This was also true for the rate of isometric force development in both experimental ($p = 0.325$) and control conditions ($p = 0.213$). See also table 4.

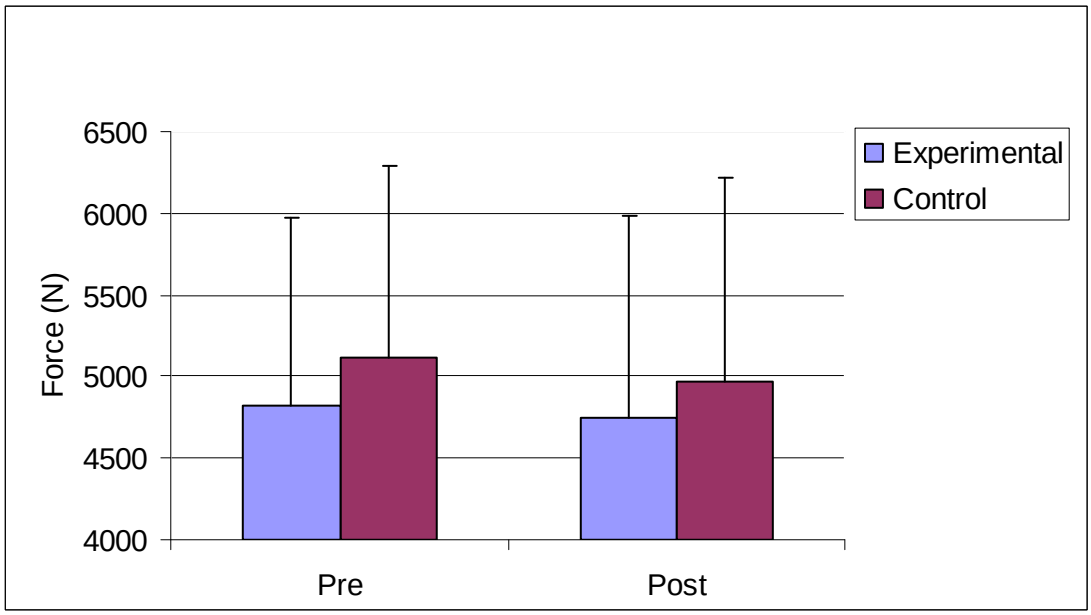

Figure 6. Maximal voluntary isometric force (mean ± SD) during the measurement periods in the experimental and control conditions.

Table 4. Physical test results (mean ± SD) during the experimental and control conditions.

Physical test	Units	Experimental pre	Experimental post	Control pre	Control post
CMJ	cm	45,05 (6,39)	45,9 (6,02)	45,9 (6,52)	45,1 (5,93)
Maximum isometric force	N	4823 (1153)	4746 (1239)	5110 (1178)	4963 (1255)
0-200ms force	N/s	3267 (733)	3216 (743)	3443 (638)	3325 (776)
Wingate average power	W/s	9,63 (0,64)	9,77 (0,75) *	9,70 (0,68)	9,67 (0,58)
Wingate average power (0 - 5 s)	W/s	13,09 (0,96)	13,46 (0,84) *	13,20 (1,18)	13,29 (0,85)
Wingate tiredness	%	47,2 (8,8)	47,8 (7,0)	46,7 (5,7)	47,7 (5,4)
Wingate lactate clearance rate	mmol/min	0,286 (0,082)	0,306 (0,063)	0,296 (0,075)	0,293 (0,086)

7.1.2 Countermovement jump

There were no significant changes in countermovement jump height during the measurement period in either of the conditions (Figure 7; Table 4).

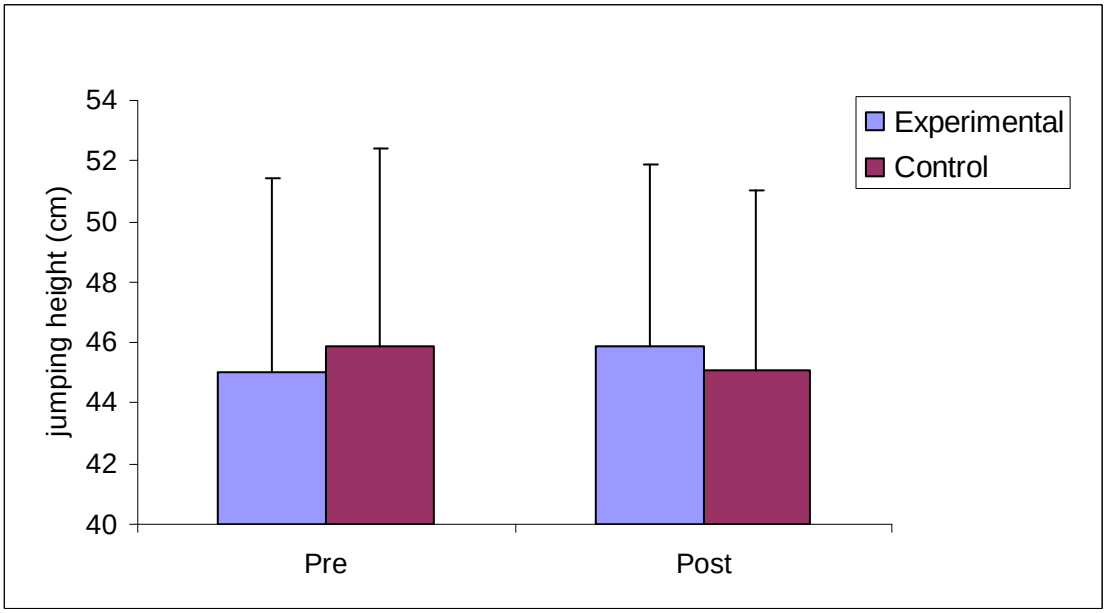

Figure 7. Average jumping height (mean ± SD) during the experimental and control periods.

Although no significant changes were observed between the two conditions, percentage CMJ height change of the individuals between the day one and five in the experimental condition was higher in seven subjects out of ten when compared to the control condition (Figure 8).

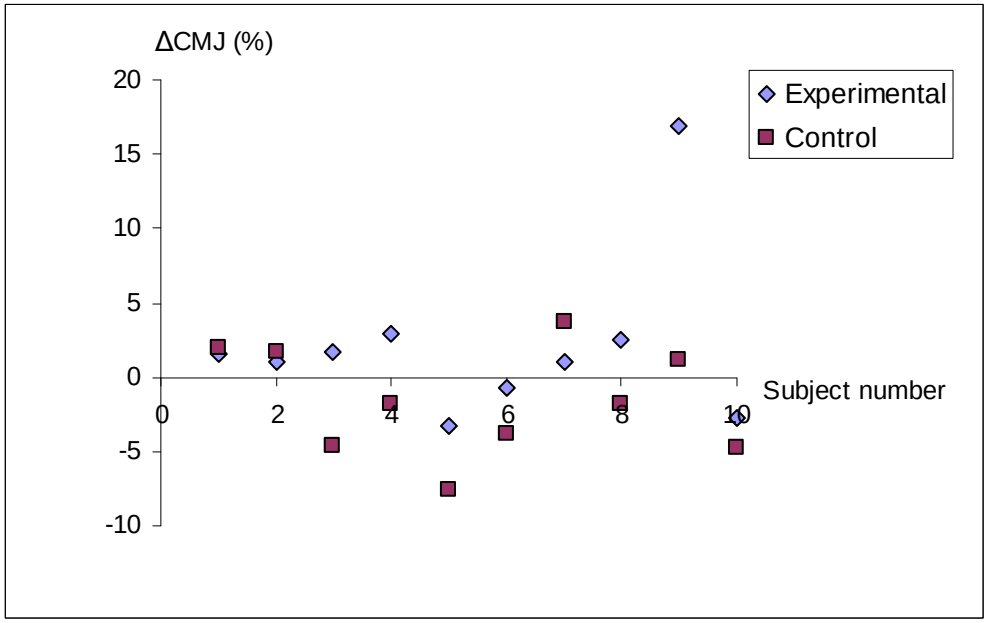

Figure 8. Individual changes (%) in countermovement jump after five days of training during the experimental and control conditions.

7.1.3 Speed endurance

Average power in the Wingate 30 seconds test ($p = 0.015$) as well as average power during the first five seconds ($p = 0.002$) in the Wingate test increased significantly during the experimental condition between the pre -and post measurements. During the control condition no significant change was observed neither in average power of the first 5 seconds ($p = 0.586$) or average power of the whole test ($p = 0.671$) (Figures 9 and 10; Table 4).

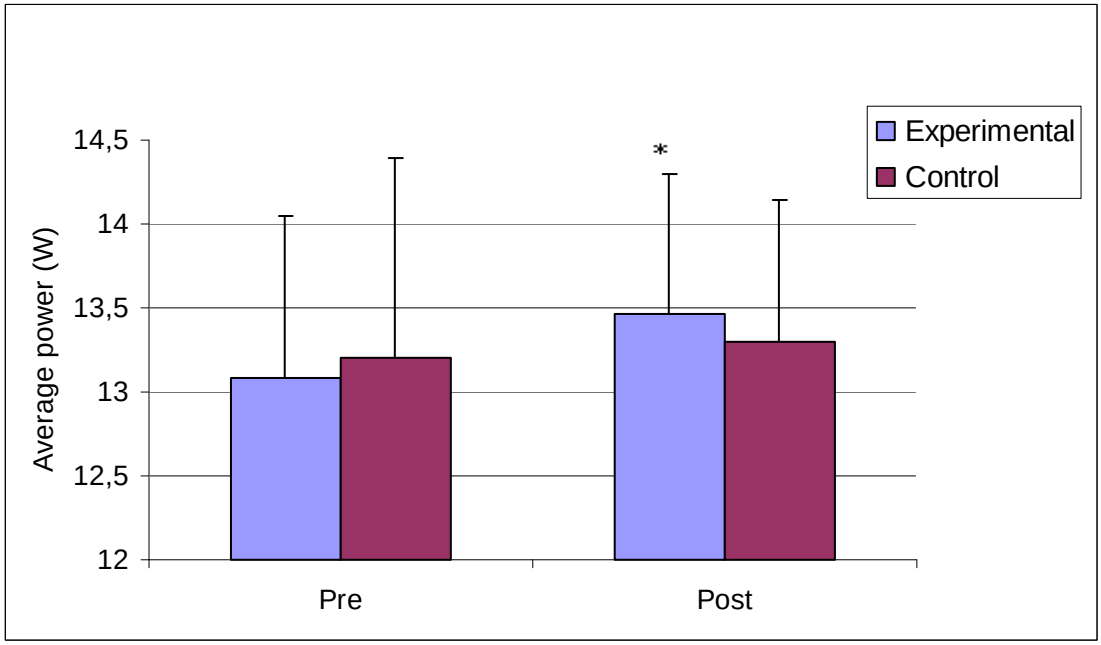

Figure 9. Average power in the Wingate test between 0 – 5 seconds (mean ± SD) during the experimental and control conditions.

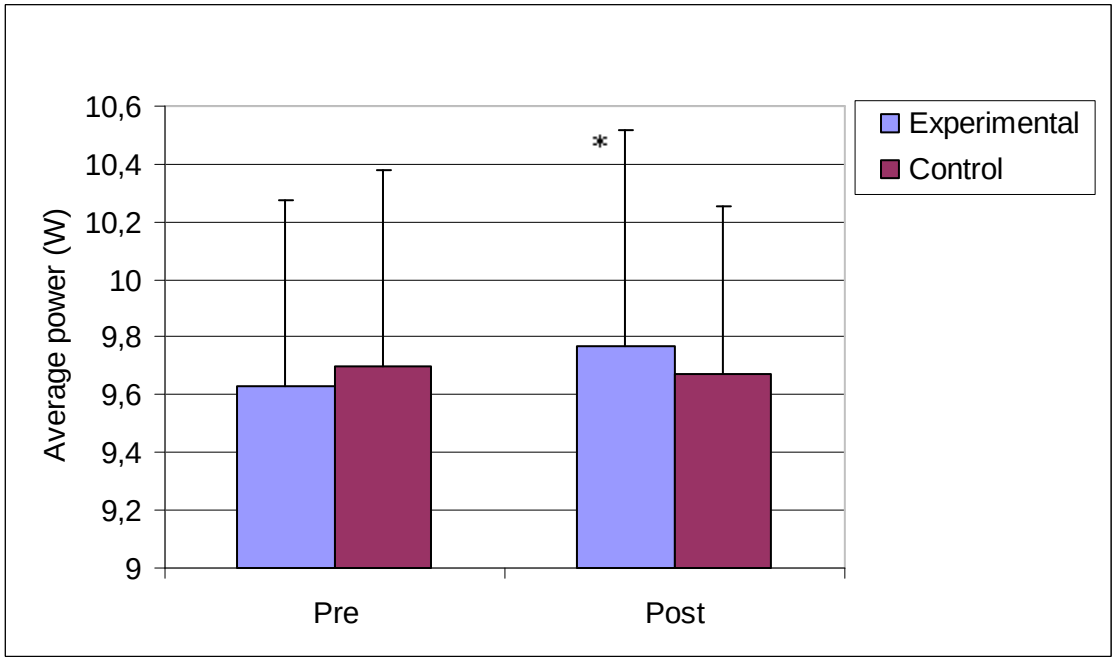

Figure 10. Average power in the Wingate test between 0 – 30 seconds (mean ± SD) during the experimental and control conditions.

Individual analysis showed that in the Wingate test percentage changes of averaged power between the pre and the post measurements were positive in all cases during the

experimental period (Figure 11). In contrast, during the control period average power was lower at the post measurements when compared to pre measurements in six subjects.

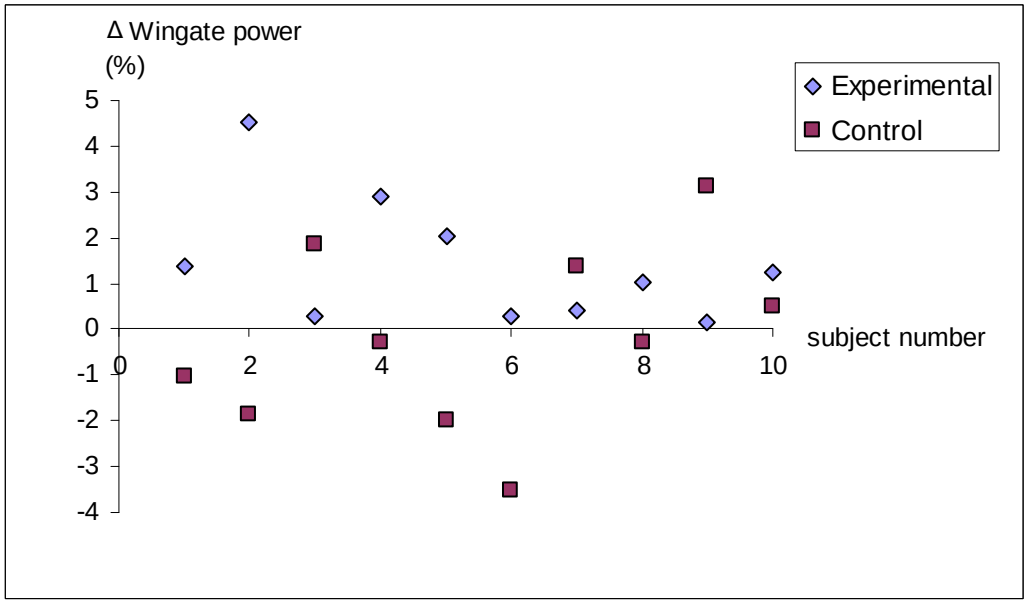

Figure 11. Individual changes (%) in averaged power of the Wingate 30 seconds test after a 5-day training period.

There were no significant changes in tiredness rate ($p = 0.650$; $p = 0.357$) or lactate clearance rate ($p = 0.433$; $p = 0.833$) during the experimental and control conditions, respectively (Table 4).

7.2 Blood variables

No significant differences were found in the levels of serum testosterone, cortisol, testosterone/cortisol ratio, SHBG, creatinekinase or hsCRP between the measurement periods (ANOVA). However, almost a significant difference between the two conditions in hsCRP ($p = 0.097$), day to day difference of creatinekinase ($p = 0.09$), and an interaction effect of cortisol ($p = 0.063$) and SHBG ($p = 0.064$) were found.

Day to day estimation made by paired samples T-test indicated that there was a significant increase ($p = 0.032$) in serum SHBG levels between days one and three during the experimental period. No other significant changes in serum SHBG in either condition were found during the training period. Serum testosterone level increased significantly (p

= 0.023) during the experimental condition between the days three and five (Figure 12). No significant changes in testosterone levels between these measurement days were found during the control condition (p = 0.935) or in the either of the conditions between the other days (Appendix 2).

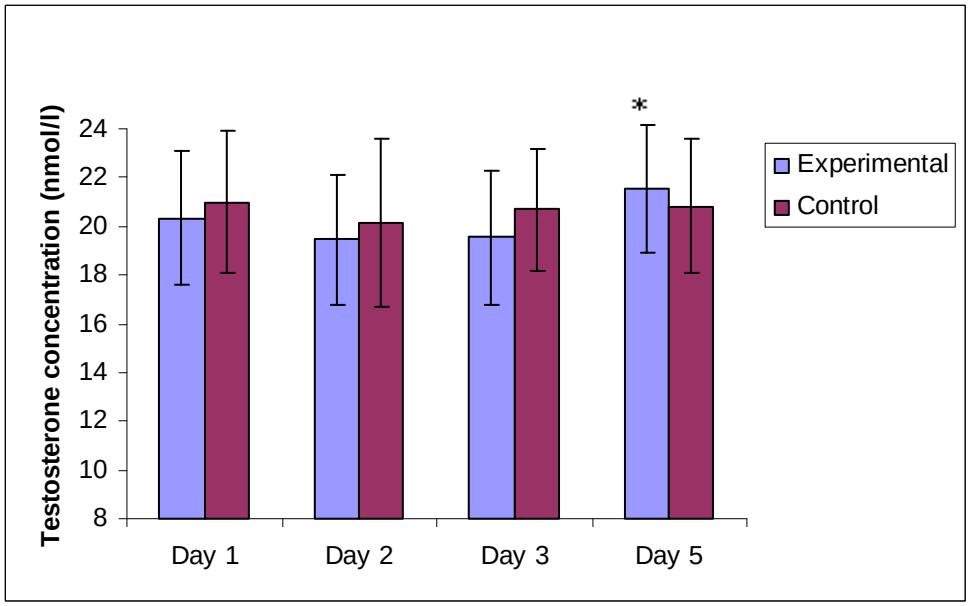

Figure 12. Serum testosterone concentration (mean ± SD) during the experimental and control conditions. Significant increase in the testosterone level was found between days 3 - 5 during the experimental condition.

Figure 13 shows serum testosterone concentration changes of different individuals between the day one and five during the experimental and the control periods. As we can see increases during the experimental condition were obvious with all individuals except the subject number one and seven. In contrast, during the control period decreases in serum testosterone concentration was observed in seven out of ten subjects. A similar but more obvious trend was observed between days three and five during the experimental condition (Figure 14).

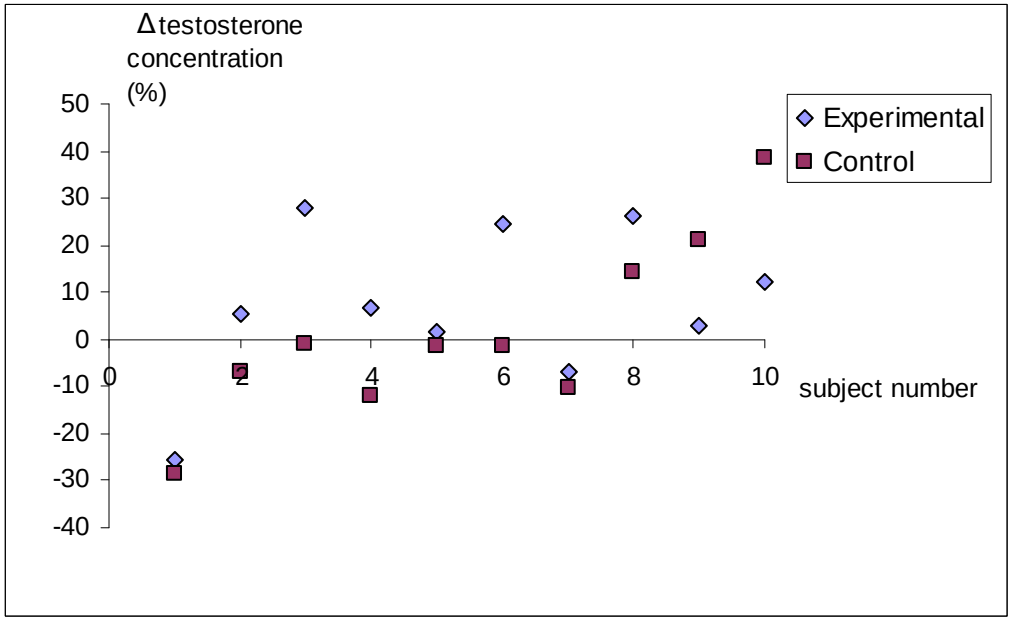

Figure 13. Individual changes (%) in serum testosterone concentration between the first and the fifth measurement days.

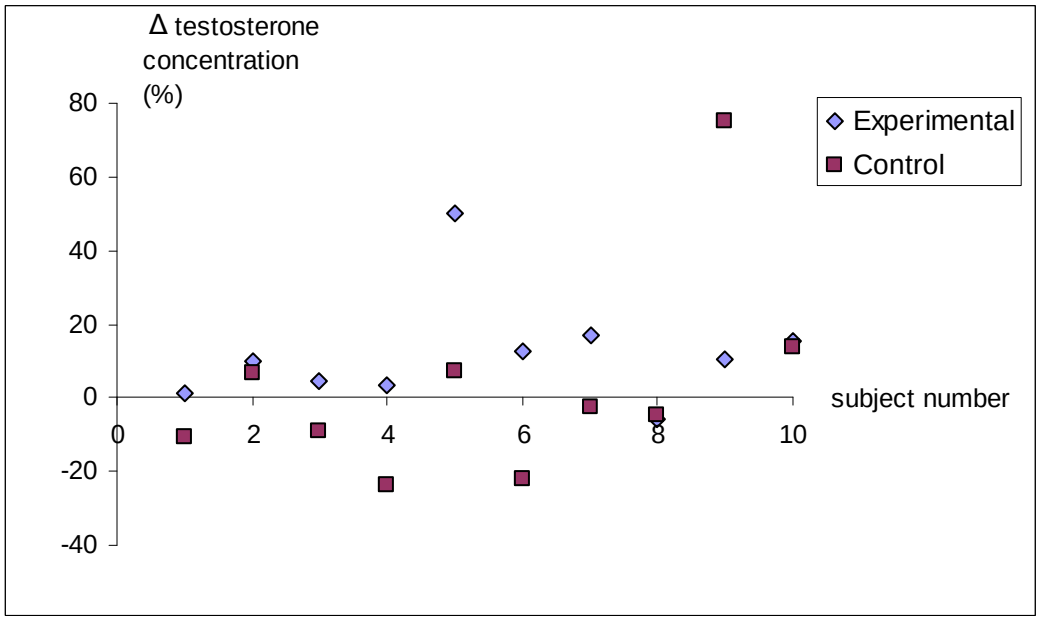

Figure 14. Individual changes (%) in serum testosterone concentration between the third and the fifth measurement days.

Day one cortisol level was significantly higher in the experimental condition than in the control condition ($p = 0.022$). No other significant changes in serum cortisol levels were found between the measurement days (Appendix 2). An individual analysis indicated that percentage changes of serum cortisol levels were much higher during the control

condition than during the experimental condition in different individuals. In the testosterone/cortisol ratio no differences were observed between the measurement days during either of the conditions (Figure 15). The relative change in the testosterone/cortisol ratio between the first and the fifth day increased significantly more ($p = 0.026$) during the experimental condition (13,1 %) than during the control condition (-4,7 %).

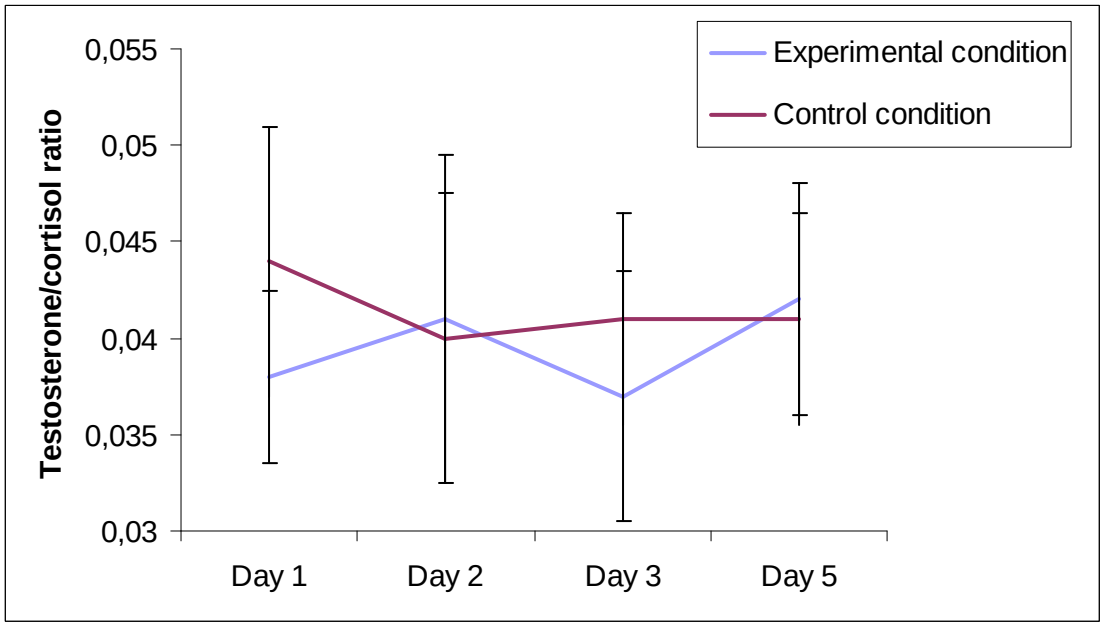

Figure 15. Serum testosterone/cortisol ratio (mean ± SD) during the experimental -and control conditions.

Level of CK was significantly higher ($p = 0.023$) in day two than in day one during the control condition, while no significant increase ($p = 0.255$) in CK during the experimental condition was observed between these days (Figure 16). A significant increase in creatinekinase concentration between the measurements days one and three during the experimental condition ($p = 0.030$) in addition to the control condition ($p = 0.007$) was observed.

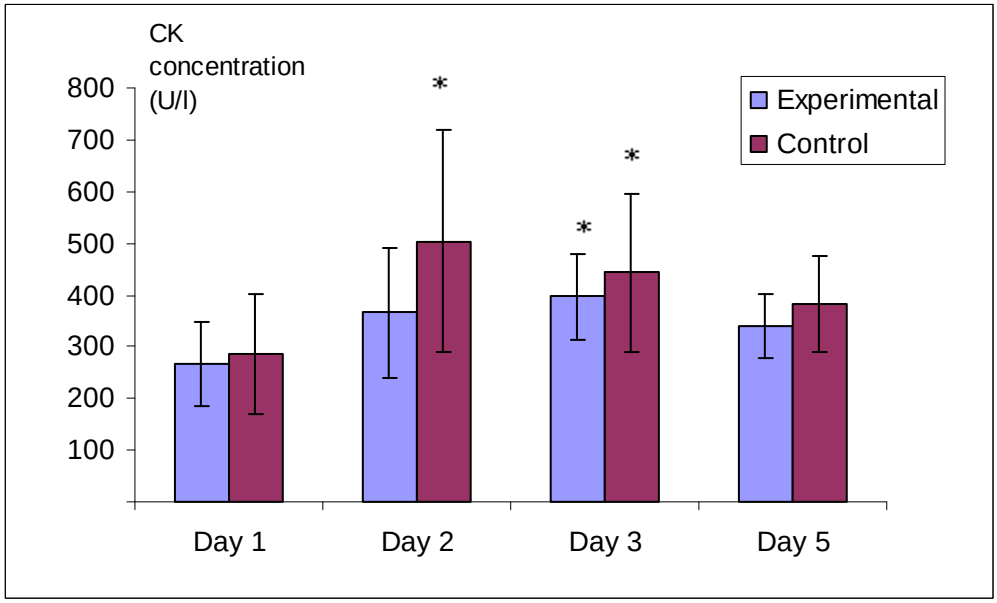

Figure 16. Creatinekinase concentration (mean ± SD) during the measurement period. A significant increase in creatinekinase level was found between days 1 - 2 during the control condition and between days 1 – 3 during both conditions.

Individual analysis of serum CK concentration showed that between days one and two percentage changes were higher in the control period than in the experimental period in eight out of ten subjects (Figure 17). This was not the case between days one and five.

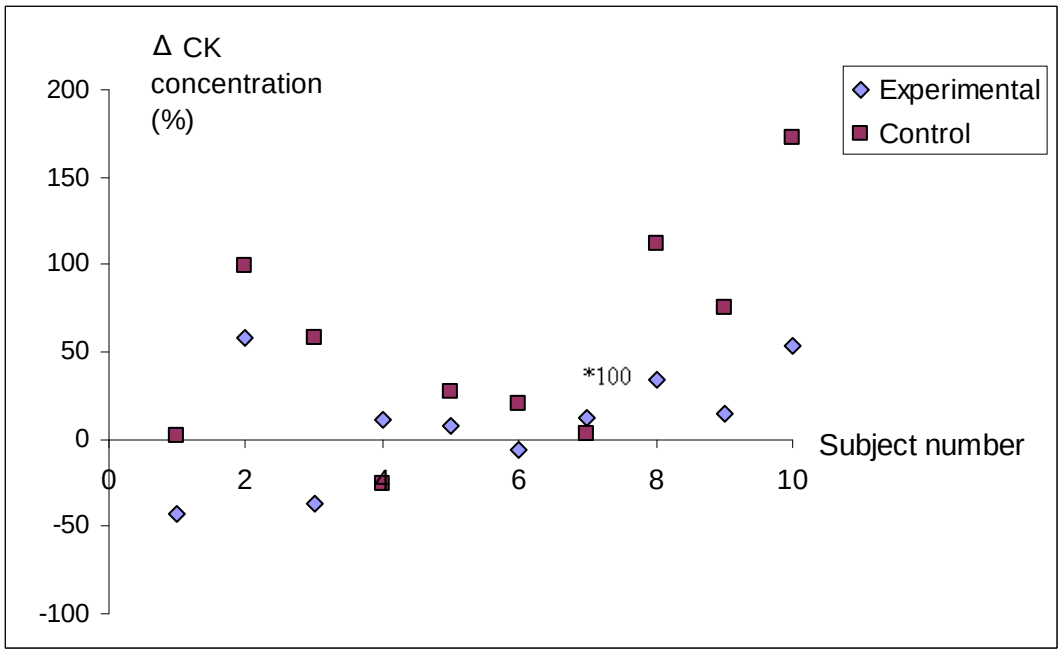

Figure 17. Individual changes (%) in creatinekinase concentration between the first and the second measurement days. Real changes of the subject seven are 100 times bigger (*100 in the figure).

No other significant changes in blood variables in either of the conditions during the training period were found (Appendix 2).

7.3 Subjective sensations

During both conditions sleep quality improved and sleep quantity increased between the first and the fifth measurement days (Appendix 3). Muscle sensations during the experimental condition were at the same level in the last measurement day when compared to the first day (mean values 3.5 at the both time points). During the control condition, mean values of the muscle sensations decreased from 3.7 to 3.1 between the pre –and post measurements, respectively (Figure 18). Training sensations improved during the experimental period from the mean value 3.1 to 3.8, while during the control period they decreased from 3.3 to 3.0. General alertness improved during both conditions, although improvement was blunter during the experimental condition.

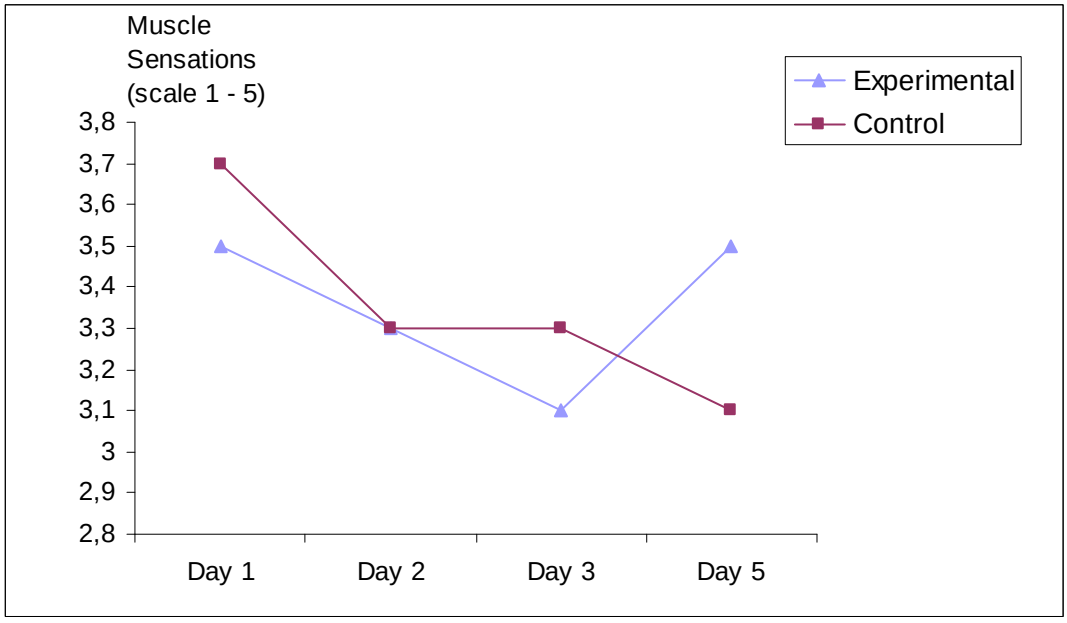

Figure 18. Mean muscle sensations during the measurement periods. Scale was 1 – 5.

8 DISCUSSION

It has been shown recently by Hausswirth et al. (2011) that FIR therapy accelerates recovery, while it is also documented that temperate water immersion does not improve performance recovery (Pournot et al. 2011). The aim of the present study was to find more concrete information about the effects of the thermal therapy and especially FIR warm on the recovery of power athletes. In order to find answers, changes in physical performance, fasting blood samples and subjective sensations during the different conditions were defined. The main findings of the present study were:

1) Anaerobic performance improved in the Wingate test significantly when FIR warm was used in recovery.
2) There were no significant changes in fasting blood variables between the two conditions.
3) The percentage change in the testosterone/cortisol ratio during the experimental period was significantly higher than during the control period.
4) Analysis of different measurement days indicated significant increase in serum testosterone concentration between days 3 – 5 and SHBG concentration between days 1 – 3 during the 5- day experimental period.
5) Muscle sensations remained at the same level between the pre and post measurements during the experimental condition, while during the control condition mean value decreased showing that muscle soreness was not so strong after use of FIR warm.

8.1 Performance

In contrast to the hypotheses of the present study anaerobic performance improved when FIR warm was used. As discussed before the significant increase was observed in average power in the Wingate 30 seconds test. In addition, average power of the first five seconds improved in this test during the experimental condition. During the control condition no significant changes were observed in the Wingate test. The individual

analysis showed that percentage change during the experimental period was positive in all subjects, but during the control period it was negative in six subjects out of ten.

Although there have been observed improved exercise tolerance after three weeks of FIR therapy in chronic heart patients (Ohori et al. 2012), it is unlikely that in well-trained athletes anaerobic capacity improved because of the FIR warm. This is the case because the load of the FIR warm is quite small and corresponds to the load of the walking at a moderate pace (Beever 2009). In addition, the five-day training period is quite short to improve anaerobic capacity.

More likely the reason can be found from other factors. Feeling in the muscles was better at the end of the experimental period than at the end of the control period. Thus, the reason can be found from the muscular level more likely than from the neural factors. In addition, there were no significant differences between the measurement periods in the countermovement jump, maximal force or in the rate of force development in the isometric test. Because neural factors are the main determinants in maximal strength performances and explosive jumps (Häkkinen 1990, 45 – 47) it could be suggested, that changes in the neuromuscular system unlikely contributed to the differences in average power of the Wingate test. However, effects of the FIR warm on the neuromuscular system can not be totally excluded because significant changes were observed in average power of the first five seconds of the Wingate test. Also individual investigation of the countermovement jump indicates that in seven cases out of ten the changes were positive during the experimental period, while during the control period they were positive only in four subjects.

It is also possible that FIR warm induced some declines on the acidosis (pH) as well as increased waste clearance during the experimental condition, what could have induced better anaerobic performance through the improved enzymatic activity. Greater acidosis is also combined with the decrease in the muscle fiber conduction velocity during the maximal bicycle tests (Schmitz et al. 2012). Thus, it is possible that decreased acidosis could have induced increases in muscle fiber conduction velocity and further anaerobic performance in the Wingate test during the experimental period when compared to the control period. Effects of the FIR warm on the acidosis need some further work.

8.2 Blood variables

The results considering the fasting serum concentrations of hormones and other blood variables support the hypotheses of the present study. The results indicated no significant differences or interaction effects in the levels of serum testosterone, cortisol, testosterone/cortisol ratio, SHBG, creatinekinase or hsCRP between the two conditions. However, almost a significant difference of hsCRP ($p = 0.097$), day to day difference of creatinekinase ($p = 0.09$) and interaction effect of cortisol ($p = 0.063$) and SHBG ($p = 0.064$) were observed between the measurement periods. Thus, effects of the day on the serum SHBG concentrations were slightly but not significantly different between the measurement periods, and between the two conditions there were slight but not significant changes in creatinekinase between the days showing some positive trends with FIR warm. According to that, it can be concluded that FIR warm had no strong effects during the five-day training period on serum fasting concentrations of blood variables, but may have some practical applications in sport training to improve recovery.

The effects of the day on serum cortisol concentrations were mainly related with different baseline levels of cortisol between the two periods. Greater increases in hsCRP at the beginning of the control period and greater decreases at the end of the control period were observed when compared to the experimental period. Although changes were not significant they probably affected to the slight changes in serum hsCRP levels between the two periods.

Testosterone and SHBG. The comparison of different measurement days during the conditions indicated significantly increased serum testosterone concentrations between days three and five during the experimental period, while no changes were observed during the control period. Also the individual analysis showed that between these days percentage changes in testosterone concentrations were positive in nine subjects out of ten during the experimental period. During the control period changes were negative in six subjects. The individual analysis, where day one and five were compared, showed that during the experimental period percentage change of the serum testosterone concentrations were positive in eight cases out of ten and during the control period it was positive only in three cases.

Theoretically increases in plasma volume could have induced decrements in serum testosterone concentration during the experimental period. However, there were no significant changes in body weight during the conditions indicating no changes in plasma volume between the pre –and post measurements during the experimental and control periods. We did not investigate the body weight in the middle of the periods, thus it could be possible that athletes tried to compensate their massive sweating during the FIR treatments by drinking more at the beginning of the experimental period. This could have induced an increase in plasma volume and further decrease in the serum testosterone levels in the middle of the experimental period. In that case a possibility to the increased testosterone levels towards the end of the measurement period would have increased. However, because the results of the other blood variables do not support this theory, it could be excluded that plasma volume would be a determinant for the changes in the concentrations of blood variables during the experimental period. In summary, other factors than a more diuretic state of the athletes must explain the changes in the concentrations of blood variables during the experimental period.

Testosterone changes were preceded by increased fasting SHBG levels between the day one and three during the experimental period. A possible reason to the increased serum testosterone and SHBG levels during the experimental period can be found from the improved anabolic state of the athletes. This is also supported by the finding that percentage change in the testosterone/cortisol ratio during the experimental period was significantly higher than during the control period ($p = 0.026$). However, baseline level of the cortisol during the control period was significantly lower than during the experimental period ($p = 0.022$), and probably affected to the changes of the testosterone/cortisol ratio. Thus, although the testosterone/cortisol ratio suggests this, it can not be kept as a totally reliable indicator of the more developed anabolic state in this case. In addition, no significant changes were observed in the testosterone/cortisol ratio between the pre and the post measurements in the either conditions.

Creatinekinase. Eccentric exercise induces typically an increase in serum creatinekinase (CK) concentrations and volume of the eccentric training determines the magnitude of the increase. CK concentration increases until the third or fourth day is reached after the hard eccentric exercise. (Nosaka et al. 2002.) In the present study CK concentrations reached its highest level already in the second day during the control period and the third

day during the experimental period. A reason to the earlier elevation can be found most likely from the type of training that did not contain a lot of eccentric training.

In the present study CK concentration increased earlier during the control condition. It could be suggested that either the use of the FIR warm delayed the increase of the CK during the training period or athletes did not follow their training diaries and training during the control period was harder and induced a greater CK response. Differences in training could also explain changes in stress state and further changes in serum testosterone and SHBG levels. However, a more precise investigation indicated no significant differences in training volumes between the conditions supporting the suggestion that FIR warm delayed creatinekinase response after the training. This finding is controversial to the finding of Hausswirth et al. (2011) who did not find significant effects of FIR therapy on the CK activity during the training period and Pournot et al. (2011) who did not find effects of thermal therapy on the reduction of CK concentration during the recovery period.

hsCRP. In the present study no significant differences were observed in hsCRP between the different measurement days during either of the conditions indicating that FIR warm does not have significant effects on the inflammation response during the 5-day training period.

8.3 Subjective sensations

Because sleep quality and quantity improved during both conditions, it could not be said that FIR warm improved sleep during the training period. More likely the reason to the improved sleep quality depended of the increased amount of exercises done during the training days, as well as increased concentration of athletes to the recovery towards the end of the training periods. Instead of that training sensations improved during the experimental period, while during the control period they were worse at the end of the training period comparing to the pre measurements. As discussed before, feelings in the muscles were at the same level in the pre –and post measurements during the experimental condition, while during the control condition values decreased. Based on

these observations of the muscle sensations and training sensations FIR warm accelerated recovery during the five day training period.

8.4 Strengths and weaknesses of the present research project

One of the biggest strength of the present research project was the use of athletes instead of sedentary active individuals. Training of athletes is as hard as possible and considering to that they also have to concentrate more on recovery. It is also possible, and in fact probable, that athletes have different responses to training as well as recovery modalities than sedentary individuals. Although this was one of the biggest strengths it induced also some challenges to the experimental design.

Athletes have periodic training programs and during the year their training volumes and intensities changes progressively. Subjects in the present study were instructed to repeat their training similar during the second measurement period as during the first measurement period based on their training diaries. However, some athletes were forced to do little changes to their training because of minor injuries. Because there were also 2 – 4 weeks between the experimental and the control periods it should not be totally excluded that the training state of the athletes could have changed between the measurement periods. However, randomization of the starting order of the athletes in the different conditions minimized the effects of the training state and minor training changes. For minimizing all training changes sedentary individuals with supervised trainings should have been used, but in that case research would have been only a simulation of the potential effects of FIR warm on recovery of the athletes.

In the present study the training period lasted five days. A longer period (two to three weeks) should have been used to induce more significant changes, for example, in blood variables. Also the greater sample size could have induced more significant changes considering the blood variables. A longer training period is also needed for defining long-term adaptations of the FIR warm. Nutrition during the measurement periods was well controlled, and although there were little changes between the measurements in some individuals considering the lunches in the University restaurants, they most likely

did not affect on the results. There were small amount of sleep disturbances in some nights during the measurement periods, but as it was investigated by Vardar et al. (2007) they most likely did not affect to the performances in a short-term. However, it is possible that sleep disturbances had small effects on the results of fasting blood values, but because they were observed in both measurement periods they probably did not induce big differences. In addition, because the starting order of the athletes in the groups was randomized it minimized the minor errors considering the nutrition and the sleep.

According to this study anaerobic performance maintained better during the training period when infrared warm was used in recovery. It can not be excluded that placebo effect would not have affected to the results of the Wingate test. It is not impossible that athletes tried more during the experimental period in that test, because they knew that far infrared warm was used in recovery. This regardless that encourage was similar in each test during the conditions.

8.5 Conclusions

According to the present study 40 minutes use of the far infrared warm in the temperature of 50 ºC every evening during a five-day training period improves recovery of the anaerobic performance in power athletes when compared to a passive recovery modality. Also subjective sensations of the muscles and subjective sensations during the training sessions indicate positive effects of FIR warm on the recovery of the athletes.

Because there were no significant effects of the FIR warm on the fasting blood variables between the two conditions more investigation is needed to define the effects of the FIR warm on these variables. However, the percentage change in the testosterone/cortisol ratio indicates improved anabolic state and accelerated recovery due to the use of the FIR warm. Also increased levels of serum testosterone and SHBG concentration between the different days indicate a probability to a more anabolic state and accelerated recovery due to the FIR warm. In contrast to the findings of Hausswirth et al. (2011), we observed that FIR warm could also delay serum creatinekinase response.

In practise, based on the results of this study FIR warm could be a beneficial tool for athletes to accelerate recovery during a strenuous training period. Accelerated recovery can enable harder training and can further accelerate athletic development. The product (far infrared bag) used in the present study provides a useful tool to accelerate recovery especially when other recovery modalities are not available. Additional research with a longer training period is needed for verifying the results of this research and defining the long-term effects of the FIR therapy on the sport performance and recovery. In future effectiveness of the long-term use of the FIR warm as a recovery tool should also be compared with other recovery modalities.

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10 APPENDIXES

APPENDIX 1. Question form used in the research.

QUESTIONNAIRES OF THE SENSATIONS

Surround option that describes your sensations best; 5 = very good, 4 = quite good, 3 = average, 2 = quite bad and 1 = very bad

Sleep quality	1	2	3	4	5
Sleep quantity	1	2	3	4	5
Muscle sensations	1	2	3	4	5
Alertness	1	2	3	4	5
Sensations after using the bag	1	2	3	4	5
Sensations in yesterday training	1	2	3	4	5

Free comments:

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APPENDIX 2. Means ± SD for averaged serum hormone concentrations, creatine kinaze and hsCRP. *Significant difference between the measurement days during the condition ($p \leq 0.05$) #Significant difference in the measurement days between the experimental and the control conditions ($p \leq 0.05$).

		Day 1		Day 2		Day 3		Day 5	
Hormones	Units	Experimental	Controls	Experimental	Controls	Experimental	Controls	Experimental	Controls
Testosterone	nmol/l	20,34 (5,50)	21,00 (5,83)	19,45 (5,39)	20,14 (6,86)	19,54 (5,55)	20,69 (4,99)	21,51 (5,24)*	20,83 (5,54)
Cortisol	nmol/l	538 (49)	477 (63) #	506 (102)	515 (68)	538 (78)	515 (74)	522 (85)	518 (92)
SHBG	nmol/l	40,85 (8,56)	47,56 (15,54)	42,66 (8,99)	45,68 (12,60)	44,01 (7,13)*	46,16 (10,31)	42,90 (6,75)	45,46 (12,40)
Creatine kinase		266 (161)	287 (232)	365 (250)	504 (426)*	397 (166)*	444 (305)*	340 (123)	384 (185)
hsCRP	mg/l	0,64 (0,97)	0,87 (1,24)	0,67 (1,15)	1,22 (1,76)	0,70 (1,28)	1,27 (1,81)	0,48 (0,91)	0,81 (1,34)

APPENDIX 3. Means for the subjective sensations during the measurement periods. Numbers after the condition names (experimental; control) indicate the measurement days during the training period.

Questionnaires	Experimental 1	Experimental 2	Experimental 3	Experimental 5	Control 1	Control 2	Control 3	Control 5
sleep quality	2,9	3,7	4	3,9	3,3	3,6	4	4,2
sleep quantity	2,8	3,6	3,7	3,3	3	3,35	3,8	3,7
muscle sensations	3,5	3,3	3,1	3,5	3,7	3,3	3,3	3,1
alertness	3,5	3,5	3,7	3,9	3,6	3,15	3,7	3,7
sensations after infraredbag		3,8	3,8	3,9				
training sensations		3,1	3,7	3,8		3,3	3,3	3