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Effects of Far Infrared Heat on Recovery in Power Athletes

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Abstract

Objective: The purpose of this study was to investigate the effects of the far infrared (FIR) heat on the recovery of the power athletes during the 5-day intensive training period.

Methods: The experimental group acted also as its own control group and it consisted of ten national level male athletes (22.3 ± 4.5 years) from power events. Training consisted of strength-, power-, and technique sessions. Performance tests included isometric strength tests, a countermovement jump (CMJ) and a Wingate 30 s test. Serum concentration of testosterone, cortisol, sex hormone binding globulin, high-sensitivity C-reactive protein and creatinekinase were analysed. During the experimental condition the participants used whole body infrared bag (40 min at temperature of 50°C) every evening on consecutive four days.

Results: CMJ height ($p \leq 0.05$) and peak power in the Wingate test ($p \leq 0.05$) were greater after the experimental condition. The increase in the testosterone/cortisol (T/C) ratio between the pre- and post-measurements was significantly greater ($p \leq 0.05$) during the experimental condition than during the control condition.

Conclusions: The present study indicates that the FIR heat improves recovery of the neuromuscular performance during the 5-day intensive training period associated with the increase in the T/C ratio. Improved recovery can enable harder training and can further accelerate athletic development. FIR heat provides a useful tool to accelerate recovery, but it does not replace other strong recovery supporting modalities like nutrition, sleep, and muscle massage.

Keywords

Far infrared heat; Recovery; Sport performance; Testosterone; T/C ratio; Wingate test; Counter movement jump

Introduction

Intensive training exposes athletes to physical and mental stress which is essential for improvement, but it can also induce overtraining and even severe injuries. This may occur, if recovery is not sufficiently integrated into the training program. To accelerate recovery and to enable more intensive training, athletes and coaches have tested different recovery modalities. Water immersions, cryotherapy, thermal therapy and active recovery modalities [1], just to mention a few have become a daily or at least a weekly part of training and rehabilitation programs. However, scientific evidence that supports their use is somehow limited, especially when considering the use of thermal therapy.

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Electromagnetic radiation can be divided into different parts according to its wavelength. Between microwaves and visible rays we can differentiate infrared rays. Further, the infrared rays can be divided into near-, middle- and far infrared rays. The function of the infrared sauna and the infrared bag is based on the warming effect of far infrared (FIR) radiation. Wavelengths of the far infrared are between 5.6 and 1000 micrometres. Vibration frequency characteristic of human body is, in turn, between 6-20 µm [2]. The mechanism by which FIR radiation exerts its effect is not known [3]. It has been suggested that similar wavelength of the FIR radiation and vibration frequency characteristics of the human body allows FIR heat to penetrate deeper (2.5 cm) under the skin to the muscles, blood vessels, lymphatic glands and nerves than warmed air (for example in traditional saunas) [2]. The load of the FIR heat is quite small and corresponds to the load of walking at a moderate pace [2].

FIR therapy has been shown to accelerate recovery of maximal strength, improve well-being and reduce pain more than passive recovery intervention [4,5]. Beneficial effects of infrared radiation have also been observed on chronic low back pain [6], on the vascular endothelial inflammation [3], heart and coronary diseases, body weight, heart rate variability and systolic blood pressure [7,8]. Three weeks use of the FIR sauna has also been observed to improve exercise tolerance and peak VO2 and ventilation efficiency slope in exercise testing in patients with chronic heart failure. In addition, significant decrements in plasma norepinephrine and brain natriuretic peptide are associated with the use of FIR therapy [9]. Despite of the beneficial effects of the FIR therapy it has been shown that whole body cryotherapy accelerates recovery of maximal strength more than FIR therapy after one treadmill running performance [4].

Serum testosterone/cortisol (T/C) ratio is considered as a simplified indicator of the anabolic and catabolic balance [10] and, thus, it could reflect a recovery state of athletes. T/C ratio has been observed to decrease until 48 hours recovery after the single official elite football match indicating increased catabolic hormonal environment [11]. In training studies during one week intensive strength training in weight-lifters basal levels of testosterone have been demonstrated to decrease indicating changes in physiological stress of short-term training [12]. This is supported by Fry et al. [13], who observed decreased basal testosterone concentrations and increased basal cortisol concentrations after one week increased training volume (overreaching) in junior weightlifters.

The purpose of this study was to examine effects of 4-day FIR heat on selected physiological variables such as serum concentration of testosterone, cortisol and sex hormone binding globulin, creatinekinase and high-sensitivity C-reactive protein, as well as physical performance of power athletes during a 5 -day training period. This design aimed to define the effects of FIR heat on recovery of power athletes from intensive training. We hypothesize that there will be positive effects on physical performance and consequently the FIR heat will be useful in sport.

Methods

Participants

The experimental group consisted of ten national level male

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athletes from track and field, gymnastics and Finnish baseball (Table 1). Track and field athletes were either jumpers, decathletes or sprinters, thus all of the athletes were from speed–strength (power) events. Before participating in the study participants signed an informed consent, which indicated all procedures and possible risks and benefits of the study. The Ethics Committee of the University of Jyväskylä provided ethical permission for the study.

Design

The experimental group acted also as its own control group (cross-over design) and the order was randomized. Thus, five participants performed the first measurement period using the infrared bag (Figure 1) and the second measurement period without using it, while the remaining five participants vice versa. There were 2-4 weeks between the measurement periods depending of the participant's training and training camp schedules. Training and nutrition during the measurement periods were controlled. Before the first measurement day, one day of complete rest from training and two days of light training prior to the measurements were instructed. Participants were instructed to avoid alcohol consumption three days before and during the period. They were instructed not to receive massage four days before and during the measurement period, and to use a regular sleeping rhythm two days before the measurements and during the actual period. Sleeping time was instructed to be between 11 pm and 7.30 am (Table 2).

Methodology

Training: Participants kept a training diary during the first measurement period. Training consisted mainly of strength-, power- 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, thereafter, the participants were supervised to train in a similar way during the second measurement period.

Nutrition: Each participant kept a precise food diary for five days during the first measurement period, one day before the measurements and the first four days during the measurement period. They were given a copy of their diary and instructed to repeat nutrition similarly during the second measurement period based on their diaries. Sport supplements were not allowed to use during this 5-day period. Food diaries were analyzed by the Nutri-Flow software (Flow-Team Oy, Oulu, Finland).

Use of the infrared bag: Participants drank 0.4 l water before using the bag and immediately after that. No food was eaten for half an hour before and after using the bag. Temperature and time of the treatment were 50ºC and 40 minutes, respectively. Participants wore only short under-wear in the bag and they lay supine so that whole body received the treatment. During the control condition the infrared bag was not used. The FIR bag (FIR65º, U2i / You Two Import Ltd., Oulu, Finland) was made of nylon, polyuretan textile and space carbon fibre. The size of the bag was 1.80 m × 0.92 m and the mass 7.4 kg. The control unit consisted of one channel with a switch to turn 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 changed it to the wavelengths of far infrared. When the bag was "on" it emitted this FIR heat and induced a warming effect to the participant.

Anthropometric measurements: Body mass and height were measured after ten hours of fasting.

Performance tests and blood lactate: Participants were instructed to perform a similar warm-up before each test session. Performance tests were done in the following order; isometric strength tests, countermovement jumps (CMJ) and a Wingate 30 s anaerobic test. Maximal isometric strength of the leg extensors and rate of isometric force developed during the first 200 ms were measured using an isometric leg dynamometer (knee angle 107º) [14]. In this test a participant was in a horizontal sitting position and he was instructed to produce maximal force as fast as possible during 2.5-4.0 seconds. Participants performed a minimum of three trials and the best performance regarding the maximal peak force was analysed. If the third trial was the best one, they performed 1 to 2 more efforts so that the true maximum was achieved. Rate of isometric strength during the first 200 ms was analysed from each trial that was within 95% of the true isometric maximum during the testing session and the best performance was used in the statistical analyses. Jumping height was calculated from the impulse of the CMJ on a force platform. Analog data was changed to digital by an AD- transducer (CED, Power 1401, Cambridge, England) and recorded on a computer. Signal version 4.04 (CED, Power 1401, Cambridge, England) was used in both CMJ and isometric tests for analysing the results. The sampling rate in all tests was 1000 Hz.

Anaerobic performance was investigated with the Wingate 30 s test using a Monark cycle ergometer (Sweden). Participants performed one maximal 30 s cycling performance, which started with 4 seconds of acceleration to the maximal speed without any load. After participants attained the maximal speed a load equal of 1/13 of their body mass was added and they continued to cycle maximally 30 s with that load. Mean power (MP) was calculated from the whole 30 s test and peak power (PP) was defined as the highest average power output during any 5 s interval during the test. A similar procedure has been widely used in many studies [15,16]. The lowest average power output (LP) in any 5 s interval during the latter part of the test was used for determining the fatigue index (FI). FI was calculated using the formula (PP-LP) / PP×100 and it indicated the rate of power decrease during the test. Blood samples (20 µl) from the finger were taken before and immediately after the Wingate test performance and during the recovery at time points 5, 10 and 30 min for examining peak blood lactate and its clearance rate. Samples were analysed with Biosen C line EKF Diagnostic device (Magdeburg, Germany; coefficient of variation <1.5 %). Lactate clearance rate was determined by calculating the difference in lactate concentration between immediately after and 30 minutes after the Wingate test and dividing this difference by the recovery time.

Fasting blood samples. Fasting blood samples (5 ml) were taken from the antecubital vein. The samples were taken in a sitting position at 0800-0900 AM after 10 hours of fasting and they were taken from each individual exactly at the same time during both measurement

Table 1: Description (mean and SD) of the participants (age, height and body mass) involved in the study. Training hours have been summed during days 1-4. Energy intake is the average of five days.

	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 (6.6)	75.9 (9.6)	75.7 (9.6)	2814 (623)	8.00 (4.1)
Control condition	22.3 (4.5)	178.5 (6.6)	75.4 (9.4)	75.4 (9.5)	2814 (623)	8.05 (3.9)

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Figure 1: The infrared bag. The power source and the control unit are next to the infrared bag.

periods. Samples were stored in the fridge before analysing. They were analysed by an immunometric chemiluminescence method with Immulite® 1000 (Siemens, Llanberis, UK). Creatinekinase (CK) was assessed by the spectrophotometric method with Konelab 20 XTi (Thermo Fisher Scientific, Vantaa, Finland). Statistical analyses. Statistical analyses were performed with PAWS Statistics version 20.0 for Windows (SPSS, Inc, Chicago, IL). Differences between conditions were determined through Analysis of Variance (ANOVA). Paired samples t-test was used for pairwise comparisons when appropriate. Data are presented as means ± SDs. The statistical difference was considered to be significant at the $p \leq 0.05$ level.

Results

Training and nutrition

There were no significant differences in training or nutrition between the experimental and control conditions.

Maximal and explosive strength

A significant (p=0.034) interaction effect between the experimental and control condition was found in CMJ (Table 3). No significant changes in maximal or explosive strength were observed between the pre- and post- measurements during either of the conditions.

Wingate test for speed endurance

There was a significant difference in PP in the Wingate test (p=0.032) between the conditions. PP increased significantly during the experimental condition between the pre-and post- measurements (p=0.002), while during the control condition there was no significant change between the pre- and post- measurements (p=0.586) (Figure 2). The trend difference was observed in MP in the Wingate 30 s test (p=0.087) between the conditions. The increase in MP was significant during the experimental condition between the pre -and post -measurements (p=0.015), while during the control condition no significant change between the pre- and post- measurements was observed (p=0.671).

Blood variables

No significant differences were found in the concentrations for serum testosterone, cortisol, T/C ratio, SHBG, CK or hsCRP between the measurement periods. Whereas trends for a difference for CK (p=0.090), cortisol (p=0.063) and SHBG (p=0.064) were found. The change in the T/C ratio between the first and the fifth day was significantly greater (p=0.030) during the experimental condition than during the control condition (Table 4).

Discussion

The main findings of the present study were that significant positive effects on both CMJ and on PP in the Wingate test were observed with the FIR heat condition. In addition, the increase in the T/C ratio during the experimental condition was significantly higher than during the control condition.

FIR heat

Function of the infrared sauna and the infrared bag is based on the warming effect of FIR radiation. It has been suggested that similar wavelength of FIR radiation compared to the human body can be one possible factor that enables FIR heat to penetrate deep under the skin to the muscles, blood vessels, lymphatic glands and nerves [2]. It is possible that FIR heat have some effects on the function of fast twitch muscle fibres, especially because these fibres are observed to locate in a greater amount in the superficial layers of the muscle than in the deep layers [17]. Via that mechanism it is possible that FIR heat improves explosive performances as indicated in part by the present results. As far as we know there are no previously published studies that have investigated effects of the FIR heat on the recovery of athletes. In the present study FIR heat was used 40 min in the temperature of 50ºC every evening on four consecutive days during the experimental condition. In all, FIR heat was used 2 h 40 min during four days. During the control condition FIR heat was not used. According to participants the first treatment session was the hardest one, but

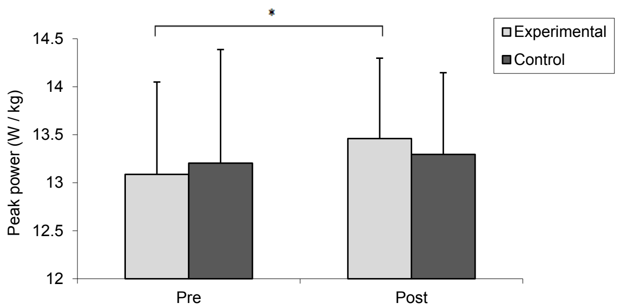

Figure 2: Peak power in the Wingate 30 s test (mean ± SD) in the experimental and control conditions. *=Significant difference between the pre- and post- measurements (p=0.002).

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after that single treatments became more relaxing. Sweating during the treatments was heavy and it started usually quite suddenly after twenty minutes use of the infrared bag. Despite of heavy sweating the participants felt their muscles more relaxed after the treatments.

Performance

A significant interaction effect in the CMJ performance during the conditions and a significant difference in the PP in the Wingate test indicate positive effects of the FIR heat on recovery. Improved voluntary muscle activation is accompanied with improvements in explosive force production and speed performances [18,19]. Thus, it could be suggested that changes in the neuromuscular system could have contributed to changes in CMJ height and the PP in the Wingate test. Almost a significant difference in maximal isometric strength between the conditions supports the finding of possible positive effect of the FIR therapy on the neuromuscular system.

There was almost a significant difference in MP in the Wingate 30 s test supporting slightly positive effects of the FIR therapy on the anaerobic performance. Mainly this was due to the significant improvement in MP between pre- and post- measurements during the experimental condition, because during the control condition no significant changes were observed. The analysis of individual values showed that percentage change during the experimental condition was positive in all participants, but during the control condition the change was negative in six participants out of ten. This supports in part the positive effects of FIR therapy on the anaerobic performance.

Although improved exercise tolerance after three weeks of FIR therapy has been observed in chronic heart patients [9], it is unlikely that in well-trained athletes anaerobic capacity (30 s or more) improves due to the FIR heat treatment. This is the case because the load of the FIR heat is quite small and corresponds to the load of walking at a moderate pace [2]. The five-day training period is also quite short to improve anaerobic capacity, especially in well trained power athletes.

Because no significant changes were observed in peak lactate concentrations or in lactate clearance rates after the Wingate test, FIR heat probably did not accelerate energy production via the anaerobic glycolysis. Thus, the small differences in anaerobic glycolysis probably were not reflected in changes in MP in the Wingate test. However, the role of immediate energy sources is also remarkable during the 30 s anaerobic performance [20]. Therefore, it is possible that FIR heat accelerated the use of immediate energy sources (adenosine triphosphate and phosphocreatine) which could have improved the performance in the Wingate test. Effects of FIR heat on immediate energy sources requires further research.

Most likely a trend for a slight improvement in MP of the Wingate test performance during the experimental condition is a result of improved neuromuscular performance as observed by the improved CMJ height. This confirms previous studies that have indicated positive correlations between a short explosive strength performance and anaerobic lactic performance [15,21].

Serum hormone concentrations and proteins

Serum T/C ratio has been used as a simplified practical measure to indicate recovery and readiness for training. The increase in the T/C ratio between the pre- and post- measurements was significantly greater during the experimental condition than during the control condition. Although not significantly, testosterone concentration increased slightly and cortisol concentration decreased slightly during the experimental condition while contrary changes were observed during the control condition. These small changes could induce the greater increase in the T/C ratio during the experimental condition than during the control condition.

The increase in T/C ratio indicates improved anabolic-androgenic activity [10]. Thus, these results indicate a better recovery state when FIR heat was used in recovery. Accordingly, it seems that even short use of FIR heat may have some positive effects on the anabolic-catabolic balance. This finding is a bit surprising, because it occurred during a short training period. In previous training studies significant changes in T/C ratios have been observed after relatively long training periods (e.g. 20 weeks) [10,22], and no changes after 1-week training period with increased training volume [13]. Maresh et al. observed that there were no changes in the T/C ratio or in blood testosterone concentration after a 5 % loss in body mass due to dehydration [23]. Thus, relatively small changes in body weight (0.2 %) in the present study are unlikely to affect the T/C ratio or concentrations of the other blood variables. Thus, we can assume that the T/C ratio indicates a more developed anabolic-catabolic balance when using FIR heat during every day during the present short intensive training period.

In addition to testosterone and cortisol, the results of the fasting serum concentrations of other variables indicated no significant differences in SHBG, creatinekinase or hsCRP between the two conditions. The present finding in testosterone is different compared to the finding of Häkkinen et al. [12] who observed a decrease in serum testosterone concentration during a one-week training period. The decrease in serum testosterone concentration observed by Häkkinen et al. [12] may be due the fact that the weightlifters trained twice a day with high intensity during the one-week training period, thus, much more than participants in the present study. Although almost a trend in difference in CK, cortisol and SHBG were observed between the two conditions, any strong effects cannot be observed in these variables with the FIR heat. Accordingly, it can be assumed that the FIR heat had no effects during the 5-day training period on the above mentioned variables.

Practical applications

In practise, based on the results of present study FIR heat could be beneficial for athletes to accelerate recovery during strenuous training periods. The far infrared bag provides a useful tool among

Table 2: The experimental design. Both the experimental- and the control condition lasted five days. During the experimental condition, a whole body infrared bag was used every evening between day 1 and day 4. Body weight, height and performance tests were measured on the first and the fifth day. Food diaries were kept for five days during the first measurement period, one day before the measurements and for the first four days during the measurement period. During the measurement period fasting blood samples were taken every morning (except the fourth).

	Day 1	Day 2	Day 3	Day 4	Day 5
08-09 AM	Weight, height, blood samples	Blood samples	Blood samples		Weight, height, blood samples
02–04 PM	Performance tests: CMJ, isometric leg press, Wingate 30s. food diary	Training, food diary	Training, food diary	Training, food diary	Performance tests: CMJ, isometric leg press, Wingate 30s
07-09 PM	Infrared bag (40 min/50ºC)	Infrared bag (40 min/50ºC)	Infrared bag (40 min/50ºC)	Infrared bag (40 in/50ºC)	

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Table 3: Physical performance (mean ± SD) in CMJ, isometric strength tests and Wingate test during the experimental and control conditions. *=Significant difference between the conditions (p ≤ 0.05); **=Significant interaction effect between the conditions (p ≤ 0.05); ***=Significant difference between the pre- and post-measurements (p ≤ 0.05).

Physical performance	Unit	Experimental pre	Experimental post	Control pre	Control post
CMJ **	cm	45.1 (6.4)	45.9 (6.0)	45.9 (6.5)	45.1 (5.9)
Maximum isometric force	N	4823 (1153)	4746 (1239)	5110 (1178)	4963 (1255)
0-200 ms force	N/s	3267 (733)	3216 (743)	3443 (638)	3325 (776)
Wingate mean power (MP)	W/kg	9.63 (0.64)	9.77 (075)	9.70 (0.68)	9.67 (0.58)
Wingate peak power (PP) *	W/kg	13.09 (0.96)	13.46 (0.84) ***	13.20 (1.18)	13.29 (0.85)
Wingate fatigue index (FI) Peak lactate in Wingate	% mmol/l	47.2 (8.8) 14.39 (2.40)	47.8 (7.0) 14.86 (2.00)	46.7 (5.7) 13.71 (1.77)	47.7 (5.4) 13.21 (1.98)
Lactate clearance rate	mmol/l/s	0.29 (0.82)	0.31 (0.06)	0.30 (0.08)	0.29 (0.09)

Table 4: Fasting values (mean ± SD) for serum testosterone, cortisol, testosterone/cortisol (T/C) ratio, Δ T/C ratio, sex hormone binding globulin (SHBG), creatinekinase (CK) and high-sensitivity C-reactive protein (hsCRP). *=Significant difference (p=0.030) between the conditions in Δ T/C ratio between the first and the fifth day.

		Day 1		Day 2		Day 3		Day 5	
Hormones	Unit	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Testosterone	nmol/l	20.3 (5.5)	21.0 (5.8)	19.5 (5.4)	20.1 (6.9)	19.5 (5.6)	20.7 (5.0)	21.5 (5.2)	20.8 (5.5)
Cortisol	nmol/l	538 (49)	477 (63)	506 (102)	515 (68)	538 (78)	515 (74)	522 (85)	518 (92)
T/C ratio		0.038 (0.009)	0.044 (0.014)	0.041 (0.017)	0.040 (0.015)	0.041 (0.013)	0.040 (0.011)	0.042 (0.012)	0.041 (0.011)
Δ T/C ratio *								0.004 (0.01)	-0.004 (0.013)
SHBG	nmol/l	40.9 (8.6)	47.6 (15.5)	42.7 (9.0)	45.7 (12.6)	44.0 (7.1)	46.1 (10.3)	42.9 (6.8)	45.5 (12.4)
CK	U/l	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)

other recovery methods. The accelerated recovery can enable harder training and can further accelerate athletic development.

One limitation of the present research was sample size. The greater sample size might have induced more significant changes considering especially blood variables. Secondly, there was no placebo treatment during the control condition and expectations could have affected in some level to the performance tests. Additional research with a longer training period is also needed for verifying these results and defining long-term effects of the FIR therapy on sport performance and recovery. In future, effectiveness of the long-term use of the FIR heat as a recovery tool should also be compared with other recovery modalities.

Conclusions

The use of FIR heat for 40 min at a temperature of 50 °C every evening during a 5-day intensive training period improves recovery of the neuromuscular performance in power athletes when compared to a passive recovery modality. The increase observed in the serum T/C ratio supports possible positive effects of FIR heat on recovery.

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