VERSITA

ORIGINAL PAPERS

International Journal of Occupational Medicine and Environmental Health 2011;24(2):184–191
DOI 10.2478/s13382-011-0017-z

THE INFLUENCE OF SINGLE WHOLE BODY CRYOSTIMULATION TREATMENT ON THE DYNAMICS AND THE LEVEL OF MAXIMAL ANAEROBIC POWER

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Abstract
Objectives: The objective of this work was to determine the dynamics of maximal anaerobic power (MAP) of the lower limbs, following a single whole body cryostimulation treatment (WBC), in relation to the temperature of thigh muscles. **Materials and Methods:** The subjects included 15 men and 15 women with an average age (±SD) of 21.6±1.2 years. To evaluate the level of anaerobic power, the Wingate test was applied. The subjects were submitted to 6 WBC treatments at –130°C once a day. After each session they performed a single Wingate test in the 15, 30, 45, 60, 75 and 90th min after leaving the cryogenic chamber. The order of the test was randomized. All Wingate tests were preceded by an evaluation of thigh surface temperature with the use of a thermovisual camera. **Results:** The average thigh surface temperature (T_{av}) in both men and women dropped significantly after the whole body cryostimulation treatment, and next increased gradually. In women T_{av} remained decreased for 75 min, whereas in men it did not return to the basal level until 90th min. A statistically insignificant decrease in MAP was observed in women after WBC. On the contrary, a non-significant increase in MAP was observed in men. The course of changes in MAP following the treatment was similar in both sexes to the changes in thigh surface temperature, with the exception of the period between 15th and 30th min. The shorter time to obtain MAP was observed in women till 90th min and in men till 45 min after WBC compared to the initial level. **Conclusions:** A single whole body cryostimulation may have a minor influence on short-term physical performance of supramaximal intensity, but it leads to improvement of velocity during the start as evidenced by shorter time required to obtain MAP.

Key words:
Cryostimulation, Cryogenic temperature, Hypothermia, Maximal anaerobic power, Anaerobic capacity

This paper was supported by the Ministry of Science and Higher Education, Grant No: NN404 027235.
Received: July 31, 2010. Accepted: March 9, 2011.
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INTRODUCTION

Whole body cryotherapy in comparison to local cooling has a relatively short history. The first cryogenic chamber was constructed in Japan in 1978 [1], while the first ones in Europe were introduced in Germany in 1982 and in Poland in 1989. At first, cryogenic chambers were used only for therapeutic purposes, mainly to treat patients with rheumatic disorders.

A review of literature confirms a positive effect of cryogenic treatments on a wide variety of illnesses and after injuries. A positive effect of cryotherapy on metabolic and regenerative processes in bone tissue, joint cartilage, ligaments, as well as in the skin has been observed [2,3]. Anti-inflammatory [4] and pain relieving [5] effects of low temperatures are also often indicated. Other research supports significant benefits of cryogenic treatments in curing of the peripheral nervous system and the muscular system [6–9], as well as the central nervous system [10–12]. A positive effect of low temperatures on the mental state has also been observed [13,14]. Benefits of cryotherapy were also registered in the treatment of the respiratory system [15]. There is a lot of research supporting positive effects of cryogenic treatments on the immune [16,17] and endocrine systems [18,19], which significantly improve the regulatory processes of the body.

As an effect of application of extremely low temperatures, a series of physiological mechanisms are triggered. This influences most of the systems in the human organism. Benefits of cryotherapy are observed not only in patients with different diseases, but also in athletes in the treatment of sports injuries and during recovery from high training loads and competition [20–24]. The applications of low temperatures accelerate recovery after surgery and diminish the reoccurrence of tissue disruption [25]. Of great significance to athletes subdued to great physical stress is the alleviation of pain and decreased post injury inflammation [20,24–26].

The available data on the effects of low temperatures on physical performance usually relates to the rate of post injury recovery [22,24] following local cooling treatments with liquid nitrogen, CO_2, ice packs or cold water immersion. The influence of whole body cryostimulation on physical work capacity has not been extensively addressed.

The application of low temperatures on the muscular system causes a gradual decrease in the temperature of the skeletal muscles and a concomitant decrease in blood flow though the capillaries. After a treatment in which the muscles have been exposed to cryogenic temperatures, a secondary dilation of capillaries occurs. This dilation significantly increases flow of blood, oxygen and nutrients into the body and speeds up removal of metabolic waste products.

Fifteen to 20 min after the cryogenic treatment, due to enhanced blood flow through the muscles, an increase in muscular temperature occurs which may exceed the one from before the treatment and remain at that level for several hours [5]. Such physiological reaction should bring improvements in physical work performance, since muscular work is significantly dependent on body temperature and blood flow. Changes in muscle temperature of the lower limbs will influence the level of maximal anaerobic power. Therefore, the main objective of this work was to determine the dynamics of maximal anaerobic power (MAP) of the lower limbs following a single whole body cryostimulation treatment depending on the surface temperature of the thighs.

MATERIALS AND METHODS

Thirty volunteers, both female (n = 15) and male (n = 15) with an average age (±SD) of 21.6±1.2 years participated in the study.

The research project was approved by the Ethics Committee for Scientific Research at the Local Medical Institute in Kraków. All persons gave their written informed consent prior to their inclusion into the study.

Before the beginning of the experiment, basic anthropometric data was collected, which included: body height and mass (BH, BM), body mass index (BMI), fat content (%F), fat mass (FM) and fat free mass (FFM). The anthropometric variables considered in this work are presented in Table 1.

Table 1. Female and male subjects characteristics

Characteristics	Female		Male	
	x	SD	x	SD
Age (years)	21.70	0.88	21.20	0.86
BH (cm)	165.90	7.19	182.30	7.64
BM (kg)	57.70	6.09	74.80	5.84
BMI (kg×m^{-2})	21.00	1.70	22.50	1.55
F (%)	20.80	4.69	11.70	2.29
FM (kg)	12.20	3.81	8.70	1.84
FFM (kg)	45.50	2.97	66.00	5.43

SD — standard deviation; BH — body height; BM — body mass; BMI — body mass index; F — fat content; FM — fat mass; FFM — fat free mass.

At the beginning of the experiment all of the tested subjects were put through a medical examination to confirm their health status and the ability to perform exhaustive exercise and participate in cryostimulation. Following this, two exercise tests were carried out to determine aerobic and anaerobic capacity of all subjects.

To evaluate the level of anaerobic power and capacity, a 20 s Wingate [27] test was conducted at the beginning of the experiment. The test was preceded by a 2 min warm-up with a load of 1 W×kg^{-1}, and several 5 s accelerations. The main test was conducted over 20 s with the load set at 7.5% body mass for men and 6.5% for women. The following variables of anaerobic power and capacity registered in the Wingate test were considered in the work: maximal anaerobic power of lower limbs (MAP), average power (AP), time to obtain (t_{obt}) and sustain MAP (t_{sus}), fatigue index (FI), and total external work (W_{tot}).

After the exercise tests had been conducted, all subjects participating in the experiment were subjected to whole body cryostimulation treatments, once a day, according to the generally accepted protocol for these treatments in a cryogenic chamber. Before entering the cryogenic chamber the participants dried their bodies thoroughly to eliminate the sensation of cold. They all breathed through a surgical mask. For protective purposes, all subjects wore gloves, socks, special footwear and head bands to protect the ears. The males wore shorts, while females wore bathing suits.

To achieve the initial adaptation to low temperatures, the subjects entered the vestibule (temperature –60°C) for 30 sec, and then later were exposed for three minutes to –130°C in the main chamber. After leaving the chamber they entered room temperature. The treatments were carried out between 3:00–3:30 p.m. with the generally accepted rules of cryotherapy.

After each cryogenic treatment the participants performed a single Wingate test according to the earlier specified procedures. Each subject performed the Wingate test 6 times randomly in the 15, 30, 45, 60, 75 and 90th min after leaving the chamber without any warming-up to avoid changes in muscle temperature.

Each exercise test was preceded by an evaluation of thigh surface temperature with the use of a thermovisual camera. To determine the front and back temperature of the thigh, a thermovisual camera "ThermaCam 1500" was used. To evaluate body mass and body composition, an electric impedance apparatus was applied: "Tanita" — Body Composition Analyzer, model TBF-300 (Japan). The Wingate tests were performed on a "Monark 818E" (Sweden) ergocycle which registered the number of revolutions with the precision of 0.001 s. The whole body cryostimulation treatments were performed in a modern, computerized cryogenic chamber at the Center of Cryotherapy in Kraków.

Statistics

The resultant data were analyzed statistically. The results were presented as arithmetic means (x) and standard deviations (SD). Data were checked for normal distribution using the Shapiro-Wilk test. ANOVA with repeated measurements was used to compare data over time. When a significant F-value was found, a Dunkan post-hoc test was performed. In order to demonstrate whether the observed correlations were statistically significant, Spearman's rank correlation coefficient was applied. The accepted level of significance was defined as $p < 0.05$.

RESULTS

The changes in indices of maximal anaerobic power and temperature of the thigh surface area before and after the whole body cryostimulation treatment are presented in table 2 for females and 3 for men as well as in Figure 1.

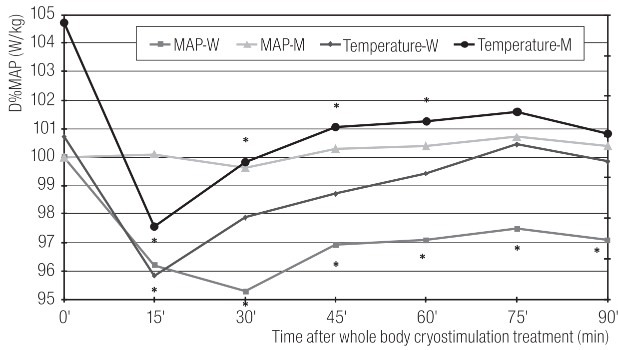

Fig. 1. The changes in maximal anaerobic power of the lower limbs and average thigh temperature.

The most pronounced and statistically significant changes were observed in the thigh surface temperature and in the time to obtain MAP.

The temperature of the thigh surface decreased after whole body cryostimulation. The lowest T_{av} was noted 15 min after WBC in both groups and remained below the initial values for 90 min; however, the rise of T_{av} was observed

Table 2. Indices of maximal anaerobic power of the lower limbs and thigh temperature in the 15, 30, 45, 75 and 90th min after whole body cryostimulation treatment in females

Time		Rev (nr)	Rythm ($1 \times min^{-1}$)	W_{tot} (kJ)	MAP (W)	MAP ($W \times kg^{-1}$)	AP (W)	AP ($W \times kg^{-1}$)	FI ($W \times kg^{-1} \times s^{-1}$)	t_{obt} (s)	t_{sus} (s)	T front (°C)	T back (°C)	T average (°C)
Before WBC	x	37.50	136.30	8.30	500.60	8.70	436.10	7.60	0.16	7.89	3.75	30.00	30.10	30.00
	SD	2.50	8.14	0.91	56.98	0.51	47.28	0.46	0.04	1.24	1.07	0.83	0.99	0.83
15'	x	35.90	131.00	7.95	480.45	8.35	418.74	7.24	0.16	6.94*	3.44	26.36*	26.76*	26.58*
	SD	2.53	9.31	0.99	59.79	0.59	53.01	0.48	0.04	0.87	0.50	1.29	1.39	1.19
30'	x	35.80	129.70	7.91	478.31	8.27	416.23	7.20	0.16	6.92*	3.56	27.93*	28.07*	28.01*
	SD	2.58	11.07	0.96	64.62	0.71	52.83	0.54	0.05	0.52	0.90	0.95	1.13	0.97
45'	x	36.10	131.90	7.99	482.24	8.41	418.69	7.25	0.17	6.94*	3.29	28.77*	28.39*	28.61*
	SD	2.50	10.21	1.08	59.46	0.65	54.96	0.51	0.03	0.97	0.46	0.74	1.07	0.82
60'	x	36.30	132.30	8.01	483.34	8.43	421.96	7.31	0.16	6.93*	3.56	29.19*	28.94*	29.09*
	SD	2.89	10.50	1.06	58.94	0.67	52.38	0.50	0.04	1.10	0.92	0.80	0.75	0.75
75'	x	36.80	132.40	8.02	487.77	8.46	423.76	7.34	0.15	7.06*	3.44	29.80	29.76	29.81
	SD	2.13	7.02	0.96	51.47	0.46	46.73	0.36	0.03	1.03	0.49	0.79	0.74	0.70
90'	x	36.60	132.20	8.01	481.48	8.43	421.30	7.33	0.16	7.05*	3.71	29.40	29.33	29.39*
	SD	2.73	11.54	1.05	62.83	0.74	54.56	0.58	0.03	0.92	0.96	0.68	0.73	0.66

W_{tot} — total external work; MAP — maximal anaerobic power of lower limbs; AP — average power; t_{obt} — time to obtain; t_{sus} — sustain MAP; FI — fatigue index.

* $p < 0.05$ after WBC vs. initial level.

Statistically significant differences $p < 0.05$ in comparison to the subsequent evaluation.

Table 3. Indices of maximal anaerobic power of the lower limbs and thigh temperature in the 15, 30, 45, 75 and 90th minute after whole body cryostimulation treatment in males

Time		Rev (nr)	Rythm ($1 \times min^{-1}$)	Wtot (kJ)	MAP (W)	MAP ($W \times kg^{-1}$)	AP (W)	AP ($W \times kg^{-1}$)	FI ($W \times kg^{-1} \times s^{-1}$)	t_{obt} (s)	t_{sus} (s)	T front (°C)	T back (°C)	T average (°C)
Before WBC	x	41.70	151.10	13.80	830.30	11.10	723.90	9.70	0.21	6.67	3.76	32.6	33.00	32.80
	SD	2.02	9.74	1.13	71.45	0.72	58.59	0.49	0.06	1.06	0.97	0.73	0.76	0.67
15’	x	41.4	151.30	13.64	831.46	11.13	714.73	9.57	0.22	5.81*	3.50	2 7.19*	28.32*	27.79*
	SD	1.55	6.26	0.95	56.50	0.46	50.06	0.32	0.03	0.91	0.55	1.40	1.09	0.82
30’	x	41.10	150.40	13.63	830.90	11.07	713.70	9.51	0.21	5.70*	3.51	29.20*	29.48*	29.37*
	SD	2.03	8.88	1.13	79.83	0.65	60.92	0.47	0.04	0.81	0.78	0.89	0.90	0.81
45’	x	41.10	150.20	13.62	831.77	11.15	716.05	9.55	0.21	5.75*	3.63	29.69*	30.71*	30.23*
	SD	1.46	6.79	0.96	67.71	0.52	51.12	0.37	0.04	0.68	0.63	0.87	0.55	0.64
60’	x	41.60	151.80	13.74	836.27	11.17	723.09	9.66	0.22	6.14	3.78	30.05*	30.65*	30.38*
	SD	1.71	7.77	1.02	72.55	0.57	55.68	0.43	0.05	0.94	0.79	1.05	1.22	0.98
75’	x	41.80	152.30	13.65	837.75	11.20	717.59	9.60	0.22	6.07	3.41	30.43*	30.77*	30.62*
	SD	2.29	7.28	1.17	77.53	0.54	60.71	0.47	0.03	0.84	0.64	0.92	1.02	0.82
90’	x	41.10	151.90	13.56	834.72	11.17	716.76	9.59	0.23	6.14	3.39	29.93*	30.17*	30.07*
	SD	1.64	7.94	1.05	70.23	0.58	55.14	0.39	0.04	0.51	0.48	0.45	1.13	0.62

Abbreviations as in Table 2.

for 75 min after the treatment. Statistically significant decrease of T_{av} continued for 60 min in women and for 90 min in men.

The decrease in MAP from 500.6 W to 478.3 W 30 min after WBC in females was also observed. The value of MAP remained decreased for 90 min. On the contrary, a small rise in MAP from 830.3 W was noted in men just after WBC with a slow increase till the highest values in 75th min. However, the observed changes were not statistically significant in both groups. The course of changes in MAP following the treatment was similar in both sexes to the changes in thigh surface temperature, with the exception of the period between the 15th and 30th min. However, no correlation was noted between changes in MAP and thigh temperature.

The other interesting effects observed in this study include changes in the time to obtain MAP. In both sexes, t_{obt} was shortened after WBC ($p < 0.05$). In females, t_{obt} was significantly shorter up to 90th min, whereas in men up to 45th min. The changes of other indices of anaerobic power were minor and statistically not significant.

Discussion

Cooling the whole body for 3 min in a cryogenic chamber at –130°C is a very strong stimulus, during which adaptive changes occur in two phases. A short-lived constriction of blood vessels in the skin is followed by a dilation, which causes a significant increase in blood flow. During the whole body cryostimulation treatment, skin blood flow decreases due to blood vessel constriction that may last for about a minute since the end of the treatment. A secondary dilation of blood vessels occurs a few minutes after the cryogenic treatment and it may last for up to two hours. We suppose that such reactions have a significant effect on blood flow and body temperature, which may influence the level of generated power.

No data regarding the influence of whole body cryostimulation on physical work capacity could be located in the accessible literature. Most scientists have addressed the effects of local cryotherapy treatments, where particular parts of the body were cooled, on the level of chosen motor abilities or physical work capacity, under different temperatures [18,28–33]. Other authors evaluated the influence of local cooling on the rate of recovery following injuries [20,22,24].

Whole body cryostimulation has a significantly greater effect on the entire organism, affecting almost all of its systems. Considering that physical effort in most sport disciplines is general in nature, treatment which is directed at all muscle groups as well as other organs considerably engaged during exercise, it seems reasonable to assume that whole body cryostimulation significantly influences physical work capacity; however, no clear evidence exists.

No data in the accessible exercise physiology literature about the influence of whole body cryostimulation on physical work capacity inspired the authors of this paper to study this problem in some detail. Thus, the results of local cooling treatments and their influence on physical work capacity and particular motor abilities have been used as the basis for the discussion.

The level of velocity during the start can be evaluated by the time to obtain MAP during the Wingate test. In the conducted research, significant reduction was observed in this variable after the cooling treatment in both sexes, thus it was concluded that single whole body cryostimulation treatment could influence speed endurance significantly in short physical efforts of supramaximal intensity.

Crowley et al. [29] showed a decrease in maximal anaerobic power, average power, and total external work during a Wingate test after local cooling of the lower limbs. At the same time, he observed a smaller drop in the level of the fatigue index. The decrease in MAP was a result of a lowered muscle temperature, which hinders the ability of fast twitch muscles to contract forcefully during short intensive efforts. Klimek et al. [34] showed that series of ten whole body treatments in a cryogenic chamber caused a significant increase in anaerobic power and capacity in men. It seems that, in sport disciplines with a predominance of anaerobic metabolism, it is probably advisable to incorporate whole body cryostimulation treatment in the training process, at least in men.

Other research showed a positive influence of different cooling procedures, applied 20 min before the onset of sprint effort performed on an ergocycle, on the level of maximal anaerobic power [18]. Cooling the whole body prior to exercise causes a lowering of internal temperature, which positively influences thermoregulatory processes during physical efforts of maximal intensity [35]. Research results are thus unequivocal. Such discrepancies were observed in this research project. As noted, whole body treatments caused a small decrease in values of MAP in females, and only a small and not significant increase in male subjects after a single cooling of the whole body in comparison to the values reached without the treatment. The improvement in males was small and insignificant but one must remember that the Wingate tests following the cooling treatment were performed without a warm-up, which may have considerably hindered performance. The presented research should be continued with the application of a standard warm-up 75 min after the treatment. During this research the warm-up was omitted because the effects of thigh temperature after cryostimulation on the level of anaerobic power were considered.

The research of Sleivert et al. [33] showed that cooling of the torso only did not lower maximal and average power, regardless whether the test was preceded by a warm-up or not. It was also shown that such cooling treatments did not increase the ability to perform high intensity exercise lasting 45 s, yet it might decrease these abilities if the working muscles had a lowered temperature. A short warm-up prior to exercise may effectively diminish the negative effects of whole body cooling by elevating deep muscle temperature, thus confirming the thesis presented earlier that incorporating a warm-up procedure after whole body cryostimulation could increase the level of anaerobic power.

It is well known that muscle temperature has a significant effect on the level of generated power. In the presented research a thermovisual camera was used, that allows to evaluate the resultant temperature of the body, which is strongly affected by the temperature of the skeletal muscles.

Results of research regarding the influence of deep muscle temperature on the level of muscular strength and power indicate reductions in maximal peak force and power by 21% after cooling the muscles to 29°C [32]. In the presented research, a similar course of changes in thigh temperature and MAP of the lower limbs was observed with the exception of the 15 and 30 min interval following the cryostimulation treatments. In those time intervals, MAP decreased, despite an increase in average thigh temperature.

CONCLUSIONS

It may be concluded that single whole body cryostimulation may have a minor influence on short-term physical performance of supramaximal intensity but leads to improvement of velocity during the start as expressed by shortened time to obtain MAP. Further studies are required to elucidate the influence of whole body cryostimulation on physical work capacity and the level of particular motor abilities.

ACKNOWLEDGEMENTS

The authors express special thanks to Katarzyna Babraj and Roman Wodka — managers of The Center of Cryotherapy in Kraków — for making the cryostimulation treatments possible, and to dr Jan Tabak — for medical supervision during cryostimulation treatments. We are very grateful to Ms. Danuta Charland and Ms. Tamika D. Jeune for correcting the English grammar and style of the final version of the manuscript.

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