Motor activities and physical efficiency

Research by Łuczak, carried out on a large group of athletes (300 people), was meant to find an optimal operating temperature during the whole-body cryostimulation for the improvement of motor skills. The effects of exposure were compared between two 10 minute whole-body cryostimulations (at -100°C, -130°C and -160°C) and physical efficiency, based on an assessment of agility, balance, speed and dynamic strength of abdominal muscles. The analysis of the results showed no effect of cryostimulation on the level of agility. Balance improved significantly in groups exposed to temperatures below -100°C, while no significant effects were observed for -100°C. Parameters evaluating speed and dynamic strength of abdominal muscles improved most after the application of -100°C. It was proposed that whole body cryotherapy exerts positive effects on human motor characteristics, although the lowest cryogenic temperatures should be used in only specific cases [Łuczak et al. 2006]. Subsequent studies showed that a series of 20 stimulations with an average temperature -130°C performed on martial arts competitors, resulted in an extended duration of exercise and lower subjective feeling of fatigue at increasing mean speed and angle of treadmill inclination during an exercise according to the Bruce protocol [Hagner et al. 2009]. A recent study on the effects of whole-body cryostimulation on aerobic and anaerobic capacities showed that three 10 minute sessions (average temperature -130°C) increased maximal anaerobic power in males but not in females, and did not influence aerobic capacity in either gender [Klimek et al. 2011]. There are also reports of improved exercise tolerance, expressed by a lower level of lactates, heart rate and increased threshold capacity during a rowing ergometer test by Olympic team athletes (rowers) after 23 cryostimulation sessions (3-minutes at a temperature of -150°C, 2 x day) [Chwalbińska-Moneta 2003].

Cardiovascular response

It is known that cold exposure is a risk factor for hypertension. In physiotherapeutic practice, it is standard procedure to test participants before cryostimulation where a blood pressure control is measured, but contraindications to the use of cryotherapy or whole-body cryostimulation do not include unstable blood pressure or hypertension. Literature data on changes in key cardiovascular indicators in humans exposed to cryogenic temperatures are ambiguous. Some of them report a significant but short-term increase in systolic and diastolic blood pressure after WBC in both normotensive and mildly hypertensive individuals [Westerlund et al. 2004; Fricke 1989; Taghawinejad et al. 1989]. Similarly, Komulainen et al. [2004] observed a rapid increase in blood pressure in mildly hypertensive subjects exposed to -15°C. Other authors reported that thermal stress (-110°C) did not cause changes in systolic or diastolic blood pressure but only a decrease in the heart rate [Zalewski 2009].

In our experiments we observed no changes in blood pressure or heart rate influenced by the potential stress resulting from the planned participation in cryostimulation. However, we observed a statistically significant increase in systolic ($p \leq 0.001$) and diastolic ($p \leq 0.05$) blood pressure immediately after a 3 minute long whole-body cryostimulation. These changes did not last more than 10 minutes after the cryostimulation when the values returned to initial levels [Lubkowska & Suska 2011]. In another study, in which we used 15 daily cryostimulations (-130°C/3min), the average increases in SBP and DBP on the first day were 20 mmHg and 6 mmHg. All the observed changes in the circulatory system subsided after 10 minutes of resting in a sitting position. Changes in blood pressure were accompanied by a decrease in heart rate by 8±4 bpm. The mentioned changes were not different on the 1st, 5th, 10th and 15th days of the experiment and it can therefore be argued that no adaptation changes occurred in response to the repeated stress associated with the cold [Lubkowska & Szyguła2010].

Lipid profiles

There are only a few reports in literature on the influence of whole-body cryostimulation on lipid levels in blood serum. The first information comes from experimental animal models [Skrzep-Poloczek et al. 2002]. Our last report concerned the results of lipid profiles in response to different procedures of whole-body cryostimulation in a cryochamber (-130 °C) for five, ten and twenty sessions. We ascertained that five sessions of whole-body cryostimulation in a cryogenic chamber did not change the lipid profile; while in a group subjected to a series of 10 sessions, the level of TG values statistically significantly decreased, and the changes were more pronounced in the group subjected to 20 sessions: a significant reduction in LDL, reduction in total cholesterol, while a significant increase was observed for HDL fraction. Comparing the ratios of individual lipid fractions, a statistically significant decrease in the TG fraction was observed in relation to total cholesterol, while the HDL fraction increased in comparison with total cholesterol and LDL cholesterol after 20 cryostimulations. No changes in the proportions between lipid fractions were observed after 5 and 10 cryostimulations [Lubkowska et al. 2010]

Hematology

Literature on changes in haematological indices induced by cryostimulation are often inconsistent and insufficient. Blatteis [1998] reported a decrease in leukocytes and erythrocytes in healthy subjects after a series of cryostimulations. No significant increase in leukocytes was reported by Stanek et al. [2006], although they also observed a significantly increased percentage of monocytes in healthy individuals after a series of 10 two-minute long cryostimulations at -120ºC. Similarly, in our studies the increase concerned the number of lymphocytes and monocytes, and to a lesser extent, neutrophils and eosinophiles [Lubkowska et al. 2009]. With regards to information on the effect of cryotherapy or cryostimulation on the red blood cell system, data is still very scarce. The only available paper is Banfi et al. [2008] which investigated the effects of 5 session of whole-body cryotherapy treatment on haematological values in athletes. The paper suggested that cryotherapy does not have detrimental effects on the mentioned parameters, but a small significant decrease in haemoglobin concentration, mean corpuscular haemoglobin and mean reticulocyte volume were observed.

In terms of the participation of white and red blood cells in effort ability and tolerance, further studies are required on potential changes in haematological indices in response to varied number of cryostimulation in a series.

Hormones

A single cryostimulation at -130°C causes increased concentration of a proopiomelanocortin-related hormone (ACTH adrenocorticotropic hormone), β-endorphin, adrenaline and noradrenaline in men and women, and a significant increase in testosterone in men [Zagrobelny 1993]. Soccer players undertaking ten sessions of cryostimulation followed by 60 minutes of kinesitherapy, had a significant decrease in the concentration of testosterone and estradiol. There were no changes in the level of luteinizing hormone (LH) and dehydroepiandrosterone sulphate [Korzonek-Szlacheta 2007]. Reports of changes in the level of cortisol (defined as the stress hormone) are divergent. Smolander et al.[2009] concluded that WBC treatments (-110°C), for 2 min, three times a week for 12 weeks, do not lead to disorders related to secretions of the growth hormone, prolactin, thyrotropin or thyroid hormones in healthy females.

Literature data indicate that in elderly women, cryotherapy at temperatures of -110ºC to -150ºC influence the level of bone conversion markers (a decline in osteocalcin, increased alpha type I collagen in blood serum) [Skrzek et al. 2003], and that rheumatoid arthritis patients were reported to have a decreased histamine level [Wojtecka-Łukasik et al. 2010].

Antioxidant defence system

Even one session of whole-body cryostimulation causes changes in the prooxidant-antioxidant balance – the level of total oxidative status in plasma was statistically significantly decreased at 30 minutes after leaving the cryochamber and remained lower the following day, whereas the level of total antioxidative status decreased after cold exposure and increased the next day [Lubkowska et al. 2008]. Additionally, a 36% increase was observed in the activity of superoxide dismutase (SOD), glutathione peroxidase (GPx) and conjugated dienes (CD) in healthy individuals after a single stimulation [Woźniak et al. 2007]. Duge et al. [2005] observed a significant increase in total peroxyl radical trapping antioxidant capacity of plasma (TRAP) in healthy women 2 minutes after the cold stress but only after the first 4 weeks of the 12 weekend long study. Additionally those authors concluded that prolonged, regular cryostimulation or winter swimming for 12 weeks did not appear to be harmful regarding antioxidative capacity. Further studies are needed for the confirmation of potential adaptational advantages occurring in antioxidative response to cryostimulation.

Immunology and inflammation

Cryotherapy is used in the early treatment of acute injuries (sprains, strains, fractures) but only a few papers discuss any possible influence of whole-body cryostimulation on inflammation mechanisms or immunology. In studies by Jackowska et al. [2006] it was ascertained that IgA, IgG, IgM and C3, C4 complement protein levels increase during cryostimulation, yet after cryotreatment, the levels of the mentioned markers were similar to initial values. Leppäluoto et al. [2008] did not observe changes in plasma level of IL-1β, Il-6 and TNFα during prolonged treatment (12 weeks) with cryostimulation (-110°C; 2min; 3 times a week). In our studies, we observed an increase in the level of white blood cells in response to a series of 10 cryostimulations, and at the same time we showed that a single 3 minute long whole-body cryostimulation (-130°C) leads to an increase in the level of interleukin 6, which is maintained for the next 10 stimulations [Lubkowska et al 2010]. This was later confirmed in the next experiment, which additionally showed the more advantageous effect of 20 sessions compared to 10 or 5 cryostimulations. This advantageous effect – an increased level of anti-inflammatory cytokines (IL-6, IL-10, IL-12) - was maintained during the whole series of cryostimulations, and receded no earlier than after two weeks after the completion of the cryostimulations, regardless of the number of treatments. However, although the decreased level of pro-inflammatory IL-1α was observed during the series of 5 and 10 treatment, in an examination two weeks after the last stimulation the IL-1α decrease was maintained only after the series of 20 cryostimulation treatments [Lubkowska et al. 2011].

The anti-inflammatory effect of cryotreatment on rugby players lead to an increase in anti-inflammatory cytokinase IL-10 with a decrease in pro-inflammatory IL-2 and chemokine IL-8. It was postulated that cold exposure had an immunostimulating effect related to enhanced noradrenaline response and can be connected with paracrine effects. Similar tendencies in decrease in pro-inflammatory cytokine (IL-2, Il-8) and increase in anti-inflammatory one (IL-10) after cryostimulation were observed by Banfi et al. [2009].

Recovery from exercise-induced muscle damage

Some of the latest papers on cryotherapy relate to the use of cryostimulation in athletic recovery, acceleration of recovery to full physical ability, and removing the results of muscle fibre damage caused by intense exercise. It is promoted as a treatment method for muscle injuries, syndromes of overuse and to enhance recovery between training sessions [Banfi et al. 2010].

Difficulty with the evaluation of the advantageous effect of cryostimulation is associated, as in earlier aspects, with the very small number of papers in this field. Costello et al. [2011] performed very interesting studies to evaluate the immediate effect of cryostimulation on proprioception and tried to evaluated the effectiveness of this treatment in muscle soreness and function following eccentric exercise damage. Based on obtained results, the authors suggest that although cryostimulation does not increase the risk of proprioceptive related injury, it is ineffective in improving recovery if administered 24h after exercise. In another study [Pournot et al. 2011] researchers compared the effect of two different recovery modalities: cryostimulation (3 min at -110°C) and passive recovery, on markers of exercise- induced muscle damage and inflammation obtained after a simulated trail running race. The recovery session was applied immediately after, 24h, 48h and 72h after subjects performed a

48min running treadmill exercise. The author observed that a unique session of cryostimulation performed immediately after exercise enhanced muscular recovery by restricting the inflammatory process. They suggested that soluble receptor antagonist IL-1ra increases after single whole-body cryostimulation and restricts the inflammatory response to exercise by a decrease in the magnitude if IL-1β and protein C-reactive. This research indicates that this physiotherapeutic treatment reduces the time of recovery, although depending on the time lag from the intense effort to cryostimulation. Further studies are required for a detailed understanding of mechanisms of response to cryogenic temperatures to find their most effective application in athletic training and recovery.