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Whole-body cryostimulation increases parasympathetic outflow and decreases core body temperature

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ABSTRACT

The cardiovascular, autonomic and thermal response to whole-body cryostimulation exposure are not completely known. Thus the aim of this study was to evaluate objectively and noninvasively autonomic and thermal reactions observed after short exposure to very low temperatures. We examined 25 healthy men with mean age 30.1 ± 3.7 years and comparable anthropomorphical characteristic. Each subject was exposed to cryotherapeutic temperatures in a cryogenic chamber for 3 min (approx. −120 °C). The cardiovascular and autonomic parameters were measured noninvasively with Task Force® Monitor. The changes in core body temperature were determined with the Vital Sense® telemetric measurement system. Results show that 3 min to cryotherapeutic temperatures causes significant changes in autonomic balance which are induced by peripheral and central blood volume changes. Cryostimulation also induced changes in core body temperature, maximum drop of core temperature was observed 50–60 min after the stimulation. Autonomic and thermal reactions to cryostimulation were observed up to 6 h after the exposure and were not harmful for examined subjects.

1. Introduction

The term "whole-body cryotherapy (cryostimulation)" (WBC) refers to an array of therapeutic applications, that utilize cryogenic temperatures. Usually, the cryogenic temperatures used during WBC range from −110 °C down to −150 °C. The treatment is based on a relatively short (usually up to 180 s) exposure of the whole body to extremely cold air, in order to achieve considerable cooling of the skin. This is associated with resultant activation of processes that lead to accumulation of heat and counterbalance its loss (Costello et al., 2012a,b,c, 2014; Banfi et al., 2010; Guillot et al., 2014).

Typically, WBC is recommended for alleviation of pain and treatment of inflammatory conditions, acute injures of soft tissues, rheumatic diseases and neurodegenerative disorders; however, it can be used in patients with depressive and anxiety disorders as well. Moreover, whole-body cryotherapy is very popular as a method of wellness treatment and athletic recovery. Initially introduced in Japan, Germany and Poland, WBC has gained increasing popularity worldwide (Costello et al., 2012b, 2014; Banfi et al., 2010; Guillot et al., 2014; Lubkowska and Szygula, 2010; Lubkowska and Suska, 2011).

Rapid cooling of virtually the whole surface of the body during WBC results in strong vasoconstriction of the skin capillaries. This is associated with enhanced venous return of cooled blood. Increased perfusion of large vessels of the trunk results in immediate activation of arterial baroreceptors and increase in

Abbreviations: ANS, autonomic nervous system BPV, blood pressure variability; BRS, baroreceptor reflex sensitivity; BSA, body surface area; dBP, diastolic blood pressure; dBPV, diastolic blood pressure variability; HF, high-band frequency spectrum; HF-dBP, HF-component of dBPV; HFnu-dBP, normalized "HF-component" of dBPV; HFnu-RRI, normalized "HF-component" of HRV; HFnu-sBP, normalized "HF-component" of sBPV; HF-RRI, HF-component of HRV; HF-sBP, HF-component of sBPV; HR, heart rate; HRV, heart rate variability; LF, low-band frequency spectrum; LF/HF, sympatho-vagal balance LF-dBPV/HF-RRI; LF/HF-dBP, LF/HF ratio of dBPV; LF/HF-sBP, LF/HF ratio of sBPV; LF-dBP, LF-component of dBPV; LFnu-dBP, normalized "LF-component" of dBPV; LFnu-RRI, normalized "LF-component" of HRV; LFnu-sBP, normalized "LF-component" of sBPV; LF-RRI, LF-component of HRV; LF-sBP, LF-component of sBPV; mBP, mean blood pressure; PSD-dBPV, power spectral density of dBPV; PSD-RRI, power spectral density of HRV; PSD-sBPV, power spectral density of sBPV; sBP, systolic blood pressure; sBPV, systolic blood pressure variability; TFM, Task Force® Monitor; WBC, whole-body cryostimulation

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parasympathetic stimulation of the heart (Zalewski et al., 2013; Hausswirth et al., 2013). Cyclic circadian changes of core body temperature constitute a well-known physiological process which is under tight control of the nervous system. As such, this mechanism can be disturbed by a number of stressors, e.g. very low temperature.

According to most authors, core body temperature does not change in response to whole-body cryotherapy (Selfe et al., 2014; Komulainen et al., 2004). However, this apparent lack of changes could also be a consequence of the exposure to the cryogenic factor being too short (no longer than 2 min), inaccurate method of measurement, and particularly characteristics of the study sample.

Thermoregulatory mechanisms are based on a tight relationship between superficial and core body temperature. WBC decreases the temperature of the skin, especially in the lower limbs (Cholewka et al., 2011). According to some authors, systemic cryostimulation does not cause significant changes in anal temperature, and the lowest local superficial temperatures are recorded on the forearms. However, data on the distribution of superficial temperatures after whole-body cryostimulation remain inconclusive (Costello et al., 2012a,b,c). Nevertheless, WBC is not associated with the risk of hypothermia (Westerlund et al., 2003).

In addition to changes in superficial body temperature, whole-body cryotherapy also affects function of the cardiovascular system. Exposure to cryogenic temperatures is reflected in a decrease in heart rate (HR) and an increase in stroke volume (SV) and stroke index (SI). In contrast, the values of systolic (sBP), diastolic (dBP) and mean blood pressure (mBP), cardiac indices (CO, CI) and total peripheral resistance (TPR, TPRI) do not alter significantly in response to WBC (Zalewski et al., 2013; Bonomi et al., 2012). The spectrum of changes in the abovementioned parameters suggests that systemic cryotherapy causes an increase in preload but does not affect afterload of the heart (Zalewski et al., 2013). However, some studies have documented a significant increase in systolic and diastolic blood pressure as a form of stress response to whole-body cryostimulation (Lubkowska and Suska, 2011). Typically, women and men did not differ significantly in terms of their response to WBC (Westerlund et al., 2004).

All reflex mechanisms of the cardiovascular system are integrated and controlled by the autonomic nervous system. Therefore, the activity of autonomic fibers that innervate the heart and blood vessels can be determined non-invasively, using heart rate and blood pressure variability.

The aim of this study was to analyze the effects of whole-body cryostimulation on core body temperature and the autonomic nervous system of healthy individuals.

2. Material and methods

2.1. Subjects

The study included the group of 25 healthy men aged between 25 and 39 years (mean: 30.1 ± 3.7 years). Anthropometric characteristics of the study participants are presented in Table 1. Any functional disorders of the cardiovascular and autonomic nervous system (ANS), and other contraindications to whole-body cryotherapy constituted exclusion criteria from the study. Each of the participants was subjected to a single 3-min procedure of whole-body cryotherapy (at a chamber temperature of between −120 °C and −110 °C). The research project was conducted in one of the Polish modern rehabilitation clinics (Rehabilitation Clinic "*Pod Tężniami*", Ciechocinek, Central Poland). Prior to the exposure, and during the post-cryotherapy period, the participants remained in a dedicated faculty for cryotherapy procedures that included an air-conditioned room with constant ambient temperature and humidity. During the whole experiment (up to 6 h after exposure) each subject stayed in a resting room which also controlled ambient conditions, and their activity was supervised by research staff. Physical activity of the subject was limited to a necessary minimum, they were allowed only to walk across the room or watch TV. Subjects did not participate in any activities which could influence natural core body temperature balance. All subjects were non-smokers and were also instructed to refrain from caffeine, alcohol ingestion, and intensive physical activity on the day of investigation and ate a light breakfast only. Food intake during the experiment was also controlled by research staff. During the whole experiment subjects were allowed to drink only water and had two light, thermoneutral meals between "after_WBC"–"WBC+3 h" and "WBC+3 h"–"WBC+6 h" stages; first water consumption was allowed two hours after telemetric capsule intake.

Table 1
Basic characteristics of the study participants (*abbreviations are listed in* Section 1).

Parameter	**Subjects *n*=25 only men**	
	Mean	**Range**
Age (years)	30.1 ± 3.7	25–39
Body height (m)	1.79 ± 0.05	1.69–1.87
Body weight (kg)	83.2 ± 11.0	62–103
BMI (kg/m^2)	25.9 ± 2.8	21–31
BSA (m^2)	2.0 ± 0.1	1.7–2.2

The study was approved by the Human Research Committee of the Nicolas Copernicus University in Torun, The Ludwik Rydygier Collegium Medicum in Bydgoszcz, and the subjects gave their written consent to participate after being informed about the whole procedure and the study protocol.

2.2. Whole-body cryotherapy stimulation

Each participant was exposed to a cryotherapeutic factor (whole-body cryotherapy/cryostimulation, WBC) at a temperature of approximately −120 °C for a period of 3 min. A modern cryochamber (*Cryotherapy chamber – "Stan-Mar", Poznan Poland*), divided into three compartments with different temperatures (−10 °C, −60 °C and −120 °C) was used. The subjects entered the chamber in swimwear, equipped with headband, facemask, gloves and wooden clogs to prevent frostbites. During the exposure, the participants were allowed to walk slowly, avoiding any rapid body movements. All the WBC procedures took place between 9 am and 11 am.

2.3. Autonomic nervous system assessment

All measurements were performed with a dedicated device – Task Force Monitor (TFM, *CNSystems*, *Medizintechnik*, Graz, Austria). The main area of TFM application is an automated and computerized beat-to-beat analysis of impedance cardiography (ICG), electrocardiogram (ECG), oscillometric and non-invasive continuous blood pressure measurement (oscBP, contBP). These three biological signals are used for calculation of hemodynamic and autonomic parameters. The availability of continuous (beat-to-beat), reliable and reproducible measurement of all parameters represents a main advantage of the device.

Task Force Monitor allows intervention marks to be set for defined periods to allow automated basic statistical analysis. Each measurement was performed continuously for 10 min after all signals stabilized; this allowed a reliable analysis of hemodynamic and baroreceptor parameters. The Task Force Monitor measurements were performed four times, at the following stages "before WBC", "after WBC", "WBC+3 h" and "WBC+6 h". The first measurement was treated as a baseline for the remaining three