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Thermal and hemodynamic response to whole-body cryostimulation in healthy subjects ☆

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ABSTRACT

Whole-body cryotherapy (WBC) is an increasing applied cryotherapeutic method, that involves application of a cryotherapeutic factor to stimulate the body by the means of intense hypothermia of virtually the body's entire area. This method is still not well recognized in Western Europe. However in recent years it is becoming increasingly popular in sports medicine and also in clinical application.

Cryotherapeutic agents used in WBC are considered to be a strong stress stimulus which is associated with a variety of changes in functional parameters, particularly of the cardiovascular and autonomic nervous systems. However, such strong influence upon the entire body could be associated with the risk of unexpected reactions which might be dangerous for homeostasis. The present study evaluated the complex hemodynamic physiological reactions in response to WBC exposure in healthy subjects. Thirty healthy male volunteers participated. Each subject was exposed to WBC (−120°C) for 3-min. None of the participants had been exposed to such conditions previously. The research was conducted with modern and reliable measurements techniques, which assessed complex hemodynamic reactions and skin temperature changes non-invasively. All measurements were performed four times (before WBC, after WBC, WBC + 3 h and WBC + 6 h) with a Task Force Monitor (TFM – CNSystems, Medizintechnik, Gratz, Austria). Body superficial temperature was measured by infrared thermographic techniques – infra-red camera Flir P640 (Flir Systems Inc., Sweden). Our results show a significant decrease in heart rate, cardiac output, and increase in stroke volume, total peripheral resistance and baroreceptors reflex sensitivity. These changes were observed just after WBC exposure. At stages WBC + 3 h and WBC + 6 h there was observed a significant drop in baroreceptors reflex sensitivity due to increased thermogenesis. In conclusion, the present findings suggest that WBC strongly stimulates the baroreceptor cardiac reflex in response to body fluid changes which sequentially modulate HR and BP control in supine and resting healthy subjects. The study was performed on randomized and homogenic group of young healthy subjects. Our findings are important for WBC safety determination in research and clinical studies.

Introduction

The effect of thermal factors on the human body has been the subject of numerous studies over many years. Thermal stimuli are widely applied in clinical and sport practice. Thermotherapeutic stimuli, including those characterized by extremely low temperatures – cryotherapeutic factors (e.g. local and a whole-body cryotherapy – WBC), are a frequently used form of physical therapy, used commonly in Eastern Europe. Over recent years, this method has become increasingly popular in other countries [1–3]. WBC is the application of a cryotherapeutics factor (−110 °C to −160 °C) for a short time (2–3 min) to stimulate the body by the intense peripheral hypothermia of virtually its entire area. WBC utilizes the vapors of liquid gases, e.g. nitrogen or atmospheric air. Despite

Abbreviations: AR_0X, selected skin area in thermographic analysis; ANS, autonomic nervous system; BRS, baroreceptor refex sensitivity; CI, cardiac index; CO, cardiac output; dBP, diastolic blood pressure; HR, heart rate; mBP, mean blood pressure; sBP, systolic blood pressure; SI, stroke index; SV, stroke volume; TFM, Task Force Monitor; TPR, total peripheral resistance; TPRI, total peripheral resistance index; WBC, whole-body cryostimulation.

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employing thermal stimulation that utilize very low temperatures, (from −100 °C to −170 °C), when performed properly the procedure is not associated with risk of side effects, such as frostbite or other injuries to the skin [4–6]. WBC is mostly used as a procedure to relieve pain symptoms, inflammatory condition, acute injures soft tissue rheumatic disease, neurodegenaritve conditions and depressive and anxiety disorders. This method is also very popular for wellness treatment and athletic recovery [1,2,7,8].

Whole-body cryotherapy activates a number of physiological mechanisms which attempts to maintain a constant body core temperature. Acute exposure to cryotherapeutics ambient temperatures is an extreme stressful situation for a human body which induce primarily rapid and short-term regulatory mechanisms. Most of these mechanisms are strictly depended on cardiovascular functions. Constriction of peripheral blood vessels is the principal response of the body to stimulation with, cold and the resulting decrease in temperature of the involved skin area. This mechanism restricts perfusion of the skin vascular bed, and thus reduces convective and conductive thermal loss [9,10]. As a functional component of the cardiovascular system, blood pressure undergoes constant and dynamic changes. Blood pressure is modulated both by intrinsic and extrinsic factors, and the extent of these influences is partially controlled by arterial baroreceptors, particularly in terms of short-term regulation. The baroreceptors found in the aortic arch and carotid sinuses are stimulated by stretching of the walls of vessels during the rhythmic diastolic–systolic changes of arterial blood pressure. The baroreceptors play an essential role in short-term regulation but by beat-to-beat, negative-feedback regulation of blood pressure. There are evidences that in experimental animals and also human's local and a whole body cooling stimulates the hypothalamus and thus modulate the arterial pressure and heart rate response [11–13].

There are only limited reports regarding the cardiovascular and autonomic effects after WBC exposure in healthy subjects. Most available literature concerns WBC in clinical use, but there is a significant lack of randomized and objective studies focused upon healthy subjects. There are available a number of possible indications and contra-indications for WBC therapy which have been presented by members of the rehabilitation, physiotherapy, sports medicine and cryo-medicine scientific societies. Most of suggested criteria were introduced on the basis of empirical experience not of reliable scientific studies. Introducing a medical procedure without through scientific validation might not be safe for patients [9,10,14].

Thanks to available modern experimental techniques we were able to assess the cardiovascular system effectors organs non-invasively. Due to technical advances, these methods enable a reliable and reproducible measurement of many variables. Application of advanced mathematical models during non-invasive assessment allows measurements to be obtained that are comparable to those recorded using invasive methods, with a concomitant reduction in risk for examined individuals. This is particularly important in the case of the studies that involve healthy subjects examined under physiological conditions. Such individuals are usually reluctant to participate in any procedures associated with potential health risk or marked discomfort [15,16].

The aim of this study was to evaluate the complex hemodynamic physiological reactions which occur in response to WBC exposure in healthy subjects.

Material and methods

Subjects

We have studied 30 healthy male volunteers who did not meet exclusion criteria for the experiment, i.e.: disease or functional disorders of the cardiovascular system and autonomic nervous system according to the functional assessment of the short version of autonomic symptoms profile, none of the subjects were taking any on medication [15,17]. Each subject was examined by a specialist in cardiology and physical medicine prior to the procedure.

Mean age 32.8 ± 6.9 years, mean body height and mass 1.7 ± 0.0 m and 82.0 ± 6.9 kg, mean body mass index 25.6 ± 2.9 kg/m^2, body surface area 2.0 ± 0 m^2, systolic blood pressure at rest 118.3 ± 6.2 mmHg and diastolic blood pressure at rest 75.1 ± 4.3 mmHg. More details regarding the specific characteristic are given in Table 1. 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. All subjects were instructed to refrain from smoking, caffeine, alcohol ingestion, and intensive physical activity on the day of investigation and ate a light breakfast only. They were also asked to avoid taking part in any exercise at least 24 h prior WBC exposure.

Cryostimulation (WBC)

Each participant was exposed to a cryotherapeutics factor (whole-body cryotherapy/cryostimulation WBC) with a temperature of approximately −120 °C for a period of 3 min. In the study a modern cryochamber divided into three compartments with different temperatures was used. First one with a temperature of −10 °C, second one with −60 °C followed by the main compartment with −120 °C (Cryotherapy chamber – "Stan-Mar", Poznan, Poland). Subjects were exposed to the cryotherapeutics stimuli in swimwear, to prevent frostbites they were equipped with headband, facemask, gloves and wooden clogs. During exposure subjects walked slowly without rapid body movements. In all subjects WBC procedure were performed between 9 am and 11 am.

Body superficial temperature assessment

The temperature of the selected areas of body surface was assessed by means of the infrared (IR) thermoimaging procedure, according to the thermal image acquisition criteria described by Ring and Ammer [18]. This method allowed us to study the intensity of body superficial cooling during WBC procedure.

A thermographic IR-camera Flir P640 was used and allowed the capture of high resolution thermographic images. The IR-camera was maintained at a distance of 1.5 m from the subject at a height of 1.5 m from the floor, in stable ambient conditions. The first measurement was performed after 60 min of the subjects adjustment to examination conditions (before-WBC), the second was taken immediately post WBC exposure with the subject and the camera positioned as described in the guidelines [18]. The post-WBC images were captured 3 h and 6 h subsequently after WBC exposure. The mean temperatures were calculated with the processing

Table 1
General characteristics of examined group $n = 30$.

Characteristic	$n = 30$ only men	
	Mean	Range
Age (years)	32.8 ± 6.9	25–49
Body height (m)	1.78 ± 0.0	1.65–1.87
Body mass (kg)	82.0 ± 6.9	62–103
Body mass index (kg/m^2)	25.6 ± 2.9	20–31
Body surface area (m^2)	2.00 ± 0.1	1.98–2.06
sBP at rest (mmHg)	118.3 ± 6.2	107.5–129.8
dBP at rest (mmHg)	75.1 ± 4.3	64.2–86.4