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Cardiovascular and autonomic responses to whole-body cryostimulation in essential hypertension ☆

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ABSTRACT

Over recent years, a considerable increase in the popularity of cryostimulation and whole body cryotherapy (WBC) procedures has occurred both among healthy individuals and in various groups of patients, including those with primary untreated hypertension. The aim of this study was to compare the effects of WBC on the functional parameters of cardiovascular system in normotensive and primarily hypertensive individuals.

The study included 26 young male volunteers with normal blood pressure range (NormoBP) and 13 with essential arterial hypertension (HyperBP). Each subject was exposed to cryotherapeutic factor (whole-body cryotherapy/cryostimulation, WBC) at a temperature of approximately −115 °C to −125 °C for a period of 3 min. The cardiovascular and autonomic parameters were measured noninvasively with Task Force® Monitor. Measurements in a supine position and tilt test were performed "before WBC" and "after WBC".

Our study revealed that cryogenic temperatures exert strong modulatory effect on the cardiovascular system. Both groups showed adaptive changes of myocardial and vascular parameters in response to rapid cooling of virtually the whole body surface. While the profiles of some of these changes were similar in both the groups, also several considerable intergroup differences were documented. Consequently, the cryostimulation and cryotherapy treatment should be prescribed carefully to individuals who present with cardiovascular failure of any degree.

Introduction

In the medical literature, the terms "cryostimulation" or "whole-body cryotherapy" (WBC) refer to a procedure that utilizes a stimulatory effect of cryogenic temperature, typically between −100 °C and −160 °C, applied to a whole body for a short period of time, usually no longer than 3 min [5,2,28,32]. This form of physiotherapy was proved to be an efficient and safe therapeutic modality in both clinical and sports medicine [3,2,28,7]. In sports medicine, WBC is used as a treatment for acute and chronic injuries of soft tissues and as a form of biological renewal after intensive physical exercise [7,35]. In clinical practice, in turn, WBC is predominantly used in patients with musculoskeletal disorders, i.e. polyarthritis [13], rheumatoid arthritis [22] and fibromyalgia [4]. Moreover, WBC proved to be an efficient form of adjunct treatment of neurological disorders, such as spastic paresis, multiple sclerosis, anxiety and mood disorders [23,1,26].

Physiological responses to cold are associated with activation of the sympathetic component of the autonomic nervous system and constriction of superficial blood vessels. The increased peripheral vascular resistance is reflected by elevation of systolic blood pressure [6,30,18,31]. Short-term systemic cryostimulation activates physiological responses in the body, which manifests as changes

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Nomenclature

ANS	autonomic nervous system
BRS	baroreceptor reflex sensitivity
BSA	body surface area
CI	cardiac index
CO	cardiac output
dBP	diastolic blood pressure
EDI	end-diastolic index
ER	ejection rate
HR	heart rate
IC	index of contractility
LVET	left ventricular- ejection time
mBP	mean blood pressure
PEP	pre-ejection period
sBP	systolic blood pressure
SI	stroke index
SV	stroke volume
TFC	thoracic fluid content
TFM	Task Force® Monitor
TPR	total peripheral resistance
TPRI	total peripheral resistance index
WBC	whole-body cryostimulation

in the cardiovascular system; although the presence of these changes is well documented in the literature, some of their underlying mechanisms are not still completely understood.

Our previous have studies revealed that thermal stress (−110 °C) induces insignificant changes in arterial blood pressure and concomitant decrease in heart rate of healthy individuals [34]. However, contradictory findings were documented as well, i.e. the post-WBC increase in both systolic and diastolic pressure [19,20,5]. Similar effects were also observed in individuals with mild hypertension as a result of exposure to −15 °C [18]. Depending on the degree of body cooling and its duration, the heart rate can increase, decrease or remain unchanged [14]. In spite of methodological differences between the previous studies, especially with regards to duration, temperature, type of exposure and uniforms worn by the subjects, WBC seems to be well-tolerated and safe in the case of most healthy individuals [5,32,31]. However, whole-body cryotherapy is not currently recommended in subjects with severe and/or untreated hypertension [19,20]. Moreover, the exposure to extremely low temperatures and whole-body cooling is not considered suitable for persons with severe cardiovascular conditions and acute infections [24]. The character of cardiovascular response to WBC is determined by a temperature of the air, duration of the exposure, and the presence of concomitant cardiologic conditions [30]. WBC is considered a safe procedure for adults up to 70 years of age, who are free from any established risk factors of blood pressure and heart rate abnormalities. Pathological changes of cardiovascular parameters occur rarely in WBC-treated individuals and are only sporadically reported in the literature [5].

Data exploring the changes in the cardiovascular parameters, especially arterial blood pressure, in response to systemic cryostimulation are inconclusive. Consequently, the aim of this study was to compare the effects of WBC on the functional parameters of cardiovascular system in normotensive and primarily hypertensive individuals.

Material and methods

Subjects

The study included 26 young male volunteers with normal blood pressure range (NormoBP) and 13 with essential arterial hypertension (Hyper BP). A group of 21 subjects did not meet inclusion criteria (Fig. 1.) Normotensive and hypertensive subjects did not differ significantly in terms of age, anthropometric characteristics and heart rate at rest. None of the subjects were taking vasoactive and hypertensive medications that could affect cardiovascular parameters, or had a history of diabetes, hormonal disturbances, cardiovascular disease and neurological illness. The only significant intergroup differences pertained to the resting values of blood pressure parameters (systolic, diastolic and mean BP), all being significantly higher in the hypertensive group (Table 1).

Cardiovascular 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). The availability of continuous (beat-to-beat) reliable and reproducible measurement of all these parameters represents a main advantage of the device. Hemodynamic and contractility parameters were assessed in a supine position and during head-up tilt test, using a 70° angle of tilt for 10 min. All the parameters determined in a supine position were recorded continuously for 10 min after stabilization of the signaling. Cardiovascular autonomic function was assessed using baroreceptor reflex sensitivity (BRS) sequence method which is based on linear regression of systolic blood pressure (sBP) and heart period (RRI) values in baroreflex sequences. This method is based on an identification of at least three consecutive heartbeats that are defined as a single sequence and characterized by an elongation of R–R intervals (RRI) preceded by a gradual increase in systolic blood pressure (sBP), or by a shortening of the R–R intervals (RRI) preceded by a gradual decrease in the systolic blood pressure (sBP) [25,10,11].

The TFM-based measurements in a supine position and tilt test were taken twice: "before WBC" and no longer than 10 min "after WBC". All the functions of the Task Force Monitor have been validated prior to the study, and instrument has already been used successfully in many advanced clinical and scientific projects [10].

Protocol

Each participant was exposed to a cryotherapeutic factor (whole-body cryotherapy/cryostimulation, WBC) at a temperature of approximately −115 °C to −125 °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 a 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. Prior to the exposure, the participants remained in an air-conditioned room with constant temperature and humidity [12,29]. Physical activity of the subjects was limited to a necessary minimum.

Cardiovascular and autonomic examination took place in a quiet and darkened room with approximately 21 °C temperature. None of the participants were active smokers. Furthermore, they