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Effects of whole-body cryotherapy duration on thermal and cardio-vascular response

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ABSTRACT

Whole-body cryotherapy (WBC) is the exposure of minimally dressed participants to very cold air, either in a specially designed chamber (cryo-chamber) or cabin (cryo-cabin), for a short period of time. Practitioners are vague when it comes to recommendations on the duration of a single session. Recommended exposure for cryo-chamber is 150 s, but no empirically based recommendations are available for a cryo-cabin. Therefore the aim of this study was to examine thermal and cardio-vascular responses after 90, 120, 150 and 180 s of WBC in a cryo-cabin. Our hypothesis was that skin temperature would be significantly lower after longer exposers. Twelve male participants (age 23.9 ± 4.2 years) completed four WBC of different durations (90, 120, 150 and 180 s) in a cryo-cabin. Thermal response, heart rate and blood pressure were measured prior, immediately after, 5 min after and 30 min after the session. Skin temperature differed significantly among different durations, except between 150 and 180 s. There was no significant difference in heart rate and blood pressure. Thermal discomfort during a single session displayed a linear increase throughout the whole session. Our results indicate that practitioners and clinicians using cryo-cabin for WBC do not need to perform sessions longer than 150 s. We have shown that longer sessions do not substantially affect thermal and cardio-vascular response, but do increase thermal discomfort.

1. Introduction

Whole-body cryotherapy (WBC) is the exposure of minimally dressed participants to very cold air, either in a specially designed chamber (cryo-chamber) or cabin (cryo-cabin), for a short period of time (Banfi et al., 2010). The exposure to cold air usually lasts up to three minutes. Beneficial effects of WBC have been observed in recovery after training (Hausswirth et al., 2011; Pournot et al., 2011), pathology of joints (Ma et al., 2013), mental state and quality of life (Szczepanska-Gieracha et al., 2014) and in the rehabilitation of patients with rheumatoid diseases (Metzger et al., 2000).

Low temperature is regulated by repetitive short (1–5 s) injections of liquid nitrogen, which at atmospheric pressure boils at −196 °C. The temperature in the cabin or chamber is not constant as the human body works as a source of warm temperature. Hence, the nitrogen is injected when the temperature in the cabin or chamber falls below a set value (e.g. −140 °C). Actual temperature next to the skin in a cryo-cabin has been recently reported to reach substantially higher temperatures as reported by the manufacturer (Savic et al., 2013). On the contrary, Cholewka et al. (2005) reported that temperatures in a cryo-chamber are lower and closer to what is displayed by the manufacturer (between −67 °C and −125 °C). Nonetheless, Savic et al. (2013) showed that the thermal response after a cryo-cabin session is similar to the response observed after cryo-chamber cold exposure reported in previously published studies (Cholewka et al., 2004, 2012; Westerlund et al., 2003). However, Hausswirth et al. (2013) recently reported a substantial difference in skin temperature after WBC in a cryo-chamber compared to a cryo-cabin. Regardless of the skin temperature, biological responses, such as heart rate and plasma norepinephrine concentrations, are very similar after WBC in a cryo-chamber compared to WBC in a cryo-cabin (Hausswirth et al., 2013). As such, it can be concluded that WBC in a cryo-chamber or a cryo-cabin provide similar responses in a human organism.

Practitioners are vague when it comes to recommendations on the duration of a single session. Recently, Selfe et al. (2014) demonstrated that 2 min exposure at −135 °C in a cryo-chamber is optimum to elicit physiological responses. However, for cryo-cabins, practitioners recommended exposures between 2 min and 4 min.

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To the authors' knowledge, there are no peer-reviewed studies published on the effects of different durations on a biological response after a single WBC session in a cryo-cabin. Therefore the aim of this study was to examine thermal and cardio-vascular responses after 90, 120, 150 and 180 s of WBC in a cryo-cabin. Our hypothesis was that skin temperature would be significantly lower after longer exposures. In addition, heart rate and blood pressure would not be significantly different after different durations.

2. Methods

2.1. Participants

Based on the power calculation a priori, twelve healthy young male adults (age 23.9 ± 4.2 years, height 181.0 ± 7.6 cm, weight 70.3 ± 7.9 kg and BMI 21.5 ± 2.1 kg/m²) were involved in the present study. All participants were examined by a physician prior to participation to exclude any contraindication to cryotherapy. Additionally, an interview, during which the details of the study were presented, was carried out prior to the start of the experiment. Participants were requested not to eat, smoke, drink alcohol or hot drinks for 4 h before the experiment. The study was approved by the National Medical Ethics Committee and all participants signed a statement of informed consent at their enrolment.

2.2. Study design

In a random order, participants completed four cryotherapy sessions of different durations (90, 120, 150 and 180 s) in a cryo-cabin (Space Cabin, Criomed, Ltd, Kherson, Ukraine). Each session was separated by 24 h(± 0.5 h) to exclude the effect of circadian rhythm.

Each participant arrived to the cryotherapy center 30 min before the session, where they were instructed to sit down wearing only swimwear, woollen socks and wooden clogs to acclimate to the room temperature (22.0 ± 0.5 °C). Prior the WBC exposure five dots (1 cm diameter) were marked on the front right side of the middle of the shank, thigh, trunk, chest and forearm. On these locations skin temperature was measured via a noncontact digital infrared

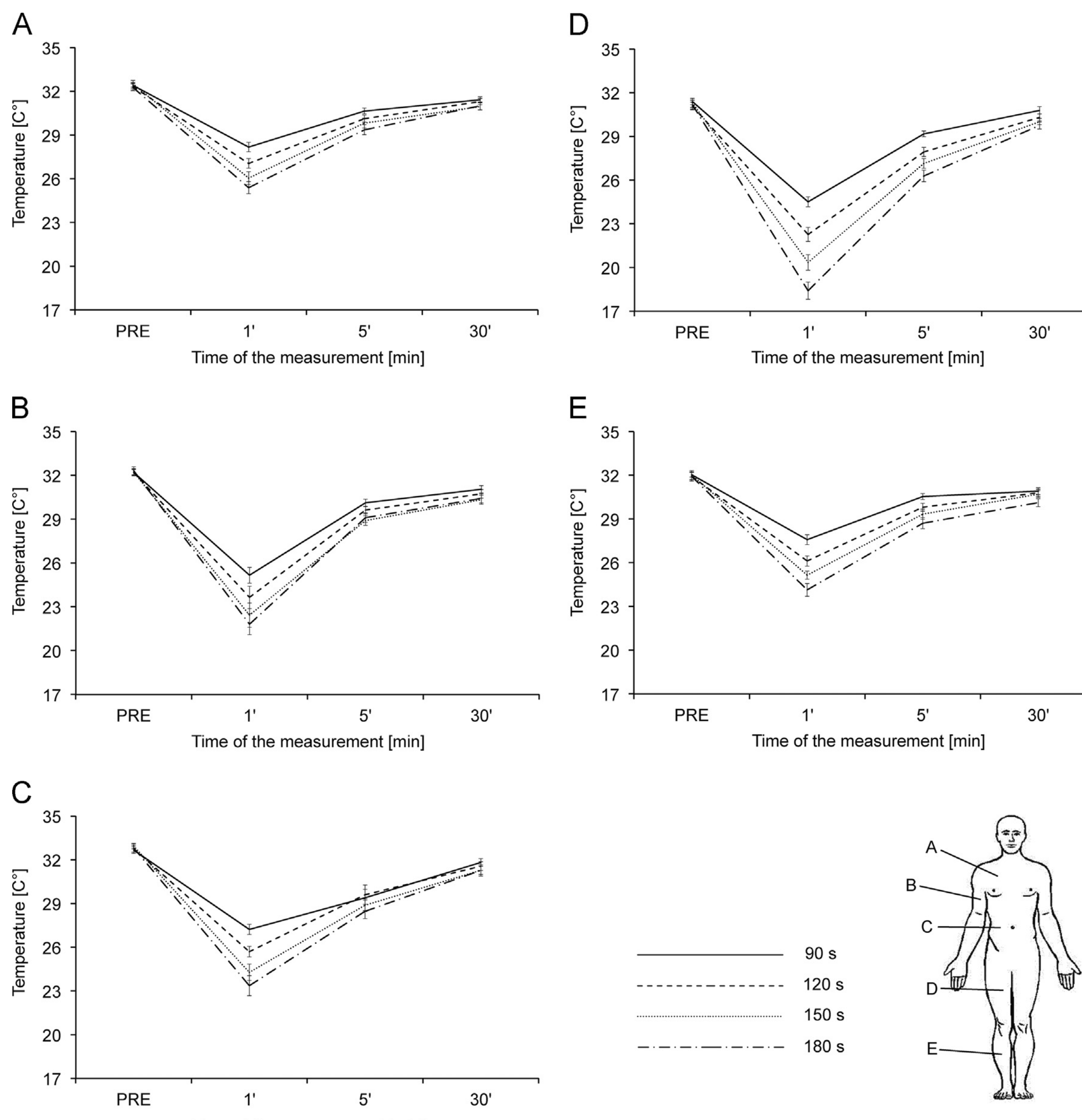

Fig. 1. Temperature profiles for different body regions at different cryo-session durations: 90 s (solid line), 120 s (dashed line), 150 s (dotted line) and 180 s (dash-dot line). A: chest; B: forearm; C: trunk; D: thigh; E: tibia.

thermometer (1760/IR800, Beta, Italy) with an emissivity set to 0.98. Blood pressure was measured on the left arm resting in a sitting position by means of a sphygmomanometer, while heart rate was assessed with an oximeter (Sat-200; Intramed, Italy).

WBC session included exposing participants to low temperatures (from −130 to −170 °C, as reported by the manufacturer) by applying one-second long injections of liquid nitrogen every time the temperature in the cabin rose above −140 °C. During the session subjects wore swimwear, a pair of gloves, woollen socks and wooden clogs to prevent the occurrence of frostbite. The head was not exposed. Participants were instructed to turn around continuously in the cabin for the time of the session. During the longest session, participants were asked to grade a level of thermal discomfort on a 10-centimetre visual–analogue scale.

All measurements of the skin temperature, blood pressure and heart rate were performed for each subject before, immediately after, 5 min and 30 min after the session by the same expert physician. Between the three measurements after the WBC, participants sat on a bench in a controlled temperature room (22.0 ± 0.5 °C). Participants were instructed not to talk, eat, smoke, drink, or do anything that could influence their thermal and cardio-vascular responses.

2.3. Statistics

For each of the measured parameters, means and standard errors were calculated. The Shapiro–Wilk test was used to test for the normality of the distribution. A 3-way repeated measures analysis of variance (ANOVA) was used to test temperature values for significant differences among all four durations throughout the time for each body region. Body region was the inter-subject factor, while the duration and time were the intra-subject factors. A 2-way repeated measures ANOVA was used to test heart rate, diastolic and systolic blood pressure values for significant differences among all four durations throughout the time.

Before each ANOVA, Mauchly's test of sphericity was performed and appropriate corrections were used when found significant ($p < 0.05$). Additionally, for every statistically significant main effect, *post-hoc* *t*-tests with a Bonferroni correction were calculated. The level of significance for all tests was set at $p < 0.05$. All statistical analyses were performed using the IBM SPSS statistics 20.0 software (Armonk, NY, USA).

3. Results

3.1. Thermal response

Cryo-session for 180 s resulted in a similar thermal response as previously reported in the literature (Savic et al., 2013). Temperature profiles for different durations are displayed in Fig. 1. There was a statistically significant main effect of different durations on skin temperature after the session ($F(2.3, 127.3) = 70.499$, $p < 0.001$, $\eta^2 = 0.562$). Furthermore, there was a statistically significant interaction between different durations and time of the measurement ($F(1.9, 107.6) = 16.122$, $p < 0.001$, $\eta^2 = 0.227$). Post-hoc tests revealed that statistically significant differences occurred between all durations ($p < 0.001$), except for the comparison between the duration of 150 and 180 s ($p = 0.318$).

3.2. Cardio-vascular response

Different durations did not significantly affect the heart rate ($F(3, 33) = 0.033$, $p = 0.992$, $\eta^2 = 0.003$), diastolic blood pressure ($F(3, 33) = 0.321$, $p = 0.810$, $\eta^2 = 0.028$) or systolic blood pressure ($F(3, 33) = 0.033$, $p = 0.992$, $\eta^2 = 0.003$) responses (Fig. 2).

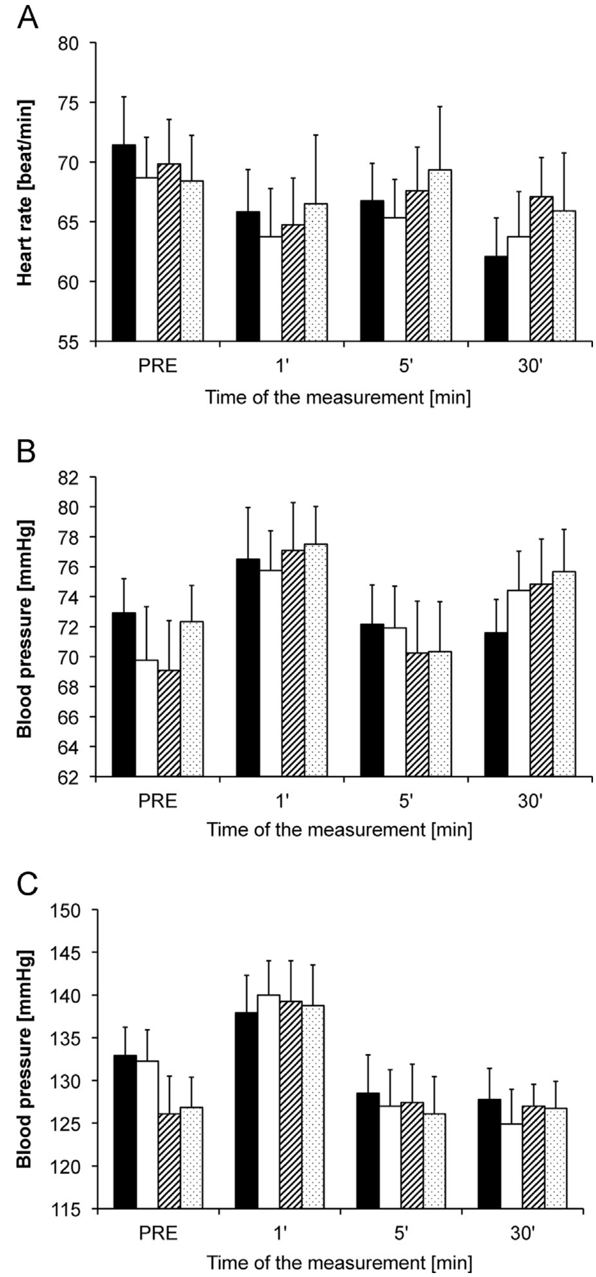

Fig. 2. Heart rate (A), diastolic blood pressure (B) and systolic blood pressure (C) responses for different cryo-session durations—90 s (black bar), 120 s (white bar), 150 s (dashed bar) and 180 s (dotted bar).

4. Discussion

The aim of the present study was to examine thermal and cardio-vascular responses after 90, 120, 150 and 180 s of WBC in a cryo-cabin. Our hypotheses were that skin temperature would be significantly lower after longer exposures, while heart rate and blood pressure would not be significantly different after different durations. Overall we can accept all our hypotheses as there was no significant difference in heart rate and blood pressure, and the thermal response differed significantly among different durations.

Practitioners and researchers who are using WBC in clinical or scientific practice are vague when it comes to the duration of a single session in a cryo-cabin. It is commonly reported that a single session should last between 2 min and 4 min (Banfi et al., 2010), but no rationales are given when or why longer/shorter durations should be used. Selfe et al. (2014) suggested that a 2 min

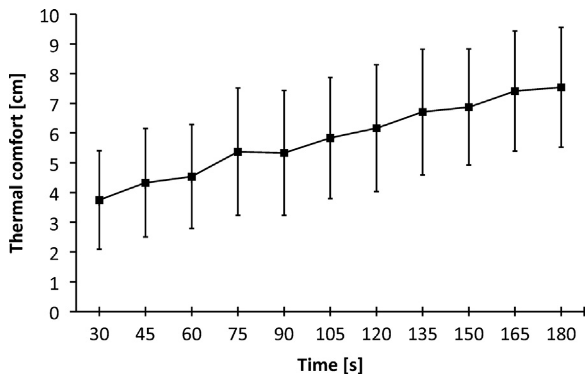

Fig. 3. Subjective thermal comfort sensation throughout a single 180 s cryo-session. Comfort was assessed every 15 s, starting after 30 s. 0 is indicating no thermal discomfort and 10 unbearable thermal discomfort.

WBC exposure at −135 °C following 30 s pre-cooling at −60 °C was the optimum WBC exposure. That was concluded based on the fact that 2 min WBC exposure induces potentially beneficial physiological and perceptual changes, greater than those achieved following a 1 min WBC exposure but without any of the negative effects demonstrated by a 3 min exposure.

Practically, shorter but equally effective protocols would provide more convenience. This is especially true for a WBC as the highest discomfort occurs at the last stage of the session and was reported to be higher for WBC compared to some other cryogenic techniques, e.g. cold water immersion (Costello et al., 2012). Our results indicate that skin temperature decreases significantly with increasing the duration up to 150 s. However, further prolongation of WBC does not affect thermal response. That supports the notion of the study by Savic et al. (2013) who reported a plateau in skin temperature after 160 s of cryo-therapy in a cryo-cabin. Our results also confirm the findings of Selfe et al. (2014) where a cryo-chamber has been used.

We observed a linear increase in thermal discomfort throughout a 3-min session (Fig. 3). This means that despite a plateau in temperature (Savic et al., 2013), perception of discomfort seems to accumulate and is in a continuous rise. Smolander et al. (2004) have shown that discomfort after a WBC decreases after several exposures as a result of a long term adaptation.

Increased arterial blood pressure and decreased heart rate immediately after a WBC session was observed in the present and also in the previous studies (Hausswirth et al., 2013; Lubkowska and Szyguła, 2010; Westerlund et al., 2004). This is probably the result of the excitation of the sympathetic α-adrenergic fibres, which are among others responsible for a peripheral vasoconstriction and consequential blood redistribution towards the core (Lubkowska and Szyguła, 2010). Additionally, Hausswirth et al. (2013) concluded that a drop in skin temperature after one cryo-stimulation affects sympathetic stimulation and consequentially blood pressure rises and heart rate drops to lower values when skin temperature drops to a lower value. Our data indicates that longer duration of a single cryo-session results in a lower skin temperature, but not in a higher blood pressure or lower heart rate immediately after a WBC. Changes in blood pressure and heart rate between partial- and whole-body cryotherapy found by Hausswirth et al. (2013) are therefore not due to lower skin temperatures after WBC. The difference could be explained by head (face) exposure in a cryo-chamber but not in a cryo-cabin. Head and hands are also known to have the highest density of adrenergic fibres, and thus exclusion of these body parts from cooling exposure could explain different cardio-vascular response. Supporting this are the results by LeBlanc et al. (1975) who showed that facial cooling increases blood pressure and results in bradycardia in resting subjects. To summarise, a smaller population of the cryo-stimulated adrenergic fibres with a cryo-cabin compared to a cryo-chamber appears as a potential reason for the slight differences in blood pressure and heart rate response.

5. Conclusions

Practitioners and clinicians using cryo-cabin for WBC do not need to perform sessions longer than 150 s. We have shown that longer sessions do not substantially affect thermal and cardio-vascular response. Additionally, perceived thermal discomfort was observed to increase even after 150 s, which means that a shorter protocol would also have positive effects on the well-being of the users. Future research should aim to examine thermal responses in different populations (eg. females, patients, etc.) so the conclusions can be specific for each group.

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