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Effect of whole-body cryostimulation on skin temperature and thermal comfort in severe obese patients

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ABSTRACT

Obesity is a global public health problem, and new non-surgical or pharmacological treatments are being explored. Among these, cryostimulation has emerged as a new beneficial non-invasive method. Several studies have reported a greater decrease in skin temperature following cryostimulation in individuals with higher BMI or body fat percentage. The aim of this study was to evaluate the effect of a single 3-min whole-body cryostimulation (WBC) session on skin temperature and cold perception in male and female obese subjects. Skin temperature changes before and after the 3-min cryostimulation exposure were measured in twenty-one participants. Our results showed that the average skin temperature decreased by 12.9 °C without reaching dangerous levels. Individual characteristics such as sex and age should nevertheless be carefully considered to ensure the safety and efficacy of the treatment.

1. Introduction

Obesity is currently a major global public health concern. It results from a complex interplay of environmental and genetic factors, and is associated with significant morbidity and mortality [12]. Various treatment options and personalized support strategies are therefore available. In addition to increasing the risk of death, obesity can lead to health problems such as type 2 diabetes, endometrial cancer, gallbladder disease, osteoarthritis, hypertension, and coronary heart disease [14]. Adipose tissue plays a crucial role in regulating many of the pathological processes associated with obesity. This organ produces specific cytokines that regulate energy homeostasis, neuroendocrine functions and immune responses. In obese individuals, the excessive amount of adipose tissue increases the levels of pro-inflammatory cytokine levels and leads to a low-grade systemic inflammation [15].

Among the new non-surgical or pharmacological treatments, cryotherapy/cryostimulation is emerging as a promising new non-invasive method. It involves a person wearing underwear, protective footwears, gloves and surgical mask entering a specialized cryochamber and being exposed to extremely cold temperatures (−60 to −195 °C, depending on the chamber) for a short time (2 to 4 min) in a specialized cryochamber [3]. Exposure to these conditions has been shown to induce anti-inflammatory, analgesic and oxidative stress-reducing effects. Whole-body cryotherapy/cryostimulation has recently been used to alleviate symptoms in patients with various pathologies, such as fibromyalgia, multiple sclerosis, and ankylosing spondylitis. In addition, cryostimulation has demonstrated beneficial effects in improving sleep quality, muscle relaxation, and mood in both healthy individuals and patients [3].

These beneficial effects of cryostimulation are due to the body's short-term adaptation to extreme cold. Exposure to extreme cold stimulates thermoreceptors in the skin, which send signals to the

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hypothalamus, the body's thermostat. The hypothalamus then initiates an adaptive response to the cold, resulting in various physiological benefits [2]. It is hypothesized that, during the cold exposure, the skin temperature must reach a minimum temperature threshold to induce systemic benefits.

Ziemann et al., 2013 [15] demonstrated that WBC could serve as a complementary approach to reduce systemic inflammation in obese patients. Ten WBC sessions were found to reduce blood levels of pro-inflammatory cytokines (IL-6, resistin, and vistafin) and inflammatory markers, while increasing blood levels of anti-inflammatory cytokines (IL-10). These effects were more pronounced in participants with lower fitness capacity than in those with higher fitness capacity. Similarly, Dulian et al., 2015 [7] reported a decrease in hepcidin levels and an increase in irisin concentration after 10 sessions of WBC. The increase in irisin was found to be correlated with the amount of adipose tissue, suggesting that subcutaneous adipose tissue is the primary source of irisin in response to extreme cold exposure. These findings are significant because irisin is considered to play a beneficial role in the treatment of obesity by promoting increased energy expenditure and oxygen consumption in white adipocytes, as well as thermogenesis.

Several studies, cited in the review of Bouzigon et al., 2017 [1], have investigated the effects of cryostimulation on the skin temperature of exposed individuals. These studies suggest that factors such as sex and BMI influence skin temperature changes during 2- or 4-min WBC exposure [1]. Women, overweight individuals and older subjects experienced a greater decrease in skin temperature than men of normal weight and younger subjects. However, no studies to date have investigated the effect of a 3-min cryostimulation session on skin temperature or assessed cold perception specifically in obese individuals and the risk of reaching a critical skin temperature susceptible to induce frostbites, particularly in female obese patients as it is known that female subjects and obese patients experience a faster decrease in skin temperature. This study therefore aims to address this gap by assessing the effect of a single 3-min WBC session on skin temperature and cold perception in obese patients.

2. Participants and methods

This study was carried out at the I.R.C.C.S. Italian Auxological Institute of Piancavallo (Italy). Twenty-one obese patients (10 men and 11 women) participated in this study (age: 54.0 ± 15.1 years old; height: 165.8 ± 10.4 cm; mass: 113.9 ± 19.4 kg; BMI: 41.2 ± 4.1 kg/m^2; bodyfat: 49.6 ± 5.9%). Body fat was estimated using a whole-body bioimpedance analyzer (BIA 101, Akern, Pisa, Italy). All participants were volunteers and signed an informed consent form at enrolment time. The study protocol was approved by the Ethics Committee of the Istituto Auxologici Italiano (reference: 2021_05_18_14) and was in accordance with the Declaration of Helsinki.

Volunteers were exposed in a WBC chamber (Cryo Arctic, Cryo Sciences, Poland) for 3 min.

They wore an ear band, surgical mask, underwear, gloves, socks and slippers. The men wore briefs, and the women panties and bras. They had to stand still and instructed not to move in the chamber. At the end of the exposure, they left the chamber within 20 s and were instructed not to rub their skin. The device was set at −110 °C.

The temperature inside the cryochamber was assessed using five T-type thermocouples (TC Direct, Dardilly, France). Skin temperature was measured before and immediately after the exposure using an Optris Pi 450i thermal camera (Optris GmbH, Berlin, Germany) connected to the Optrix software. Participants were instructed to stand still in front of a thermal camera in the same position before and after the exposure with open palms and straight head (without mask, gloves and ear band). They

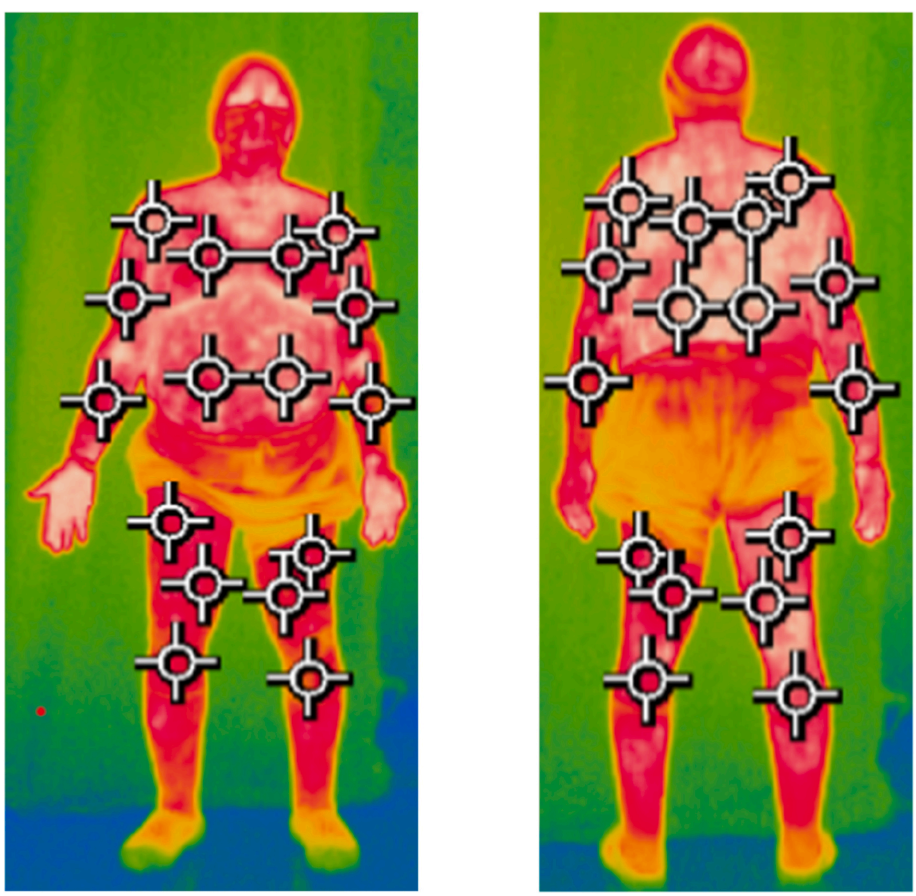

Fig. 1. Measurement zones used for the calculation of the average skin temperature.

then had to turn around so that a picture of their back could be taken.

The measurement area was between the chest and the calf (Fig. 1). The mean skin temperatures were the mean values calculated for all areas (front and back) (see Fig. 2).

Perceived temperature rate and thermal sensation were assessed as described in the study of Bouzigon et al., 2017 [1]. At the end of the exposure, participants were asked "On average, how did you feel during the exposure?". They were asked to record their perceived temperature on a nine-point scale (ISO 10551) "4 – very hot, 3 – hot, 2 – warm, 1 – slightly warm, 0 – neutral, −1 – slightly cool, −2 – cool, −3 – cold, −4 – very cold". Thermal sensation was rated on a graded thermal sensation scale from "0 – Excellent" to "10 – Unbearable".

The statistical program used was JASP 0.17 software (University of Amsterdam, Amsterdam, Netherland). Results were expressed as mean and standard deviation (SD). The normality of each variable was tested using the Shapiro-Wilk test. Analysis of differences in skin temperature before and after the exposure was performed using the repeated measures analysis of variance (ANOVA). Repeated measures ANOVA was used to identify significant mean effects for changes over time following exposure. Post hoc comparison was performed with the Holm-Sidak multiple comparison test. Correlation analyses between the several data were performed using the Pearson test. The level of statistical significance was set at $p < 0.05$.

3. Results

Temperatures measured inside the chamber during the exposures were -70.0 ± 12.9 °C and not -110 °C as expected and indicated with the original chamber sensors.

Differences in skin temperature variation between 5 men and 6 women with similar BMI (43.7 ± 4.3 vs 42.7 ± 3.7 kg/m^2, respectively) were compared. Mean skin temperatures were significantly different between the two groups before and after exposure ($p < 0.001$) and there was a significant difference in skin temperature change between the groups ($p < 0.001$).

Differences in skin temperature change were also compared between 5 men and 6 women with similar body fat (50.3 ± 2.1 vs 50.5 ± 2.7%, respectively). Mean skin temperatures were significantly different between pre- and post-exposure for both groups ($p < 0.001$), and there was a trend, although not significant, between sex in skin temperature change ($p = 0.07$).

Perceived temperature and thermal sensation were measured in 18 participants (9 men and 9 women; age 54.2 ± 16.2 years; height 165.8 ± 11.1 cm; mass 113.7 ± 20.4 kg). After exposure, the participants expressed a mean perceived temperature of 4.3 ± 2.3 and a mean thermal sensation of -2.9 ± 0.8. No differences were observed according to sex, BMI or body fat in our population of obese patients.

However, the results showed a significant correlation between thermal sensation and the age of the participants (Fig. 5) ($p < 0.05$).

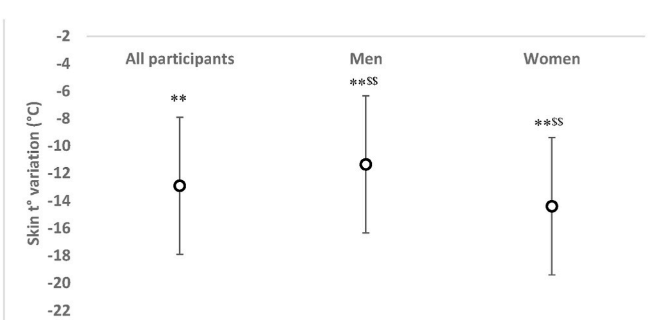

Fig. 2. Mean skin temperature variation between before and after exposure (** significantly different from pre-condition ($p < 0.001$); $^{\$\$}$ significantly different from the other gender ($p < 0.001$)).

4. Discussion

The aim of this study was to evaluate the effect of a 3-min exposure to WBC on skin temperature and cold perception in obese patients. The findings show that WBC can induce a significant decrease in skin temperature in obese individuals, with notable variations according to sex, age and morphological characteristics (BMI and body fat percentage), but with no safety risks.

Several authors have suggested that BMI and/or body fat influence the extent to which skin temperature decreases during cold exposure [6,9,10]. Their findings indicate that people with a higher BMI or body fat experience a greater decrease in skin temperature. Consistent with these reports, our study, which was conducted with obese patients only, also found a greater decreases in skin temperature in participants with higher body fat (Fig. 3) and BMI (Fig. 4).

Bouzigon et al., 2016 [3] previously reported that the mean skin temperature decrease after a 3-min exposure ranged from -4.9 to -16.5 °C depending on the device used and the skin areas measured. In our study, the mean decrease in skin temperature was -12.9 °C. Furthermore, these results indicate that WBC is safe for individuals with clinical obesity, as it did not cause dangerously low body temperatures that could potentially result in frostbite.

This is particularly important as our study examines the effects of prolonged WBC (>2 min) on skin temperature in people with severe obesity. To date, existing studies on skin temperature changes have been conducted on people of normal weight (with 2 and 3-min exposures) [1,6,9] and on obese patients but with 2-min treatments [13]. Consistent with previous studies, our results showed that women experienced a greater decrease in skin temperature than men [6,9,13]. Cuttell et al. [6] and Piterà et al. [13] hypothesized that this may be due to the higher body fat typically observed in women. Rapid cooling of the skin can reduce the thermal gradient between the body surface and the ambient temperature, helping to retain body heat and core temperature and reduce heat loss. Women also have a lower body mass to surface area ratio, which allows for faster convective cooling. However, in our study, women showed a greater decrease in skin temperature, regardless of BMI or body fat percentage. Though such statistical significance in the differences between male and female participants is reached the clinical impact of such changes is not clearly obvious. Nevertheless, gender itself may play a significant role in skin temperature responses. In their 2016 review of Castellani and Young [5] explain that the difference in peripheral responses to cold exposure between women and men could be due to estrogen increasing expression of cold-sensitive a_{2C}-adrenoceptors. This increase may contribute to increased activity of cold-induced vasoconstriction. Therefore, the sex of the individual

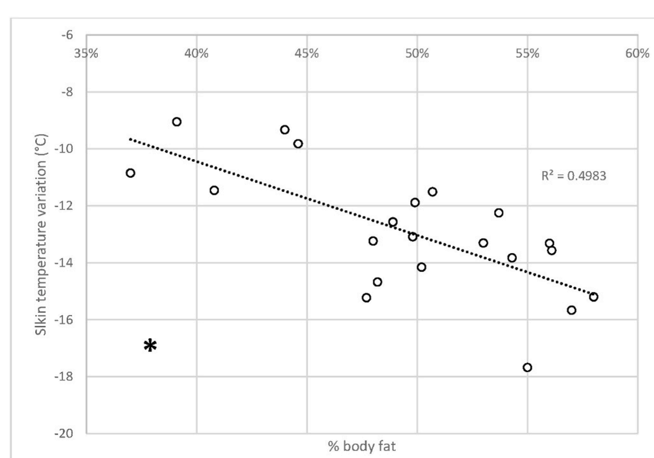

Fig. 3. Correlation between skin temperature variation and body fat percent (** = $p < 0.01$).

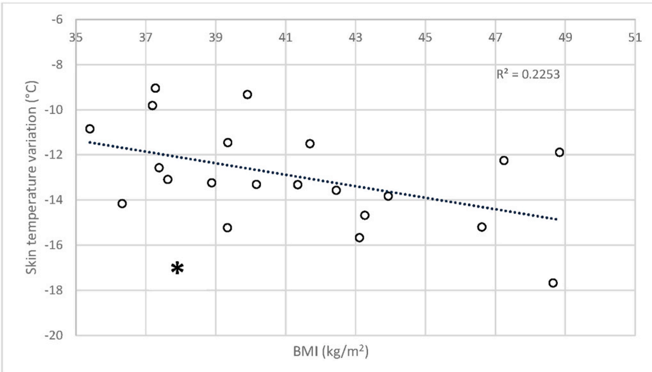

Fig. 4. Correlation between skin temperature variation and BMI (* = $p < 0.05$).

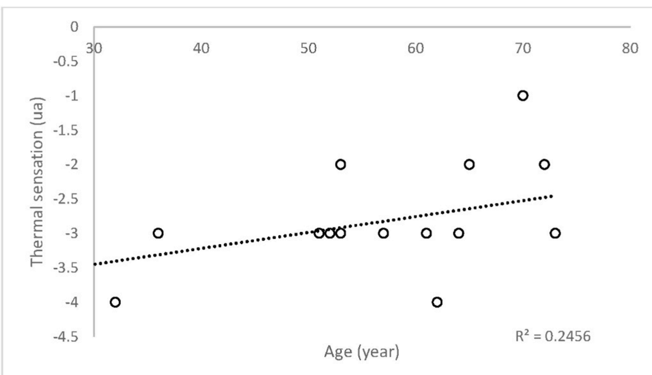

Fig. 5. Correlation between age and thermal sensation (* = $p < 0.05$).

undergoing WBC exposure should be considered when designing protocols.

We also assessed participants' perceived temperature and thermal sensation, as perceived cold sensation may be a key factor in the adaptive response to cryostimulation. However, it remains unclear whether the hypothalamic response to cold is influenced more by the objective afferent signals from skin thermoreceptors or by the subjective interpretation of these signals [4]. The perceptual interpretation of this cold stimulus is likely influenced by individual morphological and ethnological characteristics. Interestingly, our study also suggests that age may influence cold perception (Fig. 5). Indeed, it appears that elderly have a poorer perception of temperature variations which has previously been interpreted to be due to skin aging, alteration of the peripheral nervous system and reduction of skin vascularization [8].

The discrepancy between the nominal chamber temperature and the temperature actually recorded during exposure may be surprising and could be seen as a limitation of the study. However, it should be remembered that the temperature varies considerably when the chamber is empty or occupied. The temperature inside the chamber increases rapidly when a subject enters the chamber. This effect is amplified further when obese patients are inside the chamber, as they occupy a large proportion of the cabin volume. Therefore, it is impossible for the cooling system to regulate the temperature inside the chamber quickly. Another issue is where the temperature is measured: close to the subjects being exposed or close to the chamber walls, at the bottom or top of the chamber. The temperature is colder close to the walls and also at the bottom of the chamber because cold air is heavier than warm air. This can be partially resolved by using special fans to homogenise the temperature in the chamber [1]. It is nevertheless rare for the temperature inside the chamber to be checked, and discrepancies are therefore never reported. However, two recent publications indicate that the clinical impact of cryostimulation may not be entirely dependent on the temperature inside the chamber, but rather on the drop in skin temperature [10] [11]. Accordingly, we measured the skin temperature and skin temperature drop of our obese patients.

This study shows that WBC does not cause a dangerous decrease in skin temperature in people with severe obesity. This is particularly important given the potential of WBC to alleviate obesity-related symptoms (e.g. reduced systemic inflammation, increased irisin production, and improved metabolic regulation). However, future research should include larger sample sizes to observe the different effects of exposures depending on factors such as sex, age and body shape, and to further individualize exposure protocols accordingly.

CRediT authorship contribution statement

Romain Bouzigon: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Jacopo M. Fontana:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Marjorie Delecray:** Investigation, Data curation. **Paolo Pitera:** Investigation. **Federica Verme:** Investigation. **Angelo Alito:** Investigation. **Benoit Dugué:** Writing – review & editing, Conceptualization. **Paolo Capodaglio:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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