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Original Article

Repeated cryostimulation improves position sense and simple reaction time

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Abstract. [Purpose] Whole body cryotherapy has been shown to have many benefits, yet nothing is known if and how this modality can improve neuromuscular performance and retain those improvements. [Subjects and Methods] Joint position sense based on the bilateral knee joint matching test and simple reaction time was investigated in 25 young healthy adults who underwent an extended period of whole body cryostimulation. The measurements were taken at baseline and after 10, 20, and 30 whole body cryotherapy sessions, with three days elapsing after the last treatment, and comparing the results with 24 control subjects. [Results] Only when 20 sessions were completed did joint position sense and simple reaction time improve in the intervention group. After 30 sessions, the outcome was similar. Equal results were found at baseline and after 10 sessions in both groups, but the intervention group outstripped controls after 20 and 30 sessions in both joint position sense and simple reaction time. [Conclusion] These results indicate that the common standard of 10 sessions is insufficient, while approximately 20 sessions of whole body cryotherapy may efficiently enhance neuromuscular performance with an ability to sustain the effects for at least three days.

Key words: Whole body cryotherapy, Proprioception, Neuromuscular performance

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INTRODUCTION

Improvement of motor skills has a fundamental significance in sports and therapy, and every new approach that may enhance the performance outcome measures deserves the attention of researchers. Whole body cryostimulation (WBC) is one such modality, has been commonly used for decades, and was shown to have advantageous physiological and psychological effects on humans. Even a single session in a climatic chamber alleviates pain and fatigue, reduces edema and inflammation, creates a good mood, and increases vigilance and arousal[1, 2)].

A common WBC treatment consists of multiple exposures to cold, which magnifies its therapeutic effect[3)]. This evidence was recently supported by Lubkowska et al.[4)], who reported much more favorable changes in lipid profile and the activity of antioxidant enzymes after 20 WBC sessions as compared to 10 sessions. Similar results were presented by Miller at al.[2)] and Woźniak et al[5)].

Given this evidence, it can be hypothesized that repeated WBC gives rise to favorable conditions for optimizing neuromuscular control and, thus, may amend performance in selected sensorimotor tasks, in particular after a reasonable time after the last session ends. If this proposition became true, the spectrum of possible applications of cryostimulation would expand by providing new potential benefits of this therapeutic modality.

The purpose of this study was to determine the effect of repeated WBC sessions on the results of two simple neuromus-

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cular tests in young healthy adults: simple reaction time (SRT) and joint position sense (JPS). Based on Lubkowska et al.[4], Szygula et al.[6], and their results regarding the optimal number of exposures to produce beneficial hormonal changes, it was hypothesized that a standard treatment (10 WBC sessions) would have no effect on the tests scores while a longer treatment (20 or 30 WBC sessions) would decrease simple reaction times and reduce joint positioning errors.

SUBJECTS AND METHODS

Forty-nine healthy men aged 22.5 (0.7) years participated after giving informed consent to the research protocol. Twenty-four subjects constituted the control group while the remaining 25 subjects served as the research group (Table 1). None of the subjects had contraindications to whole-body exposure to cold or reported musculoskeletal or neurological disorders and/or physical injury at the time of the experiment. The members of the intervention group were examined by a physician prior to the procedure. No participants had ever been subjected to WBC. The study protocol was approved by the Bioethics Committee. The WBC treatments were conducted in a cryotherapeutic chamber (type CR-2011 CH-1/A) consisting of a vestibule and main chamber. The group was subjected to 30 sessions of daily WBC treatments for 6 consecutive weeks starting each Monday, with breaks on Saturdays and Sundays. Each session lasted 3.5 min: 30 s in the vestibule at a temperature of −60°C and 3 min in the main chamber at a temperature of −120°C. The participants were dressed in shorts, knee-length socks, gloves, wooden clogs, and headbands to protect the ears. Just prior to entering the chamber, the participants placed surgical masks over their faces to protect airways and dried their bodies thoroughly with a towel to remove sweat. While in the chamber, the participants were asked to walk slowly without any rapid body movements. According to the main purpose of this study, JPS and SRT were measured 4 times using the procedures recommended for physiological profile assessment by Lord et al[7]. Trials in the intervention group were performed on Mondays before the first, eleventh, and twenty-first sessions, with the last test performed on Monday after the last WBC session. This distribution of measurements was convenient for later comparisons of the JPS and SRT performances measured after a two-day retention period with the baseline values. The performance of participants from the control group was examined in the same way, i.e. 4 consecutive trials separated by 2-week intervals.

For the purpose of JPS evaluation, a method involving a lower limb matching task was administered[8]. Participants were seated with their eyes closed and asked to align their lower limbs simultaneously on either side of a vertical clear acrylic sheet (60 × 60 × 1 cm) inscribed with a protractor and placed between their legs. To prevent confounding of the results from limited motion at the knee joint, the examiner ensured that participants matched their limbs near the midrange of knee joint motion. Any difference in aligning the lower limbs (indicated by disparities in matching the great toes on either side of the acrylic sheet) was measured in degrees. Following 2 practice trials, the average of 5 experimental trials was recorded.

Simple reaction time was assessed in milliseconds using a hand-held electronic timer[9]. The light stimulus was located adjacent to the response switches and was bright (supra-threshold) to ensure that the tests were not influenced by the participants' visual acuity. The timer had a built-in variable delay of 1 to 5 seconds to remove any cues that could be elicited from the test administrator commencing each trial by pressing the "start" button. A modified computer mouse was used as the response box for the finger press task. Five practice trials were undertaken, followed by 10 experimental trials used to compute the average SRT for each subject. A two-way mixed ANOVA was used to study the effects of group and time on SRT results, which had a normal distribution. Tukey post-hoc analysis was applied to test for differences in SRT between baseline data and the remaining tests and between the two groups in the consecutive trials. Because the JPS results deviated markedly from normality, Friedman's Anova was used to test for differences in JPS across 4 trials. The Wilcoxon and Mann-Whitney U tests were performed to examine the differences in JPS between selected trials and both groups, respectively. The level of significance was set at $p<0.05$.

RESULTS

Friedmann Anova indicated a significant effect of time on JPS in the investigated group ($\chi^2(3)=8.57$, $p=0.035$) and no effect in the control group. Post-hoc analysis indicated that 10 WBC sessions did not change the baseline JPS while 20 and 30 sessions improved JPS ($Z=2.78$, $p<0.006$ and $Z=2.98$, $p<0.003$, respectively). There were no intergroup differences in

Table 1. Means (SD) of the simple reaction time (SRT, in msec.) and medians (interquartile range) of the joint position sense (JPS, in °) before and after 10, 20, and 30 whole body cryostimulation sessions in the research and control groups

	Before	10 sessions	20 sessions	30 session
RT research	230.7 (32.9)	223.1 (19.8)	209.3 (18.4)	206.8 (17.1)
RT control	239.4 (36.7)	236.3 (28.3)	233.0 (30.9)	242.5 (31.3)
JPS research	0.40 (0.80)	0.20 (0.40)	0.00 (0.20)	0.00 (0.00)
JPS control	0.20 (0.60)	0.20 (0.60)	0.50 (0.40)	0.40 (0.70)

JPS at baseline and after 10 sessions. However, after 20 and 30 sessions, the experimental group presented better JPS results (Table 1) than the control group (Z=2.71, $p<0.007$ and Z=2.52, $p<0.012$, respectively).

There were two main effects on SRT: group ($F[1,47]=9.71$, $p<0.004$) and time ($F[3,141]=5.44$, $p<0.002$). These effects plainly reflected the strong decrease in SRT in the experimental group after 20 and 30 WBC sessions (Table 1). Additionally, there was a group * time interaction ($F[3,141]=5.42$, $p<0.002$) which accounted for a gradual improvement in SRT over time in the experimental group as opposed to a lack of this effect in the control group (Table.1). Post-hoc analysis revealed that SRT after 20 sessions and SRT after 30 sessions were reduced compared to SRT at baseline in the experimental group ($p<0.001$ and $p<0.0002$, respectively). With regard to intergroup differences, only SRT after 20 sessions and SRT after 30 sessions were reduced in the experimental group compared to the control group ($p<0.02$ and $p<0.00001$, respectively).

DISCUSSION

Our results are not directly comparable to those of other authors because the research into the relationship between the increasing number of WBC exposures and neuromuscular performance, particularly after a considerable retention interval, does not exist. In the majority of studies, the emphasis was placed on the assessment of this performance immediately after exposure to cryogenic temperatures. These reports are inconsistent, ranging from slight improvement to modest deterioration in several neuromuscular abilities. Yet, all these changes were temporary indicating that WBC is not harmful and does not induce general or specific negative effects[10, 11]. Furthermore, the participation in prolonged WBC treatment counterbalanced the transient adverse effects confirming an efficient adaptation to repeated cold stimuli[3, 12]. These results warranted more systematic studies on the relationship between the number of WBC treatments and the desired outcomes. The pertinent work revealed that efficient adaptation to extreme cold is associated with significant hormonal changes (e.g. enhanced levels of endorphins and adrenaline, whose dynamics increase with the number of treatments)[4]. It has been reported that advantageous changes in lipid profile and the activity of antioxidant enzymes occurred after at least 10 to 20 sessions of cryostimulation[4]. Our results in the present study are comparable, indicating that a similar number of sessions are necessary to improve JPS and SRT.

However, despite the increasing number of studies reporting the effect of cryostimulation on hematological indices and hormone secretion, which may account for the central effects of long-term cold exposure, their results are limited and often inconsistent. Such findings cannot directly add to our understanding of the relationship between the cold stressor and neuromuscular performance, as their physiological significance has yet to be elucidated. Still, these results provide growing evidence of the association between the increased dynamics of biochemical changes and cold exposure duration[3, 4]. Even if the direction of these changes is variable and unpredictable, their growing intensity may account for the onset of the transition between the system's initial state and subsequent adaptation. This adaptation or acclimatization to repeated cold stimuli helps restore the organism to optimal functioning after perturbations by external stressors.

As an example, Lubkowska et al.[4] reported an increase in catalase activity in erythrocytes after 10 treatments of WBC with a subsequent decrease after 20 treatments. A plausible explanation of these varying levels of different hormones is still lacking, but it may indicate reciprocal adjustment between several biochemical variables in an effort to optimally adapt the organism to a stressor. Such an adaptation seems to be nonspecific and not limited to a particular stressor; however, it may result in an advantageous effect on the whole organism, including better proprioception and simple reaction time.

Proprioceptive acuity gains are commonly reported in scientific literature. It has been shown that elderly persons and younger adult patients with various motor disabilities may benefit from the application of different training modalities. However, similar results in the healthy population are less common, probably indicating that further improvement in proprioception is difficult and requires adequate specialized training, Adedoyin et al.[13] and Cuğ et al.[14] reported gains in proprioception in young adults from exercises performed on a wobble and Swiss board, respectively. Similar results were obtained by Pánics et al.[15] following a specific proprioceptive training program and by Han et al.[16] who used vibration stimuli to leg muscles.

The common characteristic of the four latter modalities is a sustained high level of dynamic, unpredictable challenge to muscles, tendons, and receptors, which, after an adequate time, leads to better performance and adaptation to training. Though the action of a cold stressor on soft tissue is entirely different, there are at least 2 similarities between proprioceptive loading and low temperature effects on the final outcome. First, a large number of proprioceptors receive unusual, uncertain, and/or noisy information regarding body segment alignment. Therefore, the CNS searches for alternative, more credible inputs that have the capacity to participate and play important roles, even after the training or cold exposure is terminated. Secondly, the increase in blood circulation, which is typically associated with increased physical activity, shows a similarly elevated level during and just after cold application[6].

Thus, it seems plausible to propose that persons whose afferent system was subjected to numerous disturbances from a cold stressor discovered some alternative mode of operation due to the high adaptability of the CNS. For instance, Wassinger et al.[17] did not find changes in active joint position replication while applying shoulder cryotherapy and explained this finding as a compensatory activity of mechanoreceptors which were not affected by the application of the cryotherapy. The newly recruited mechanoreceptors would supplement the activity of the original ones had such compensation been converted into adaptation, promoting enhanced proprioceptive acuity. This process requires repeated confrontation with cold stimuli over time; therefore, positive results were not seen in those undergoing less than 20 WBC sessions. With regard to SRT, it has been shown that reaction time is fastest with an intermediate level of arousal, and deteriorates when the participant is either too relaxed or too tense. An optimal level of arousal was postulated to explain better performance during the reaction time test[18, 19]. Thus, the elevated arousal following the series of WBC may have facilitated the ability of our participants to discriminate between relevant and extraneous cues during performance and to react faster to the visual stimuli. One last factor that may have supported the improved neuromuscular performance of our participants was better nourishment and oxygenation of body organs, which is associated with body cooling from vasoconstriction[6]. In cryotherapy, vasoconstriction leads to peripheral blood shunting, which results in larger blood flow and oxygen delivery to other tissues and temporarily enhances their function. A cumulative effect of 20 or 30 WBC sessions may have increased the capacity of systems vital for the JPS and SRT tasks and contributed to the outcome improvement.

This is the first study to demonstrate that repeated short-term exposure of the whole body to cryogenic temperature may promote better neuromuscular performance, provided a sufficient number of sessions are performed. In conclusion, the number of prescribed sessions of WBC should be re-examined to better serve the needs of patients. Due to the reasonable retention period (3 days) of the enhanced performance, these results may also be of some interest to athletic trainers by means of accelerating the return of injured athletes to full practice and thereby facilitating optimal preparation for competition.

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