Thermal sensation and comfort in women exposed repeatedly to whole-body cryotherapy and winter swimming in ice-cold water

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Abstract

Whole-body cryotherapy (WBC; \(-110^\circ\text{C}\)) and winter swimming (WS) in ice-cold water are severe ambient cold exposures, which are voluntarily practiced by humans in minimal clothing. The purpose was to examine thermal sensation and thermal comfort associated with WBC and WS. Twenty women similar in body mass index, age, physical activity, and use of hormonal contraception were pairwise randomized either to the WBC group or the WS group. The duration of each WBC exposure was 2 min, which was repeated three times per week for 3 months (13 weeks). Similar exposure frequency was used for the WS group, but each exposure lasted 20 s in outdoor conditions. Thermal sensation and comfort were asked with standard scales. After WBC, 65\% of the thermal sensation votes were ‘neutral’ or ‘slightly cool.’ After WS, 81\% of the thermal sensation votes were ‘warm,’ ‘neutral,’ or ‘slightly cool.’ Majority of comfort votes immediately after exposures in WBC group (98\%) and in the WS group (93\%) were ‘comfortable’ or ‘slightly uncomfortable.’ Thermal sensation and comfort became habituated in both groups at an early stage of trials, but the changes were less conclusive in WS group due to variable conditions outdoors. In the WBC group, cold sensation was less intense already after the second exposure. In conclusion, repeated exposures to WBC and WS in healthy women were mostly well tolerated and comfortable. The results indicate that during repeated severe whole-body cold stress of short duration, thermal sensation and comfort become habituated during the first exposures.

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1. Introduction

Repeated cold stress in humans leads to physiological adjustments, which can be characterized as habituation and/or acclimation/acclimatization [1]. The former presents a diminished response and the latter an enhanced or altered response to the cold stimulus. The perceptual and affective adjustments to repeated cold stress have, however, received less attention [2]. Older studies carried out on Antarctic expeditions indicated that at the same activity level and even with lighter clothing, the persons felt warmer at the end of expedition compared to the beginning despite similar outdoor weather [3,4]. Later, in laboratory conditions, cold discomfort was reduced with repeated whole-body exposure to cold air [2,5] or cold water [6].

In whole-body cryotherapy (WBC), patients are exposed to very cold air (\(-110^\circ\text{C}\)) for 1–3 min in minimal clothing. It is mainly used to alleviate inflammation and pain in, for example, arthritis [7], osteoarthritis [8], and fibromyalgia [9]. Winter swimming (WS), i.e., swimming or immersion in ice-cold water, is practiced in northern countries, where seas, lakes, and rivers freeze during the wintertime. The reported reasons for WS include improved general well-being and self-treatment or body hardening against respiratory tract infections and musculoskeletal pains [10]. WBC and WS are probably the most severe ambient cold exposures, which are voluntarily practiced by lightly dressed humans.

The present study was undertaken to examine (1) thermal sensation and thermal comfort ratings associated with WBC...
and WS in healthy women, and (2) how the ratings are changed with repeated exposures over 3 months.

2. Materials and methods

2.1. Subjects

Twenty healthy women (aged 35–45 years) with a normal body weight (body mass index < 28) and without hormonal substitution were chosen for the study from 42 volunteers, who were reached through an announcement in a local newspaper. The subjects were matched pairwise to have similar body mass index, age, physical activity, and use of hormonal contraception. The pairs were then randomly assigned either to the WBC group (n = 10) or the WS group (n = 10). None of the subjects had practiced WBC or WS regularly before the study or tried them during that winter. The subjects were moderately physically active, and no outdoor workers were included. Their characteristics are shown in Table 1.

Before the study, all subjects went through a medical check-up including a resting ECG. The protocol and procedures were done according to Helsinki Declaration and were approved by the Ethical Committee of the Hospital District.

2.2. Procedures

The study was carried out during the spring 2002. The WBC group had three 2 min exposures per week for 3 months at −110 °C in a specially built, temperature-controlled unit (Zimmer, Elektromedizin). The unit has three chambers, where the subject passes through the first chamber (−10 °C) and the second chamber (−60 °C) before coming into the therapy chamber. During WBC, the subjects wore a bathing suit, surgical mask, cap, gloves, socks, and shoes. In the therapy chamber, the subjects were instructed to slightly move their fingers and legs. Further details on WBC treatment can be found elsewhere [11].

The WS group had three exposures per week for 3 months (February, March, and April) in a small pond in the hospital area. A mechanical pump in the pond stirred the water, by which the hole in the ice was kept open all the time. By the pier, there was a sauna building with a dressing room at normal room temperature where the subjects put on their bathing suits. The WS was done without sauna bath. The subjects were instructed to stay still in the water for ca. 20 s immersed to the neck (‘head-out immersion’). In order to achieve this, they were asked to calculate slowly from 1 to 20 while immersed in the water. The personnel of the hospital’s WBC unit organised the exposures for the WBC group, but WS group carried out the exposures by themselves according to the instructions.

When humans are exposed suddenly to severe cold stress, especially water, they may experience a ‘cold shock,’ which is reduced rapidly with repeated cold stress [12]. To avoid this, the first 2-min exposure in the WBC group was at −10 °C, and the second at −60 °C. Similarly, the WS group were asked just to make a dip in the water during the first and second visit.

Subject’s height and weight were measured before and after the 3 months’ interventions, and body mass index was calculated. In addition, skinfold thickness was measured at four sites (biceps, triceps, subscapular, and suprailiac) with the Holtain skinfold caliper (Holtain, England). The subjects were asked not to change their physical activity habits during the study period.

The subjects rated their thermal sensation with a nine-point standard scale [13] before and immediately after WBC and WS (‘How are you feeling now?’ 4 = very hot, 3 = hot, 2 = warm, 1 = slightly warm, 0 = neutral, −1 = slightly cool, −2 = cool, −3 = cold, −4 = very cold). Thermal comfort was rated [13] immediately after exposures with a five-point scale (‘Do you find this,’ 0 = comfortable, 1 = slightly uncomfortable, 2 = uncomfortable, 3 = very uncomfortable, 4 = extremely uncomfortable). In the dressing room, each subject in the WS group had a diary in which she self-recorded the ratings. The subjects were instructed to relate their sensations to the time of reporting.

In addition, after each exposure WS group recorded outdoor air temperature, water temperature near the surface, and weather condition with a four-point scale (1 = sunny, 2 = half

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Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Winter swimming (n = 10)</th>
<th>Cryotherapy (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>38 (3)</td>
<td>39 (2)</td>
</tr>
<tr>
<td>Height, cm</td>
<td>167 (7)</td>
<td>166 (6)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>68 (14)</td>
<td>67 (9)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>24 (3)</td>
<td>24 (2)</td>
</tr>
<tr>
<td>Sum of four skinfolds, mm</td>
<td>62 (23)</td>
<td>56 (16)</td>
</tr>
</tbody>
</table>
cloudy, 3 = cloudy, 4 = rain/snowing). As shown in Fig. 1, the weather improved progressively during the spring being mostly sunny or half-cloudy during the last weeks (weeks 10–13). Similarly, the air and water surface temperatures were higher during the last weeks of WS intervention (Fig. 2).

The data are presented in frequency histograms or as averages ± S.E. For the analysis, the values were averaged for each week (2–13) and compared to the first exposure. The differences in thermal sensation and comfort between the two cold exposure groups with time were analyzed by the two-way analysis of variance (ANOVA) with repeated measures on time. Because during the last weeks the increases in air and water temperatures during WS were unexpectedly more pronounced, the group comparison was limited to first 8 weeks. In addition to the pooled data analysis, the results were analyzed separately for both groups by the one-way ANOVA with repeated measures on time. Comparisons of different time points against the first exposure were done with the Duncan’s test. The results were considered statistically significant, when \( P < .05 \).

### 3. Results

All subjects completed the interventions successfully. In WBC and WS group, the total number of exposures were 387 and 386, respectively. The target was 390 exposures for each group including the first two familiarization visits. No change in body weight or BMI was observed in either group, but the average sum of skinfolds was decreased slightly \( (P < .05) \) in both groups (2.5 mm in WBC group and 3.7 mm in WS group).

#### 3.1. Thermal sensation

The distribution of thermal sensation votes before and after WBC and WS for all exposures is shown in Figs. 3 and 4. Mostly, thermal sensation before the exposures was ‘neutral’ or warmer in WBC (90.4%) and WS groups (95%). In WS group, 49% of thermal sensation votes were ‘warm,’ which in part may be due to exercise as some persons preferred to walk from home to the pond. According to two-way ANOVA, the thermal sensations before exposures did not change with successive weeks, but the WS group felt significantly \( (P > .05) \) warmer compared to WBC group.

In WBC group, the thermal sensation after the exposures was in most cases (65.4%) ‘neutral’ or ‘slightly cool’ (Fig. 4). Fewer exposures (16.2%) were felt cooler after WBC. After WS, thermal sensation was mostly (81.2%) rated as ‘slightly cool,’ ‘neutral,’ or ‘warm.’ Only few exposures (3.4%) were felt cooler or colder. In both groups, only three exposures in each group were felt ‘very cold’ afterwards.

On average, the WBC group felt cooler \( (P < .05 \) for group factor) immediately after the exposures compared to WS group (Fig. 5). However, this group difference was no more significant, when the preexposure values were taken...
into account by analyzing the deltas (pre-post at each point of time) with ANOVA. Pooled data analysis indicated that cold sensation after the exposures became less intense with time \( (P < .05) \) already during the second week.

When analyzed separately, both WS \( (P < .05) \) and WBC group \( (P < .01) \) exhibited a significant increase in thermal sensation after the exposures during successive weeks (Fig. 5). In the WS group, the variability after the first exposure was rather high and the post hoc testing did not show any differences between weeks 2 and 13 and the first exposure.

In the WBC group, thermal sensation immediately after the exposures was significantly higher during each week \( (2–13) \) compared to the first exposure. A further analysis of the first 10 exposures in WBC group showed that cold sensation was less intense already after the second cold exposure \( (P < .05) \).

### 3.2. Thermal comfort

Majority of exposures in WBC group (98.2\%) and in the WS group (92.8\%) were rated ‘comfortable’ or ‘slightly uncomfortable’ (Fig. 6). Only one exposure in the WS group was rated ‘very uncomfortable.’ Analysis of the pooled data showed that thermal comfort immediately after exposures increased with successive weeks \( (P > .05) \), but the groups did not differ. In pooled data, the increase in comfort after the exposures was observed already during the second week \( (P < .01) \). Separate analysis of the groups did not give any systematic additions to the results of the pooled data analysis.

### 4. Discussion

The present results showed that the majority of WBC and WS exposures were well tolerated and comfortable when assessed immediately after the exposures. Interestingly, the ratings of thermal sensation and comfort were rather close to those recommended for an acceptable indoor climate [14].

One possible explanation is that core temperature is not changed during such short exposures, and thus autonomic effector responses (e.g., shivering) are not considerably evoked. Recently [11], we observed no change in rectal temperature during 2 min WBC whereas mean skin temperature decreased to ca. 12 °C. Similar data are not available on WS, but probably the skin temperatures (except head) approximate very rapidly water temperatures. Therefore, WS is probably a colder ambient exposure than WBC, which justifies the shorter 20-s exposure time. The hormonal responses to repeated WBC and WS seem to be rather similar (Leppäläuto et al., unpublished observations).

Also, motivational factors may partly be involved in the obtained results because our subjects were very interested to try the cold treatments. WS is gaining popularity as, according to a telephone survey made a marketing company (Gallup Finland), it was estimated that there are over 80,000 regular winter swimmers in Finland, ca. 320,000 persons had tried it once during the previous year, and ca. 1.6 million people were interested in trying that. Seventy-six percent of respondents felt that WS is a meaningful habit. High motivation may affect early reaction, anticipation, and compensation mechanisms during cold stress [15].

Leppäläuto et al. [2] exposed healthy men to cold air (2 h in a 10 °C room) daily for 11 days demonstrating that thermal sensations became habituated already after the first or second exposure. Jansky et al. [6] exposed young men to cold water (1 h in 14 °C water) three times per week for 4–6 weeks. They observed an attenuation in cold sensation after fourth exposure, and further immersions increased this response. Though the scales in these studies were somewhat different from ours, the average change in habituation of thermal sensation was rather similar (ca. one point in the scales) in all of these studies. As shown in these studies [2,6], we also observed an early habituation in thermal sensation, which was further enhanced during the following weeks. Similarly, thermal comfort votes improved after exposures during successive weeks in both groups, and improvement was seen already during the second week in pooled data.

Clear conclusions can, however, only be based on results from the controlled WBC trials, where the habituation of thermal sensation occurred already during the second exposure. Even the general response pattern of WS group was rather similar to WBC group, the variable outdoor conditions, uncontrolled activity before WS, and duration of exposure (self-timing) may all had an influence on the possible habituation. We chose to use outdoor exposures instead of indoor pool because that is the natural way people do practice the WS.

The present study was carried out in the latter part of winter season, and thus the subjects were probably already somewhat habituated to cold weather. Whether the habituation in cold sensation to cold season in everyday activities was enhanced cannot be answered by our study. Fanger et al. [16] showed that experienced winter swimmers did not prefer significantly different room temperatures than controls or cold-storage meat packers while wearing a standard uniform at rest. This may mean that perceptual habituation to cold stress is an exposure-specific phenomenon.
In the study by Jansky et al. [6], average skinfold thickness increased, however not significantly, after 4 weeks of repeated cold immersion in young sportsmen. Contrary to that, in our study a small but significant decrease in average skinfold thickness was observed in both groups of women. This difference between studies may be due to gender or changes in dietary or physical activity habits, though our subjects were asked to maintain their lifestyle as it was before participation.

In conclusion, repeated exposures to WBC and WS in healthy women were mostly well tolerated and comfortable. This may be due to the short exposure times without significant core cooling with concomitant autonomic effector responses and/or psychological factors. The results indicate that during repeated severe whole-body cold stress of short duration, thermal sensation and comfort become habituated during the first exposures.

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