

# Lung function after acute and repeated exposures to extremely cold air (−110°C) during whole-body cryotherapy

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## Summary

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Whole-body cryotherapy (WBC) is one mode of cold therapy, during which rheumatic patients are exposed to very cold air (−110°C) in minimal clothing. It is also proposed to have a bronchodilatory effect. The aim was to examine the effects of WBC on lung function in healthy humans after acute and repeated exposures. Twenty-five healthy, non-smoking subjects participated in the study. They were exposed to WBC for 2 min three times per week for 12 weeks. The peak expiratory flow rate (PEF) and forced expiratory volume in 1 s (FEV1) were measured before and after (at 2 and 30 min) the first WBC, and then similarly at 4, 8 and 12 weeks. At all time points, after 30 min of the WBC the PEF values were slightly lower compared with values before the WBC, and the reductions reached statistical significance at 1 month ( $5.1 \pm 1.2\%$ ), and at 3 months ( $3.2 \pm 1.7\%$ ). After 30 min of the first WBC, the FEV1 was significantly reduced by  $2.3 \pm 0.8\%$ , but no other changes were observed during the study. In conclusion, the WBC induced minor bronchoconstriction in healthy humans instead of proposed bronchodilatation. The WBC seems not to be harmful for lung function, but should be used with caution in susceptible individuals.

## Introduction

A sudden exposure to cold water or air (local or whole-body) may elicit several effects on the respiratory system, such as a gasp response, an increase in ventilation and bronchoconstriction (Keatinge & Nadel, 1965; Josenhans *et al.*, 1969; Berk *et al.*, 1987; Koskela & Tukiainen, 1995). At low levels of ventilation, stimulation of the face (trigeminal area) seems to be the main trigger for airway narrowing to a similar degree in healthy subjects and in patients with obstructive lung disease (Berk *et al.*, 1987; Koskela & Tukiainen, 1995). At elevated levels of ventilation, the bronchoconstriction is much stronger in patients possibly also due to direct cooling or drying effect on airway mucosa (Berk *et al.*, 1987).

Whole-body cryotherapy (WBC) is one mode of cold therapy, during which patients are exposed to very cold air (−110°C) in minimal clothing (a bathing suit, cap, gloves, socks, shoes and a surgical face mask). It is mainly used to alleviate inflammation and pain in arthritis, osteoarthritis, and pain relief in fibromyalgia (Metzger *et al.*, 2000), and also to improve lung function in asthmatics. Yamauchi (1988) has described that in Japan very intense cold exposures (up to −175°C) for several weeks improved lung function in asthmatic

patients. Similar experience-based results were reported in asthmatic children after swims in cold seawater (Menger, 1986). However, supportive data or the physiological basis for these claims is lacking. Engel *et al.* (1989) found that in rheumatic patients and healthy subjects WBC may lead to a brief and transitory increase in peak expiratory flow rate (PEF) immediately after the exposure.

The aim of the present study was to examine the effects of WBC on lung function in healthy humans after acute and repeated exposures. Although, the present study was a part of a project undertaken to ensure the safety of WBC for patients and personnel, it also allowed us to test the hypothesis that WBC improves lung function.

## Methods

Eighteen females and seven males participated in the study. They were all healthy, and non-smoking. Their mean ( $\pm$ SD) physical characteristics were the following: age  $39 \pm 10$  years, height  $169 \pm 6$ , body mass  $68 \pm 13$  kg and body mass index  $24 \pm 3$ . The ethical committee of the local hospital district approved the study protocol and informed consents were obtained from each subject.

The subjects had three 2 min WBC exposures per week for 3 months in a temperature controlled unit (Zimmer, Elektromedizin, Germany), where they passed through the first ( $-10^{\circ}\text{C}$ ) and second room ( $-60^{\circ}\text{C}$ ) before the therapy room (for details see Westerlund et al., 2003). To minimize the 'cold shock' effect, the subjects were exposed first to  $-10^{\circ}\text{C}$ , and then to  $-60^{\circ}\text{C}$  for 2 min each on separate days before the actual WBC. PEF, and forced expiratory volume in 1 s (FEV1) were determined in triplicate from the maximal flow-volume recordings (Vitalograph; Vitalograph Ltd, Buckingham, UK) before and after (2 and 30 min) the WBC. The best effort was chosen for analysis. The baseline values before WBC at different time points and at each time point before, and 2 and 30 min after the WBC were analysed for gender and time effects by two-way ANOVA for repeated measures. In the case of statistical significance, post hoc testing was performed with the Student's *t*-test for paired observations using the Bonferroni adjustment. Because no significant gender-dependent differences were found in the responses, the results of men and women were combined.

## Results

The baseline values of PEF and FEV1 measured before the WBC did not change during the 12 weeks, and the values were in the reference zone for healthy lung function (Tables 1 and 2).

During the 12 weeks, the PEF values after 2 minutes of the WBC were not significantly different from pre-exposure values

**Table 1** Peak expiratory flow rate (PEF) in  $\text{l min}^{-1}$  before and after whole-body cryotherapy (WBC).

Exposure/ testing time	PEF before WBC	PEF 2 min after WBC	PEF 30 min after WBC
$-10^{\circ}\text{C}/\text{week 1}$	514.6 (33.3)	503.7 (32.8)	502.2 (30.3)
$-60^{\circ}\text{C}/\text{week 1}$	505.2 (27.7)	505.6 (29.8)	489.6 (27.6) <sup>a</sup>
$-110^{\circ}\text{C}/\text{week 1}$	505.3 (27.6)	499.1 (28.0)	483.5 (25.8)
$-110^{\circ}\text{C}/\text{week 4}$	517.2 (27.4)	515.0 (27.6)	491.1 (27.0) <sup>a</sup>
$-110^{\circ}\text{C}/\text{week 8}$	510.4 (26.1)	508.5 (29.0)	498.0 (27.8)
$-110^{\circ}\text{C}/\text{week 12}$	512.6 (27.7)	503.6 (26.4)	493.7 (25.9) <sup>a</sup>

The values are mean (SEM) ( $n = 25$ ).

<sup>a</sup>Significantly different ( $P < 0.05$ ) from values measured before WBC.

**Table 2** Forced expiratory volume in 1 s (FEV1) in litres before and after whole-body cryotherapy (WBC).

Exposure/ testing time	FEV1 before WBC	FEV1 2 min after WBC	FEV1 30 min after WBC
$-10^{\circ}\text{C}/\text{week 1}$	3.38 (0.13)	3.38 (0.14)	3.40 (0.14)
$-60^{\circ}\text{C}/\text{week 1}$	3.40 (0.13)	3.42 (0.14)	3.36 (0.13)
$-110^{\circ}\text{C}/\text{week 1}$	3.37 (0.13)	3.31 (0.12)	3.29 (0.12) <sup>a</sup>
$-110^{\circ}\text{C}/\text{week 4}$	3.35 (0.12)	3.36 (0.12)	3.33 (0.13)
$-110^{\circ}\text{C}/\text{week 8}$	3.35 (0.12)	3.33 (0.14)	3.34 (0.14)
$-110^{\circ}\text{C}/\text{week 12}$	3.39 (0.13)	3.32 (0.12)	3.30 (0.14)

The values are mean (SEM) ( $n = 25$ ).

<sup>a</sup>Significantly different ( $P < 0.05$ ) from values measured before the WBC.

at any point of time (Table 1). After 30 min of the WBC the PEF values were slightly lower compared with values before the WBC at all time points, and the reductions (mean  $\pm$  SEM) reached statistical significance ( $P < 0.05$ ) at 1 month ( $5.1 \pm 1.2\%$ ), and at 3 months ( $3.2 \pm 1.7\%$ ).

During the first exposure to the WBC, the FEV1 was slightly ( $2.3 \pm 0.8\%$ ,  $P > 0.05$ ) reduced after 30 min of the WBC, but no other changes were observed during the study (Table 2).

## Discussion

Engel et al. (1989) found that immediately after WBC (with mask), PEF in rheumatic patients and healthy subjects increased significantly compared with pre-exposure values. After 3 min, the values were at the baseline level, similarly as our PEF results at 2 min. In our study, the PEF values were systematically lower than baseline values after 30 min of WBC, but the reductions were minor. In asthmatics the cold-induced effects are maximal within 5–15 min after the exposure, and recovery usually occurs within 30 min to 2 h (Giesbrecht, 1995). Thus, in our study the decreases in respiratory parameters might have been somewhat higher with more frequent measurements.

Forced expiratory volume in 1 s was only slightly reduced after the first WBC despite the extremely cold ambient air. The reductions were small compared to other studies, where the falls in FEV1 have usually been over 10% in healthy humans exposed to facial cold, breathing cold air or both (Keatinge & Nadel, 1965; Josenhans et al., 1969; Berk et al., 1987; Koskela & Tukiainen, 1995). Possibly, the short duration of the WBC, and the use of face mask may explain this finding. The thin paper mask covers the nose, mouth, and cheeks, and therefore presumably gives some protection against cold air effect on face and airways. Also, the subjects were standing quite still, which presumably did not elevate ventilation. At rest, adults preferentially breathe through the nose (Viinimaa et al., 1980), which effectively saturates and warms the inspired air. Although, we do not have data on temperature of the inspired and expired air, the observed minor changes in lung function and the above-mentioned factors indicate that the inspired air was probably warmed and conditioned mostly within the upper airways.

With repeated exposures to WBC the FEV1 did not decrease statistically significantly, which may indicate airway acclimatization through habituation. Haas et al. (1986) found that in asthmatic patients cold air breathing three times per week for 3 months resulted in less pronounced reduction in FEV1 with repeated exposures. Bronchial vascular adaptation, direct airway desensitization or sensory adaptations (reduced vagal activity) were the proposed mechanisms. An important finding in their study (Haas et al., 1986) was that during the 12 weeks most of the patients experienced reduced baseline FEV1 and exacerbation of symptoms indicating a possible airway injury.

Although WBC may induce a transient bronchodilatory effect (Engel et al., 1989), our data did not support the hypothesis that the WBC improves lung function. The WBC induced minor

bronchoconstriction in healthy humans, and therefore it seemed not to be harmful for lung function. However, WBC should be applied with caution in susceptible individuals, such as asthmatics.

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