Arch. Immunol. Ther. Exp. (2012) 60:145–150
DOI 10.1007/s00005-012-0163-4

ORIGINAL ARTICLE

Impact of Different Treatment of Whole-Body Cryotherapy on Circulatory Parameters

Felice Giulio Bonomi · Massimo De Nardi · Aldo Fappani · Viviana Zani · Giuseppe Banfi

Received: 13 March 2011 / Accepted: 19 September 2011 / Published online: 7 February 2012

Abstract Cryotherapy is commonly used as a procedure to relieve pain symptoms, particularly in inflammatory diseases, injuries and overuse symptoms. A peculiar form of cold therapy or stimulation was proposed 30 years ago for the treatment of rheumatic diseases. The therapy consists in the exposure to very cold air in special cryochambers. The air is maintained at temperatures between −110 and −160°C. The treatment was named whole-body cryotherapy (WBC). It consists in a brief exposure to extreme cold in a temperature-controlled chamber. It is applied to relieve pain and inflammatory symptoms caused by numerous disorders, particularly those associated with rheumatic conditions, and it is recommended for the treatment of arthritis, fibromyalgia and ankylosing spondylitis. The aim of this study was to investigate the effects of different treatment of WBC on blood pressure (BP) and heart rate (HR) parameters in adult subjects characterized from non-pathological values of BP. Eighty subjects (36 females, 44 males, age range 19–80 years) submitted to 4–17 WBC applications for a total of 816 treatments were recruited. Immediately before and after each WBC application systolic and diastolic BP and HR were measured and recorded. We did not find significant differences in BP and HR ($p > 0.05$). WBC seems to be safe with respect to unwanted BP and HR alterations for adult patients. However individual monitoring of subjects is recommended over the treatment, but pathological changes of circulatory parameters can be considered rare and occasional.

Keywords Whole-body cryotherapy · Cryochamber · Cryosauna · Blood pressure · Heart rate

Abbreviations

WBC	Whole-body cryotherapy
HR	Heart rate
BP	Blood pressure

Introduction

Cryotherapy is commonly used as a procedure to relieve pain symptoms, particularly in inflammatory diseases, injuries and overuse symptoms. A peculiar form of cold therapy or stimulation was proposed 30 years ago for the treatment of rheumatic diseases (Yamauchi 1986). The cryotherapy consists in the exposure to very cold air in special cryochambers. The air is maintained at temperatures between −110 and −160°C. The treatment was named whole-body cryotherapy (WBC). It is applied to relieve pain and inflammatory symptoms caused by numerous disorders, particularly those associated with rheumatic conditions, and it is recommended for the treatment of arthritis, fibromyalgia and ankylosing spondylitis. In sports medicine, WBC has gained wider acceptance as a method to improve recovery from muscle injury (Banfi et al. 2010).

It is still unknown and ambiguous if changes in core temperatures of the body occur after whole-body cryotreatment,

F. G. Bonomi · A. Fappani · V. Zani
Poliambulatorio BonGi, Orzinuovi, Italy

M. De Nardi (✉)
University of Milan, Milan, Italy
e-mail: massimodenardi@alice.it

G. Banfi
School of Medicine, University of Milan, Milan, Italy

G. Banfi
IRCCS Galeazzi, Milan, Italy

as well as a neuromuscular, cardiovascular and humoral parameters (Dugué et al. 2005; Jansky et al. 1996; Leppäluoto et al. 2008; Wendt et al. 1983). All of these effects are local and systemic, and influence each other. A well-known example is the "cold pressor test", in which changes of cardiovascular parameters occur after local cooling (Buemi et al. 1997). This effect is mediated by neuronal and humoral factors (Di Carli et al. 1997; Victor et al. 1987). According to Jansky et al. (2006), local cooling may have different effects on circulatory and humoral parameters compared to general cooling of the whole body. Taghawinejad et al. (1989b) described an inconsistent influence of WBC at −110°C on core body temperature. In most subjects, a falling core temperature was measured, while in others no change or even a rise of the core body temperature was observed. Obviously, subjects can adapt to the exposure to cold temperatures, as proven by several studies about thermoregulation (Dugué et al. 2005).

General temperature factors like seasonal variations, as described for arctic regions (Leppäluoto and Hassi 1991), or moderate climates (Brennan et al. 1982) can also influence blood pressure (BP) behavior. Also local temperature stimuli may have systemic effects and be dangerous for subjects suffering from a coronary heart rate (HR) disease. Wendt et al. (1983) provoked coronary spasms in patients suffering from heart disease, in some cases even accompanied by ischemic changes of the electrocardiography, both and after the cold pressor test and after the inhalation of cold air. Importantly, this mechanism may differ in normotensive subjects compared to hypersensitive subjects, as Antony et al. (1994) reported. Subjects without hypertension showed a significant vasodilatation of epicardial coronary arteries, while a vasoconstriction was observed in the hypertonic group. These authors concluded that pre-existing arterial hypertension appears to impair the vasodilator response of coronary arteries to a cold pressor test.

Whole-body cryotherapy refers to the exposure of subjects to extreme cold air (−110 to −160°C) for a short time to activate physiological regulatory mechanisms. One of these effects is the change of circulatory parameters after the exposure (Westerlund et al. 2006). A number of possible indications and contra-indications for WBC therapy have been suggested by members of the society of cryo-medicine (Papenfuss et al. 2000). Apparently, some of these criteria were introduced empirically rather than based on scientific studies. Members of this society recommend WBC e.g. for patients with rheumatic diseases, chronic pain, elevated muscular tonus as a result of multiple sclerosis or infantile palsy. They also recommend this therapy for patients suffering from a chronic inflammatory disease involving the gastrointestinal system, respiratory system and locomotor system. In addition, WBC is recommended after exhaustive sport exercise or psychologically caused distress. On the other hand, WBC is contraindicated for patients with severe cardiovascular diseases, or severe untreated arterial hypertension, acute infectious diseases, malignant tumors, seizures, allergic reactions to cold, actual drug abuse and some psychiatric disorders.

To assess the safety of the application of WBC in a cryochamber at the temperature of −120°C and in a cryosauna at the temperature of −140°C, we monitored the BP and the HR in adult subject with normal BP values. Our intention was not to examine the therapeutic effect, but to assess the safety with respect to possible BP alterations of this treatment in clinical practice.

Materials and Methods

The number of the subjects who involved in this study was 80 (44 males and 36 females). Those subjects were the actual population of the cryotherapy center, which were all normotensive and did not have any contraindication to WBC, each with different age, diagnosis and physical activity. The average age of all subjects was 47.35 (±13.96) years with a significant difference ($p < 0.05$) of females being older [52.35 (±12.83) years] compared to males [45 (±13.7) years].

We used a modern cryochamber divided into two sections with different temperatures, starting at a temperature of −60°C followed by a room with −120°C, and a modern cryosauna, equipped with a mobile floor which adapts to the height of each subject, thus the upright user is immersed only to the shoulders with the head out of the level of cold gases, where only one subject for each session was immediately exposed at a temperature of −140°C.

Subjects had their treatment in swimwear. Wooden clogs, gloves, a headband and a facemask were mandatory to prevent the occurrence of frosbites. Subjects during the treatments had to walk on the spot and gently move their limbs. After cryotherapy, examined patients had to do an aerobic work on a treadmill or on an exercise bike for at least 20 min at ambient temperature.

Whole-body cryotherapy treatments were performed three times a week at the same time, between 9 am and 10 am (Tuesday, Thursday and Saturday).

The number of cryotherapy sessions was different from subject to subject, according to their treatment established by the physiatrist. The minimum was 4 and the maximum was 17.

A total of 816 treatments were considered in 80 subjects, where were taken BP reading immediately before and after finishing each WBC application and resting in a sitting position with a clinical mercury manometer (Star; Gima, Italy) with the method of Riva-Rocci and the HR value with an oximeter (Sat-200; Intramed, Italy) by an expert

physician. All measurements after the exposure were made within 10 min, in order to inhibit the return to baseline of BP values (Lubkowska and Szyguła 2010; Lubkowska and Suska 2011).

In our study, the time of exposure could change from time to time according to the decision of the physiatrist who is treating the subject. The minimum time of exposure in the cryochamber was 30 s in the- first room (−60°C) and 90 s in the second room (−120°C), the maximum was 30 s in the first room and 150 s in the second room.

The minimum time of exposure in the cryosauna was 90 s and the maximum was 180 s. The use of the WBC in a special chamber or in a special sauna was chosen from the physiatrist in according to the patient.

Statistical evaluation

Normal distribution of analyzed continuous variables was assessed using the Kolmogorov–Smirnov test. Values are given as mean ± standard deviation and were compared using the analysis of variance (ANOVA) for trend where appropriated. Two-tailed p values <0.05 were considered significant. The Bonferroni method was used to correct in case of multiple testing. MedCalc software (Mariawerke, Belgium) was used for statistical evaluation.

Results

Circulatory Parameters Changes in All Subjects

In the total sample of all subjects, we did not observe neither changes of systolic BP values [from 122.23 (±1.[illegible]) to 123.73 mmHg (±1.27), p = 0.[illegible]], nor of diastolic values [from 74.69 (±0.70) to 74.92 mmHg (±0.68), p = 1.00], nor of HR values [from 77.90 (±1.22) to 78.22 beats min^{-1} (±1.29), p = [illegible]] after WBC compared to BP and HR values before WBC (ANOVA) (Table 1; Figs. 1, 2).

Table 1 Means, standard deviation (SD), minimum and maximum value of maximal and minimal blood pressure (BP; systolic and diastolic) in mmHg and heart rate (HR) in beats min^{-1} for all subjects

	N	Mean	SD	Minimum	Maximum
BP_Max_Pre	80	122.226	12.0231	103.500	153.750
BP_Max_Post	80	123.730	11.3590	102.500	148.500
BP_Min_Pre	80	74.693	6.2549	60.770	89.500
BP_Min_Post	80	74.916	6.0740	61.540	87.270
HR_Pre	80	77.904	10.9334	59.130	105.290
HR_Post	80	78.224	11.5011	[illegible]710	109.000

Circulatory Parameters Changes Divided by Gender

After WBC applications, we did not find significant changes in circulatory parameters both in female than in male group, as shown in Fig. 3. In the female group, we observed a non-significant change of systolic BP measurements [from 119.81 (±13.13) to 121.42 mmHg (±12.88), p = 1.00], a non-significant change in diastolic values [from 72.27 (±5.39) to 72.52 mmHg (±5.66), p = 1.00] and a non-significant change of HR values [from 80.10 (±9.90) to 81.13 beats min^{-1} (±10.09), p = 1.0]. After WBC treatments in male group, we observed a non-significant change of systolic BP measurements [from

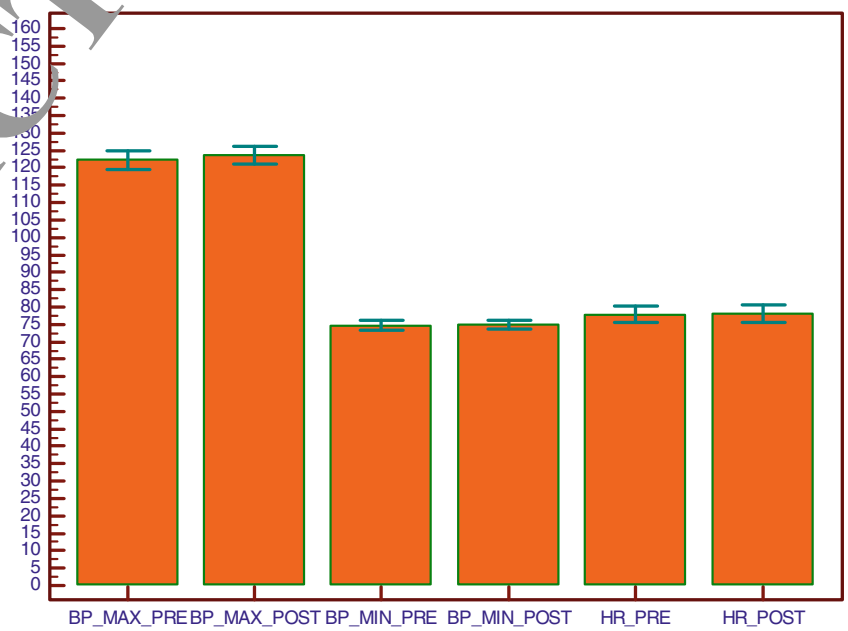

Fig. 1 Mean values of systolic, diastolic pressure (in mmHg) and heart rate (HR) measurements (in beats min^{-1}) of all subjects before and after each application of WBC

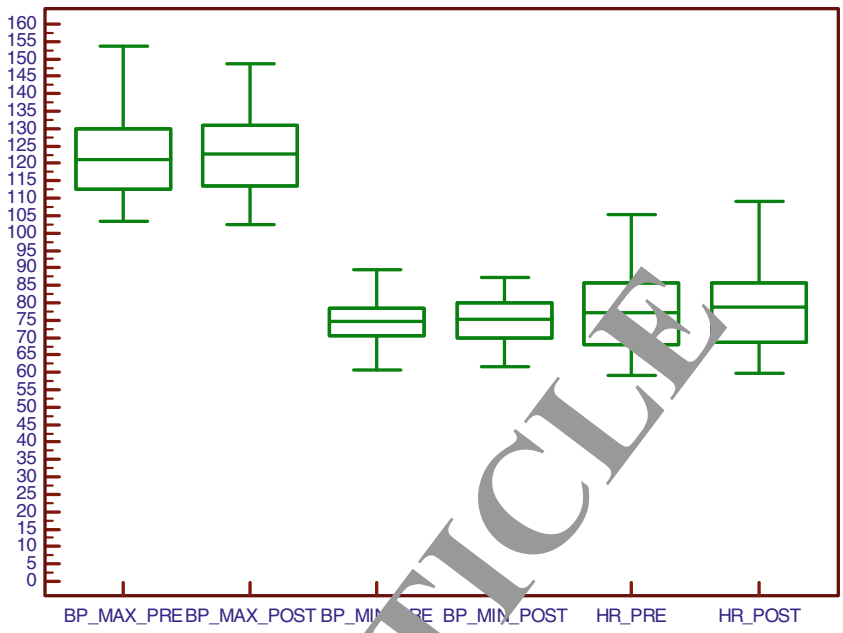

Fig. 2 *Box-and-whisker* plot (following the method of JW Tukey)of systolic and diastolic values (in mmHg) and of HR values (in beats min^{-1}) before and after WBC, showing boxes with values between 25th and 75th percentile, *whiskers* with a maximum length equal to 1.5 times the interquartile range

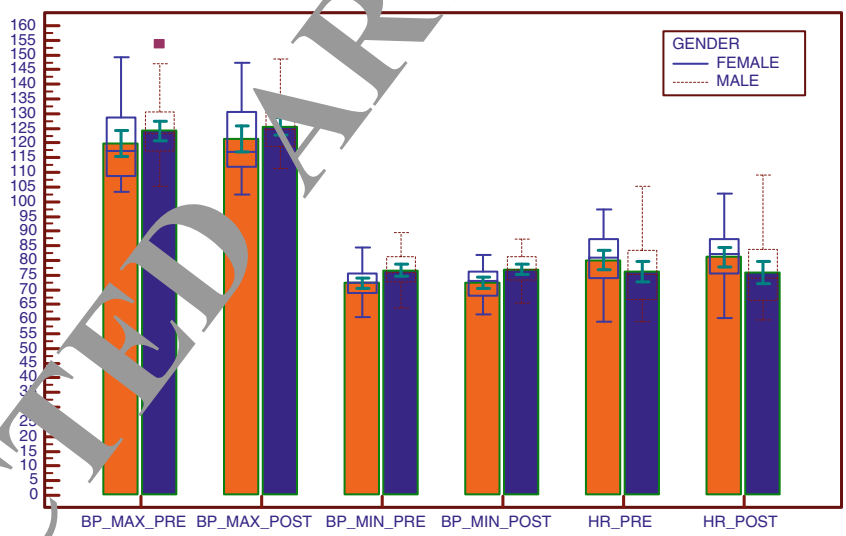

Fig. 3 Mean values of systolic, diastolic pressure (in mmHg) and HR measurements (in beats min^{-1}) of all subjects before and after each application of WBC, clustered by gender

124.21 (±10.78) to 125.62 mmHg (±9.8), $p = 0.807$], a non-significant change in diastolic values [from 76.78 (±6.27) to 76.88 mmHg (±5.4), $p = 1.00$] and a non-significant change of HR values [from 76.11 (±11.51) to 75.84 beats min^{-1} (±12.1), $p = 1.00$] (ANOVA) (Table 2).

Circulatory Parameters Changes Divided by Form of Exposure

In this study subjects were involved both in whole-body cryotreatment and in cryosauna, where the head area is not directly exposed to the cold. We did not observe changes of systolic BP values neither in the group ($N = 35$) which performed ten or more treatments in the cryochamber [from 121.55 (±1.66) to 122.88 mmHg (±1.68), $p = 0.1345$] nor in the group ($N = 13$) which performed ten or more treatments in the cryosauna [from 130.83 (±3.68) to 132.26 mmHg (±3.19), $p = 1$]. As for the systolic as for the diastolic BP values, there were not changes neither in the cryochamber group [from 75.02 (±1.17) to 75.67 mmHg (±1.04), $p = 1$] nor in the cryosauna group [from 76.84 (±2.14) to 76.46 mmHg (±1.87), $p = 1$]. Heart rate values did not change too: there were not statistical difference nor in the cryochamber group [from 71.51 (±2.19) to 70.31 mmHg (±1.90), $p = 1$] nor in the cryosauna group [from 81.70 (±2.30) to 81.32 mmHg (±1.60), $p = 1$; ANOVA].

Table 2 Means, standard deviation (SD), minimum and maximum value of maximal and minimal blood pressure (BP; systolic and diastolic) in mmHg and heart rate (HR) in beats min^{-1} for both female and male group

Gender	BP_Max_Pre		BP_Max_Post		BP_Min_Pre		BP_Min_Post		HR_Pre		HR_Post	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
N	36	44	36	44	36	44	36	44	36	44	36	44
Mean	119.806	124.206	121.422	125.618	72.268	76.677	72.519	76.876	80.97	76.110	81.134	75.843
SD	13.1318	10.7842	12.8778	9.6932	5.3923	6.2658	5.6643	5.7380	9.9063	11.5075	10.0860	12.1377
Minimum	103.500	105.420	102.500	111.250	60.770	63.750	61.540	65.380	59.250	59.130	60.360	59.710
Maximum	149.100	153.750	147.270	148.500	84.290	89.500	82.000	87.270	97.330	105.29	102.90	109.000

Discussion

Despite the wealth of literature on rehabilitation techniques, published data on WBC in physiology or rehabilitation programs are scarce. In particular, there are few recent studies on BP and HR (Lubkowska and Suska 2011; Lubkowska and Szyguła 2010; Missmann et al. 2007; Westerlund et al. 2004, 2006), or published many years ago (Fricke 1989; Taghawinejad et al. 1989a, b), by using old-fashioned technological methods.

Whole-body cryotherapy has been shown not to be deleterious to lung function: a sudden exposure to cold water or air may elicit several effects on the respiratory system, such as gasp response, increase in ventilation and bronchoconstriction, but repeated treatment are not harmful to local reaction or impairment of local immunological barrier (Smolander et al. 2006).

We analyzed BP and HR values of 80 subjects in series of various (from 4 to 17) application of WBC in a retrospective, observational study. The treatment is certainly unusual and could induce anxiety in some subjects; moreover, vasoconstriction due to cold exposure, although very short, could affect BP (Missmann et al. 2007). We did not use psychological tools to test stress and anxiety levels, which might have taken influence on BP measurements, but no evident symptoms were reported by physician and personnel.

In literature only in three studies, the exposure time was not constant for all subjects: from 30 s to 3 min (Fricke 1989; Taghawinejad et al. 1989a) and from 30 to 90 s (Taghawinejad et al. 1989b). Whereas no studies have investigated on circulatory parameters when subjects were involved in both cryochamber WBC treatment than in cryosauna ones.

In this study, no significant changes of BP and HR were observed, both considering all the subjects than divided them by gender or by form of exposure. In this study, no undesirable side-effects occurred after 816 application. The duration of treatment, e.g. the number of WBC exposures, did not affect the results: the adaptation of the subjects, almost for circulatory parameters, is immediate.

Differently from our observation previous reports described significantly large BP alterations after WBC therapy. In the study by Taghawinejad et al. (1989a), a systolic rise of 10 mmHg and a diastolic rise of 5 mmHg was reported. Yamauchi (1986) found systolic rises of 20–25 mmHg after WBC in subjects with rheumatoid arthritis. Lubkowska and Suska (2011) found a significant increase in systolic BP after cryostimulation (by an average of 21 mmHg in comparison with the initial level before cryostimulation), accompanied by a significant increase in HR (by about 10 bpm) and an increase in diastolic BP after the cryostimulation (by 9 mmHg). Lubkowska and Szyguła (2010) found a significant increase in systolic BP after each of 15 daily cryostimulation (by an average of 19 mmHg) and an increase in diastolic BP only after the first cryostimulation (by 6 mmHg). However, the BP returned to the initial value 10 min after the end of cryostimulation, so the changes are temporary and not harmful for normotensive individuals.

In general, the rise of BP readings in our study was smaller than described in other studies and however, it was always non-significant.

However, the adaptive changes after repeated treatment could be the reason for different cardiovascular reaction to extremely low temperatures. We applied various schemes of treatment, considering different need of patients' pathologies. It is possible that first stimulation can cause different response that the following ones. Further research should be deserved to the possible different effects of WBC on the basis of different number of sessions.

The changes in BP due to WBC were not significantly different between men and women, as described by Westerlund et al. (2004).

In conclusion, when subjects with known risk factors are excluded, WBC appears to be safe with respect to unwanted BP and HR alterations for adult people up to the age of about 70 years. However, we recommend BP monitoring over WBC therapy.

References

Antony I, Aptecar E, Lerebours G et al (1994) Coronary artery constriction caused by the cold pressor test in human hypertension. Hypertension 24:212–219

Banfi G, Lombardi G, Colombini A et al (2010) Whole body cryotherapy in athletes. Sports Med 40:509–517

Brennan PJ, Greenberg G, Miall WE et al (1982) Seasonal variation in arterial blood pressure. Br Med J (Clin Res Ed) 285:919–923

Buemi M, Allegra A, Aloisi C et al (1997) Cold pressor test raises serum concentration of ICAM-1, VCAM-1, and E-selectin in normotensive and hypertensive patients. Hypertension 30:845–847

Di Carli MF, Tobes MC, Mangner T et al (1997) Effects of cardiac sympathetic innervation on coronary blood flow. N Engl J Med 336:1208–1215

Dugué B, Smolander J, Westerlund T et al (2005) Acute and long-term effects of winter swimming and whole-body cryotherapy on plasma antioxidative capacity in healthy women. Scand J Clin Lab Invest 65:395–402

Fricke R (1989) Ganzkörperkältetherapie in einer Kältekammer mit Temperaturenum –110°C. Z Phys Med Balneol Med Klimatol 18:1–10

Jansky L, Matousková E, Vávra V et al (2006) Thermal, cardiac and adrenergic responses to repeated local cooling. Physiol Res 55:543–549

Jansky L, Pospisilová D, Honzová H et al (1996) Immune system of cold-exposed and cold-adapted humans. Eur J Appl Physiol Occup Physiol 72:445–450

Leppäluoto J, Hassi J (1991) Human physiological adaptations to the arctic climate. Arctic 44:139–145

Leppäluoto J, Westerlund T, Huttunen P et al (2008) Effects of long-term whole-body cold exposures on plasma concentrations of ACTH, beta-endorphin, cortisol, catecholamines and cytokines in healthy females. Scand J Clin Lab Invest 68:145–153

Lubkowska A, Szyguła Z (2010) Changes in blood pressure with compensatory heart rate decrease and in the level of aerobic capacity in responses to repeated whole body cryostimulation in normotensive, young and physically active men. J Occup Med Environ Health 23:367–375

Lubkowska A, Suska M (2011) The increase in systolic and diastolic blood pressure after exposure to cryogenic temperatures in normotensive men as a contraindication for whole-body cryostimulation. J Thermal Biol 36:264–268

Missmann M, Himsl M, Ulmer H et al (2007) Behavior of blood pressure during whole body cryotherapy in a cryo-chamber. Phys Rehab Kur Med 17:286–297

Papenfuss W, Joch W, Ückert S et al (2006) Consensus declaration on whole body cryotherapy. Second Austrian Symposium on WBCT, February 17–18, 2006, Bad Voslau Health Resort

Smolander J, Westerlund T, Uusitalo A et al (2006) Lung function after acute and repeated exposures to extremely cold air (−110°C) during whole-body cryotherapy. Clin Physiol Funct Imaging 26:232–234

Taghawinejad M, Birwe G, Fricke R et al (1989a) Whole-body cryotherapy—influence on circulatory and metabolic parameters. Z Phys Med Balneol Med Klimatol 18:23–30

Taghawinejad M, Fricke R, Dürne L (1989b) Telemetrisch Elektrokardiographische Untersuchungen bei Ganzkörperkältetherapie (GKKT). Z Phys Med Balneol Med Klimatol 18:31–36

Victor RG, Leimbach WN Jr, Seals DR et al (1987) Effects of the cold pressor test on muscle sympathetic nerve activity in humans. Hypertension 9:429–436

Wendt T, Schmidt W, Kaltenbach M et al (1983) Influence of cold-stimuli on hemodynamics and coronary diameters. Provocation of coronary artery spasm. Z Kardiol 72:24–31

Westerlund T, Schneider J, Uusitalo-Koskien A et al (2004) The blood pressure responses to an acute and long-term whole-body cryotherapy (−110°C) in men and women. J Therm Biol 29:285–290

Westerlund T, Uusitalo A, Smolander J et al (2006) Heart rate variability in women exposed to very cold air (−110°C) during whole-body cryotherapy. J Therm Biol 31:342–346

Yamauchi T (1986) Whole body cryotherapy is a method of extreme cold −175°C treatment initially used for rheumatoid arthritis. Z Phys Med Balneol Med Klimatol 15:31