EFFECTS OF WHOLE-BODY COOLING TO -110º CELSIUS ON HEART RATE DURING ENDURANCE SPORTS AND AT REST

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ABSTRACT

Treatment with cryotherapy has been known for a long time. Whole-body cooling therapy represents a new variant, which, as recommended by the Japanese practitioner Yamauchi, as a rule involves a temperature of -110º Celsius in a cooling chamber. The effects of this cooling intervention are, however, not fully known and findings have been, on occasion, even contradictory.
Problem: The question thus arises whether heart rate behaves differently following cooling to without not only under rest conditions but also under endurance loads and conditions such as are found in endurance sports. Method: For this purpose the heart rate was measured in n=17 male test persons (aged 22-25) during a standardised 26-minute endurance test and over a five-minute rest period. Result: Both under load conditions and at rest, the difference in heart rate following cooling is highly significantly (p= 0.001) lower than in the same tests without prior cooling. Conclusion: It may be concluded that the use of whole-body cooling may be successfully applied prior to endurance sports activities to optimise energy requirements and recovery.

KEYWORDS

Whole-body cooling - cold chamber - endurance load - rest

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INTRODUCTION

Body-cooling treatment (cryotherapy) has been well known for a long time and is employed effectively to treat various medical symptoms - inflammations, pain, oedema and dysfunctions associated with joint diseases [1]. In terms of its effects, however, a distinction should be made between this and whole-body cooling therapy (WBCT), which has been practiced in Germany since 1985 on the basis of the Japanese practitioner Yamauchi's procedure and involves a short exposure (normally 2-4 minutes) to a high dosage of cold of -110º Celsius in a cold chamber [2].

Cold chambers function on the 'refrigerator principle': they consist of an outer room in which the air is physically dried, to avoid excess fog building up in the main room. In the main room the air temperature is -110º Celsius (with some variation) and is cooled to this temperature using nitrogen gas [3].

The effects of this exposure to cold have been documented comparatively well, in a considerable number of studies, notably from the experiences in almost 80 German clinics over the past twenty years. Nevertheless, claims have occasionally been made concerning the state of research into cold treatments that the effects described of whole-body cooling therapy are "to a large extent still hypothetical" [4]. Taking the example of heart-rate behaviour, it is becoming clear, furthermore, that the results previously available were not uniform and indeed contradictory in places:

On the one hand - so it is postulated - heart rate is raised by cooling therapy at -110º Celsius, on average by 24 beats per minute during and 13 beats per minute after the time in the cold chamber. This finding agrees in principle with the understanding that as a consequence of intensive exposure to cold, an "increase in cardiovascular activity" would be diagnosed [6] and a significant effect of wholebody cooling therapy would consist in a circulation-'stimulating' effect [7].

On the other hand, from a thermoregulatory perspective it has been argued that if the body is cooled prior to loading (precooling), this will lead to an increase in the 02 pulse (that quantity of oxygen that can be supplied per heartbeat to the periphery of the body) during the exercise, with the effects of

- an increase in heart-beat volume, and
- an improvement in the uptake of oxygen content from the blood [8].

Both effects gave rise to a temperature-linked economising in the circulatory functions, and the people subjected to cooling would sweat less, that is, the thermoregulatory mechanism was less burdened. This would lead to an improvement in performance that would be seen in a lower heart rate and, in the first quarter hour of activity would amount to about 17% [9].

PROBLEM

In the present study, the question of whether and, if so, how a brief (2½-minute) cold treatment at a high dosage (-110º C) carried out in a cold chamber affects the heart rate of sportspeople was examined,

- both under rest conditions
- and under the conditions of a standardised endurance tests with recovery intervals.

Both variants - rest conditions and endurance load conditions - were tested in a laboratory with a normal room temperature of 20º C. Identical tests were run with and without the initial precooling.

The problem considered in this study is orientated towards a sport-related context [10]. It is not concerned with the therapeutic effects of cooling - pain relief, the treatment of inflamed rheumatic symptoms, etc. but with the thermoregulatory mechanisms associated with whole-body cooling (WBC) [11] that - in the case of heart rate during endurance activity and at rest - may be considered a basis for improved performance and/or for a reduction in the intensity of cardiovascular activity in a sports context.

MATERIAL AND METHOD

The sample chosen for study comprised n=17 males aged between 22 and 25 with a developed capacity for endurance sport but who did not specialise in such sport in a competitive sense.

Before entering the cold chamber, the heart rate was examined over a five minute rest phase in which the subjects were seated. Then followed the cooling, after which was another five minute rest period. This was followed by an endurance test of 26 minutes total duration, in which resistances corresponding to 130 and 150 watts (over a six-minute warm-up phase) and then 250W load and 150W recovery phases of two minutes each, in alternation, were applied for the remaining 20 minutes. Pedalling speed was a constant 80rpm throughout. The time interval between leaving the cold chamber and commencing the loading was seven minutes. All tests were conducted in morning sessions between 0900 and 1200. The order of testing - whether first with cooling or first without cooling - was decided randomly. All the individuals used in the test were familiar with the test situation and had participated in similar experiments with cooling on previous occasions. The endurance test was carried out using a high-performance Schoberer (SRM) ergometer. The sequence of loading used in the standardised intervallised test can be seen in Fig. 1.

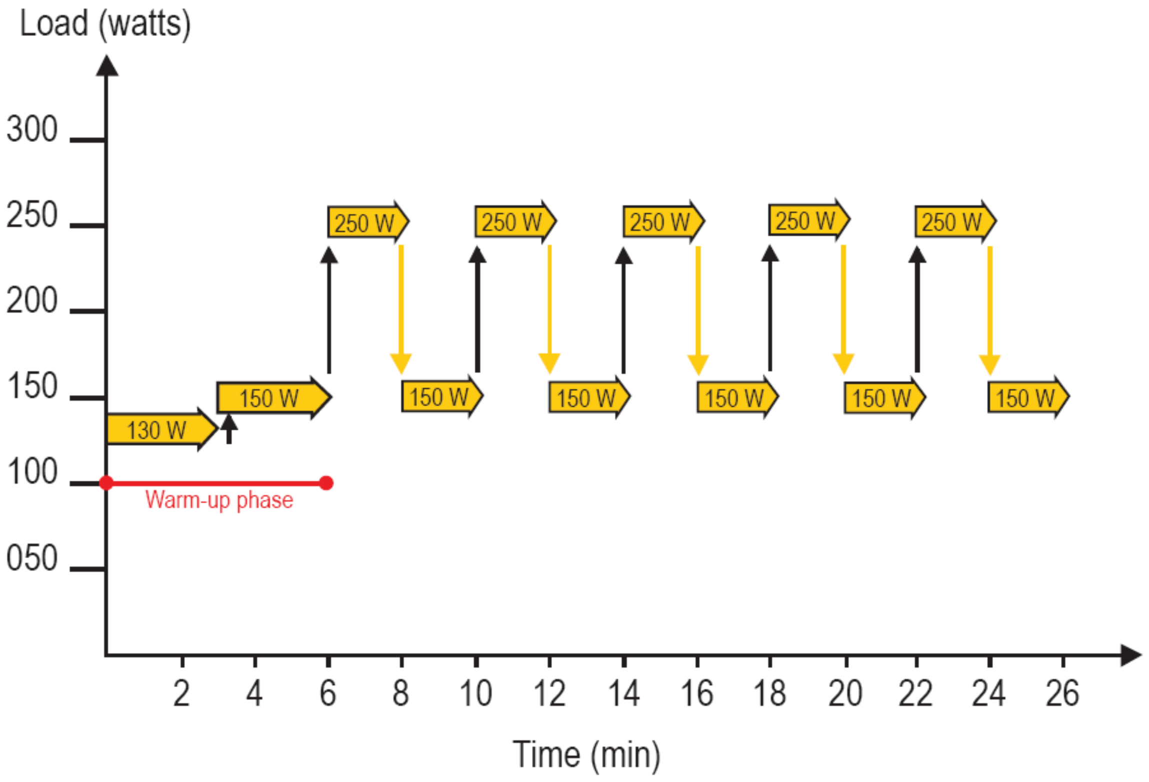

Figure 1: Time and load profile of endurance test over 26 minutes

RESULTS

General effects of cooling

Constancy of body temperature

Body temperature does not fall in response to the cooling, which is applied for a brief period at a high dosage in a cold chamber. The decisive factor for the lowering of body temperature is evidently not the intensity of cold to which the body is exposed but rather the duration of exposure. By our measurements - made using a Braun ear thermometer [12] - the body temperature changed by between 0.0 and 0.2 degrees Celsius from the initial temperature. Other authors have reported a drop in temperature of "0.1º C at the most" [13].

Vasoconstriction

Nervous regulation of the arterioles occurs primarily through the sympathetic nervous system: the regulatory centres - separately from the circulatory functions and regulation of the peripheral vessel diameters - control the pressure and depression of the vessel system. Noradrenalin plays an important role here as the transmitter. Contraction of the vessels (vasoconstriction) is detected by the areceptors in the smooth muscles of the vessel walls. The high dosage of cold evidently intervenes in this neural control mechanism of peripheral circulation, leading to pronounced vasoconstriction. As a reflection of this, an increase in circulation in the muscles below is to be expected [14].

Heart-rate behaviour under load conditions

Fig. 2 shows that the heart rate after whole-body cooling (pWBC) is on average highly significantly (p= 0.001) lower than is the case without precooling (oWBC) throughout the entire 26-minute test period. Under load conditions, then, significantly lower heart-rate values were detected than were found in identical test conditions where no preceding exposure to whole-body cooling had taken place (oWBC).

It can be seen from the diagram that the heart rate during the test - despite identical loading of 150 and 250 watts in standardised alternation (intervallised) - increases more or less constantly. This "fatigue increase", expressed quantatively as heart rate increase (beats per minute), reflects the cumulative stress experienced by the test person.

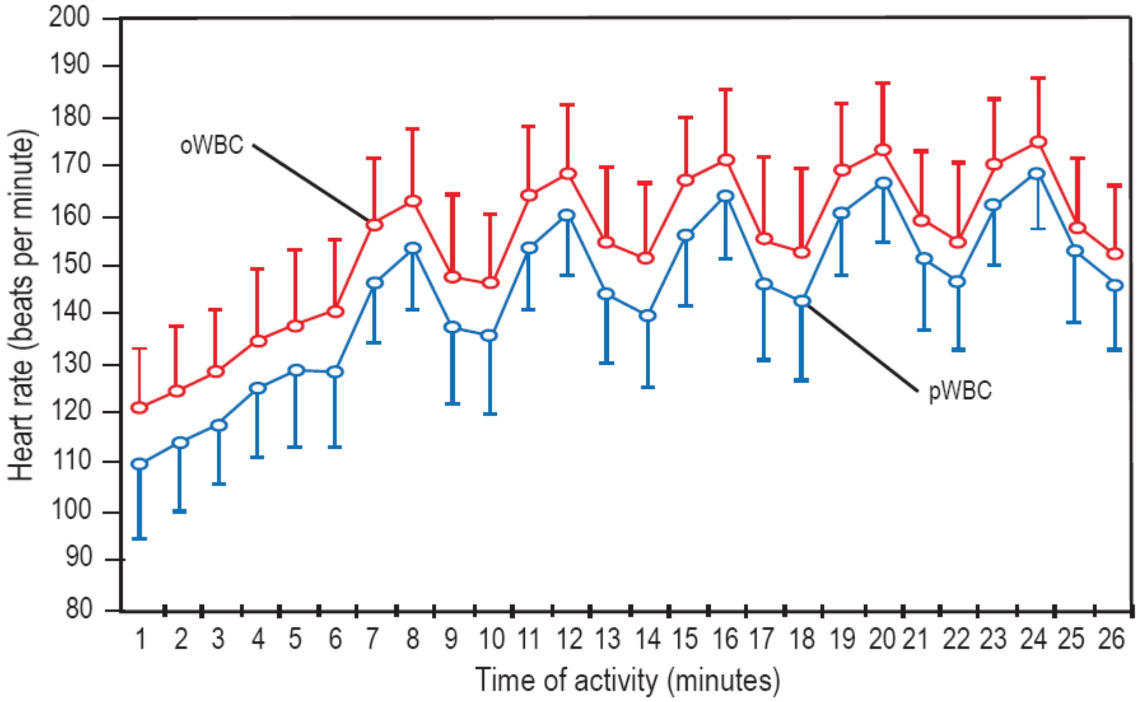

Figure 2: Heart rate (beats per minute) for each minute of the endurance test (after a five-minute rest phase) without (oWBC) and following (pWBC) whole-body cooling.

The difference between the heart rate without (oWBC) and after (pWBC) wholebody cooling had, for our experiment sequence and over the entire 26 minutes, a mean value of between 5 and 6%. This value varied at different stages of the test and tended to decrease with time (see Table 1). In minutes 1-6 the difference was 8.1% (highly significant), in minutes 7-16, 6.6% (significant) and in minutes 17-26, 4.6% (not significant). In absolute terms the heart rates varied during the actual load phase (minutes 7-26) between 147.5 (oWBC) and 137.4 (pWBC) beats per minute in minute 9 (minimum) and between 175.1 (oWBC) and 169.3 (pWBC) beats per minute in minute 24 (maximum).

From this it may be inferred that, on the one hand, the (mean) endurance load in the test did not present a difficulty for the people tested; the maximum heart rate of about 175 beats per minute represents about 90%of cardiovascular capacity. On the other hand, the positive effect of cooling on the heart rate - positive in the sense of a reduction, observed in a standardised performance test - decreases over the duration of the test. At the start of the load phase (minutes 7-8) the difference between oWBC and pWBC was 10.8 beats per minute, while at the end (minutes 23-24) it was 6.8 beats per minute.

Table 1: Heart rate (beats per minute absolute) at the end of each test minute without (oWBC) and after (pWBC) whole-body cooling during the endurance test (minutes 1-6: warm-up phase, minutes 7-26: intervallised load phase)

Heart rate (Beats per minute)

Watts	Minute	oWBC	pWBC	Diff. o/pWBC	Mean (%-Diff)
130	1	120.9	109.6	11.3	
	2	124.6	113.8	10.8	**8.8**
	3	128.1	117.4	10.7	**8.1**
150	4	134.6	125.1	9.6	
	5	138.0	128.6	9.4	**7.4**
	6	140.9	128.9	12	
250	7	158.5	146.7	11.8	
	8	163.1	153.4	9.6	
150	9	147.5	137.4	10.2	
	10	146.2	135.9	10.3	
250	11	164.5	153.4	11.1	
	12	168.7	160.4	8.3	**6.6**
150	13	154.6	144.4	10.2	
	14	151.4	139.9	11.4	
250	15	167.5	155.7		
	16	171.2	164.2		
150	17	155.1	146.1	9.1	
	18	152.9	142.4	10.5	
250	19	169.2	160.5	8.6	
	20	173.3	167.0	6.3	
150	21	159.2	151.5	7.7	
	22	154.5	146.6	7.9	**4.6**
250	23	170.5	162.7	7.8	
	24	175.1	169.3	5.8	
150	25	157.7	152.4	5.4	
	26	152.1	146.2	6.0	

oWBC = without prior whole-body cooling;
pWBC = after prior whole-body cooling;
Diff. o/pWBC = absolute difference between oWBC and pWBC;
Mean (% Diff) = average difference between oWBC and pWBC as a percentage

Heart rate under rest conditions

At rest - seated, for a period of five minutes - the heart rates after cooling are (surprisingly) unequivocal: the mean heart rate without cooling (oWBC) was 68.7 beats per minute, while that immediately after cooling (pWBC) was 61.96. This difference of 6.74 beats per minute is, in statistical terms, in the t-test for paired random samples, highly significant (p= 0.001).

The bar chart in Fig. 3 illustrates these relationships. They confirm that the heart rate after cooling at -110º C in a cold chamber is not only lower during the endurance loading than without cooling, but also under rest conditions. The presumption that the high-dosage cooling of -110º C could have the effect of a "shock" [15] can therefore not be confirmed [16].

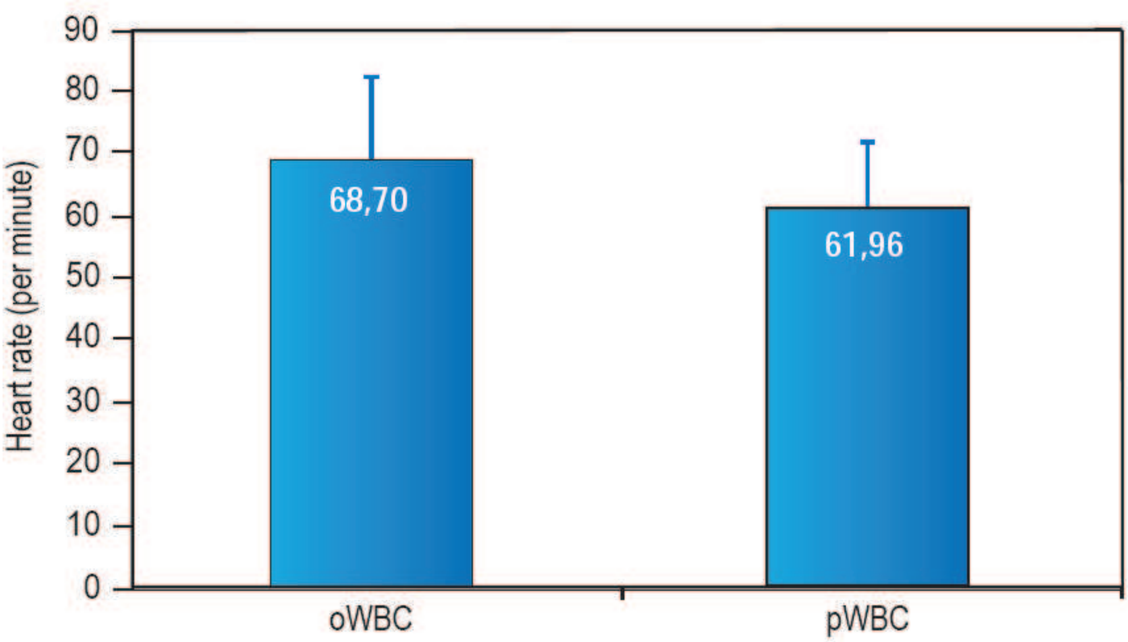

Fig. 3: Behaviour of heart-rate curves without (oWBC) and after (pWBC) wholebody cooling during a 26-minute intervallised endurance test

The differences are shown in more detail in the bar chart of Fig. 4, for each minute of the test. They demonstrate, on the one hand, that the differences between the heart rate without (oWBC) and after (pWBC) whole-body cooling are clearly and highly significantly (p= 0.001) different for each test minute, and on the other hand, that they are greatest at the beginning of the rest phase. In absolute terms the difference in the first test minute between oWBC and pWBC is 8.3 beats per minute (highly significant) and is thus higher than the average value (6.7 beats per minute). This would indicate that the heart rate is not stimulated by the cold but rather is subdued by it, and that the sooner after the exposure to the cold, the stronger is the effect.

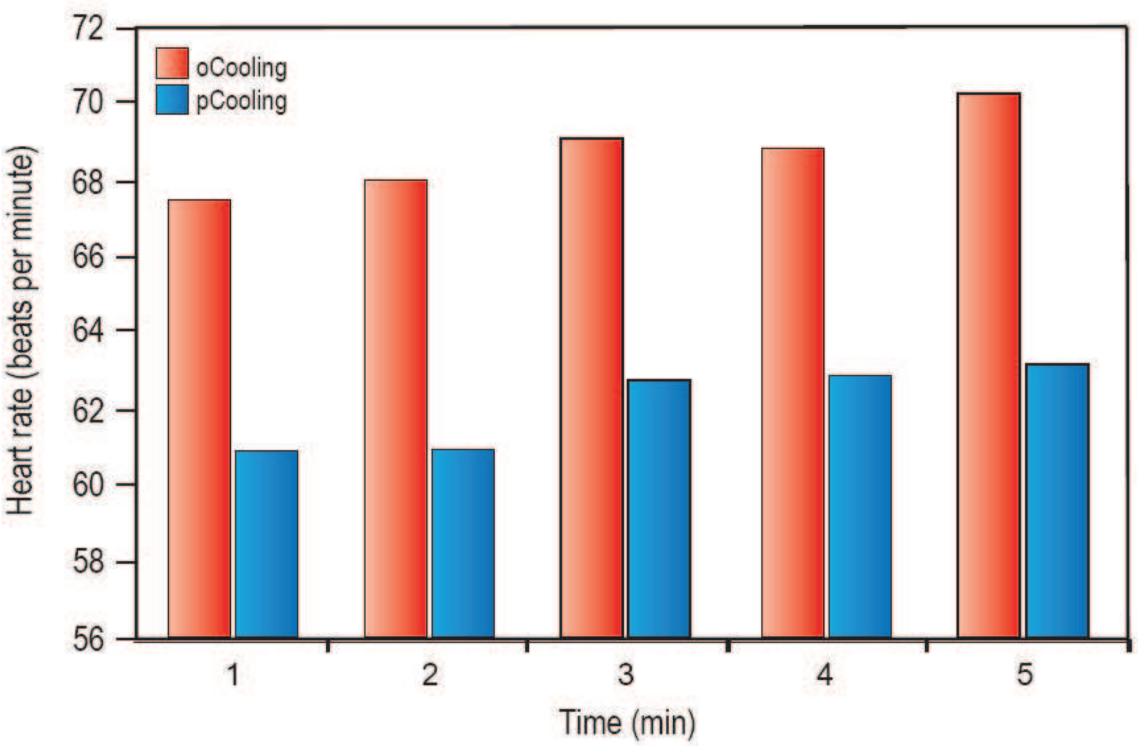

Figure 4: Mean heart rates (beats per minute) in the five-minute rest period without (oWBC) and after (pWBC) whole-body cooling.

DISCUSSION OF RESULTS AND CONCLUSION

The aim of the research into the influence of short-term, high-dosage cooling (-110º C) on heart-rate behaviour, under both rest and load conditions, was to test whether and, if so, to what extent whole-body cooling acts on heart rate, be it 'stimulating' or 'subduing' in effect. The results indicate that, under the chosen experimental conditions, the regulatory effect of cooling is to reduce the heart rate by a highly significant amount. In substantiating these results, one may turn to the outcome already quoted [18], which postulates an increase in the heart-beat volume and an improvement in the blood oxygen uptake, that is to say, an economising of cardiovascular activity. These phenomena occur both under load conditions and at rest.

For questions relating to sport, these findings are meaningful for at least three reasons:

PREPARATION FOR SPORTS ACTIVITIES

In relation to the stimulation of performance, cooling represents a part of the preparation phase ('warming up'). It should be taken into consideration that - on the basis of our results - the range of preparation and warm-up activities, stretching, mental preparation, etc. - may, and should, be increased to include cooling. In particular in endurance sport, where there is invariably an excess of heat generated by the body's activity, this involves not only avoiding the generation of still more heat during warm-up, but also the optimisation of the balance between heating and cooling. This calls for a prophylactic use of precooling. This applies all the more so the higher, on the one hand, the external temperature (e.g. hot weather) and the more limited the possibilities for cooling (e.g. lack of wind), and on the other hand, the higher the temperature rise of the body as a result of the physical work being performed.

ENERGY CONSUMPTION

The optimisation of the balance of hot and cold is therefore of additional importance in endurance sports, since the effort of cooling represents a substantial proportion of available energy, which is then not available for the muscular activity itself. In the literature it is assumed that roughly 75% of energy is required for cooling the biological system, and only the remaining 25% can be drawn on for continued activity [18]. Given a reduced expenditure on thermoregulatory cooling, however, this ratio would improve to the benefit of ongoing muscular performance.

RECOVERY

The effect of whole-body cooling on the cardiovascular system (beats per minute) under rest conditions points to the possibility of the use of cooling to aid recovery. This recovery effect is already known and used in practice; and the literature already indicates the "effects of cold in boosting recovery" [19]. The authors' research on the influence of cold on heart-rate variability further confirms these findings [20].

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