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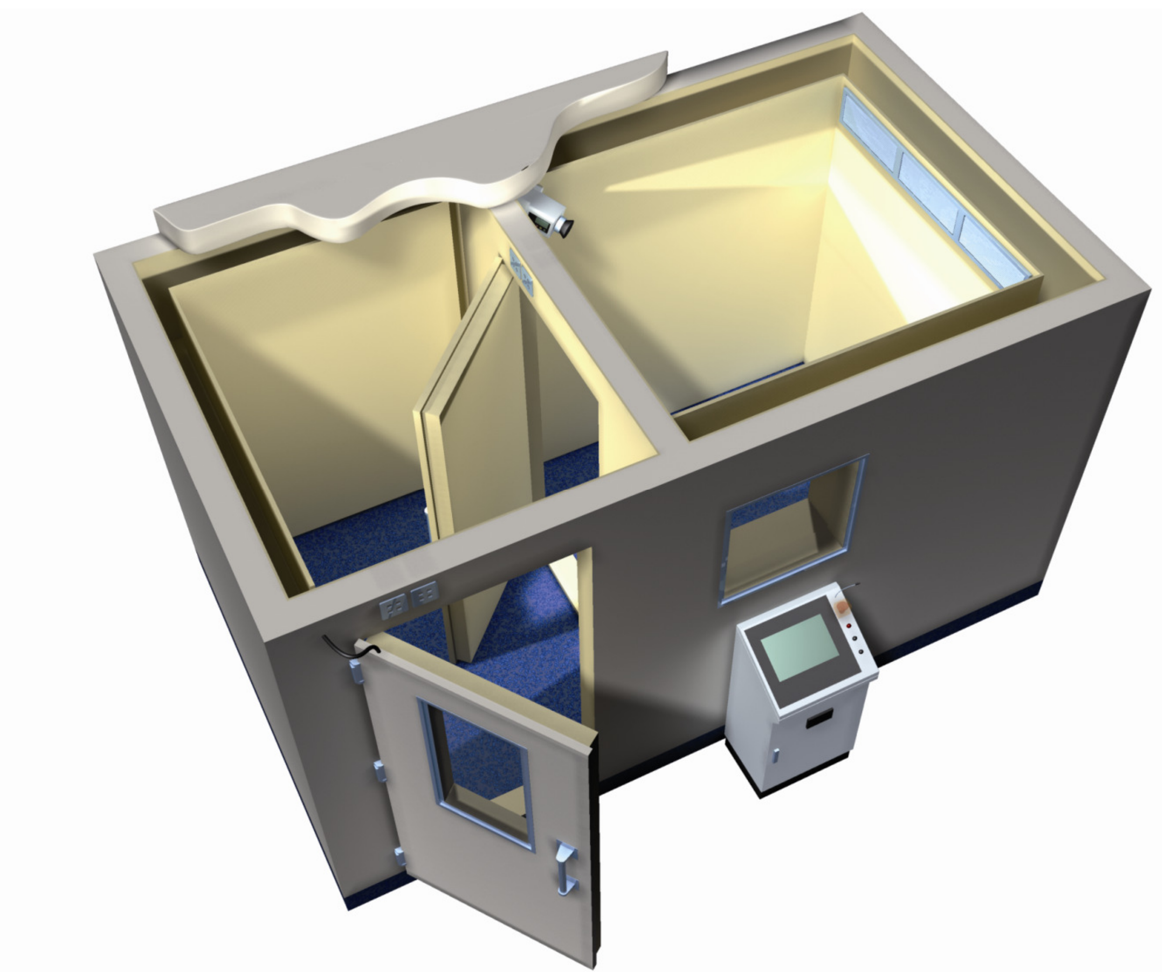

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THE VALUE OF SHORT-TERM, HIGH-DOSAGE COOLING FOR ACHIEVING HIGH SPORTS PERFORMANCE[1]

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1 THE PROBLEM

Competitive sport has developed to the point that human performance is reaching its limit. It follows that, in order to further improve performance, new resources must be deployed that were previously unknown or simply not used such as improvements in quality of training, the optimisation of loading and recovery or ways of increasing biological reserves, etc.

The conditions of thermoregulation as one such resource able to meet the demands of increased sports performance have, up to now, remained marginal in the area of sport. As a rule they have been confined to the topic of heat production in the body through physical effort, in other words, warming up. The other side of this regulatory system the interplay of heat and cold, the relationship of warming up and cooling down has so far received little attention (Joch & Ückert, 2003).

Thermoregulation in humans (Schmidt & Thews, 1990) is, however, an important and significant factor in governing performance, for a series of reasons. In endurance sports, in particular, the warmth generated through longerterm physical exertion has to be cooled, at considerable energy cost, in order to maintain the organism in a condition such that sports performance may be sustained. To maintain the optimal balance of cold and heat, particularly in endurance sport, 75% of all energy expenditure (depending on intensity and duration) must be expended on cooling, leaving only about 25% available for actual muscular activity (Marsh & Sleivert, 1999). The more intensive and longer the duration of the activity and the higher the ambient temperature (ignoring possible external cooling by factors such as wind, etc), the greater is the energy expenditure for cooling and thus also the 'loss of energy' for the actual muscular activity.

These framework conditions imposed by thermoregulation give rise to the question of the influence of systematically applied cooling on sports performance, particularly in the case of endurance sports.

2 METHOD

Test persons (n=17, male) aged between 22 and 25 were placed in a cold chamber[2] and subjected to a short (2½minute) dosage of intense cold (110º Celsius) prior to undergoing a 26minute endurance test on a Schoberer (SRM) ergometer. The test consisted of pedalling at a constant speed of 80 rpm against resistances corresponding to 130150W (warmup phase) and 250W (load phase). The initial cooling thus fulfilled the function of precooling (Kay et al, 1999).

1 VF 0407/05/04/200203
2 There have been cold chambers in Germany since 1980; now there are about 80, mostly in rheumatism clinics. The first cold chamber was built in Sendenhorst for Prof Dr Reinhard Fricke on the model of the Japanese practitioner Yamauchi. Our research was carried out using the cold chamber at Vlotho (WeserlandKlinik) and that of the St Josef Foundation in Sendenhorst. We would like to express our gratitude here to the directors of both clinics for allowing us to use their facilities without charge.

Figure 1 shows the structure of the test. The two warmup phases (130W and 150W, three minutes each) were followed by five load phases (250W) of two minutes each, interspersed with active recovery phases (150W). Data was recorded for heart rate (continuously throughout the 26minute test), the concentration of blood lactate (at the 8th, 16th and 24th minutes) and heartrate variability at the ends of the load phases (250W, two minutes each). Measurements were taken using the Polar S 810 heartrate monitor watch.

The tests were carried out in a standardised form using the cold chamber of the St Josef Foundation in Sendenhorst and that of the WeserlandKlinik in Vlotho. They were repeated several days later, without the use of the cold chamber, under otherwise identical conditions.

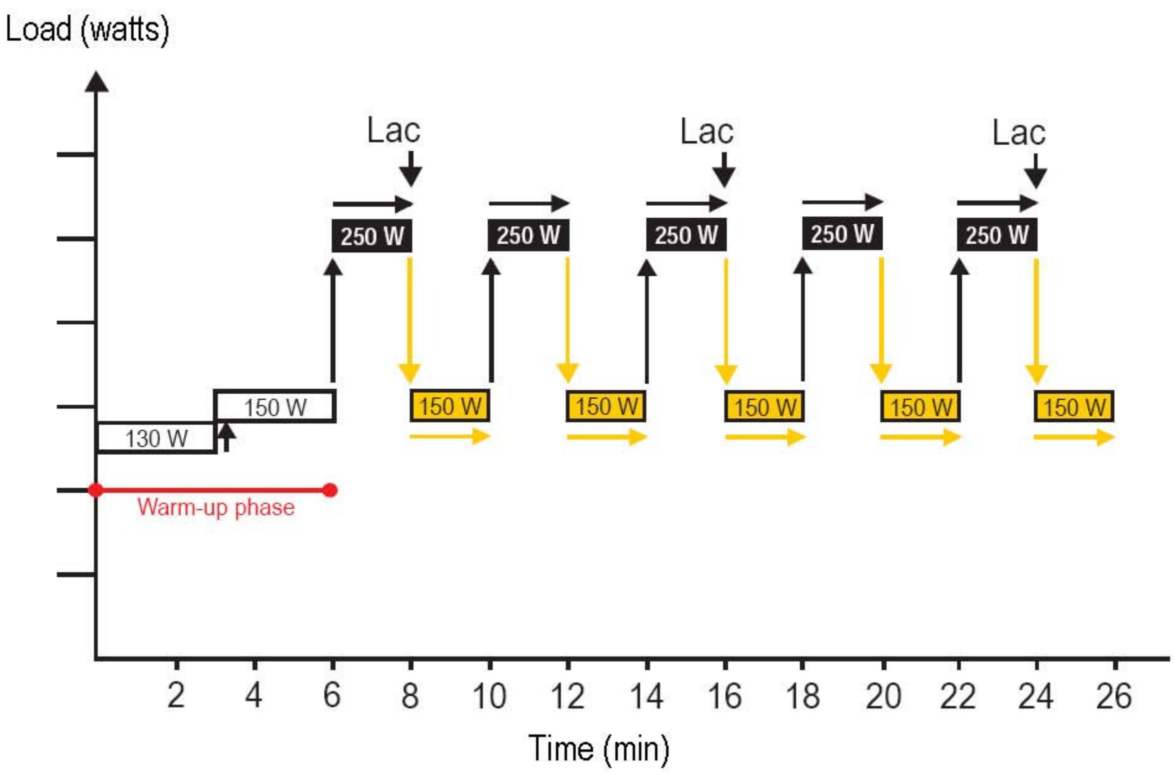

Fig. 1: Test structure

3 Results

3.1 Heart-rate behaviour

As can be seen from Fig. 2, the heart rate after wholebody cooling (pWBC) is very significantly ($p = .001$) lower throughout the entire 26minute test than is the case under normal conditions, i.e. without initial wholebody cooling (oWBC). While the difference between the two heartrate characteristics varies over the duration of the test, they are at all times significantly lower after wholebody cooling than without it.

Thus it cannot be confirmed that, under endurance load conditions, cold and in particular, prior wholebody cooling in a cold chamber 'stimulates' the heart rate despite the fact that research using cardiography has indicated that the heart rate increases on average by 24 beats per minute during the cooling and by 13 beats per minute after cooling (Taghawinejad et al, 1989, 33).

Those authors suggest that cryotherapy (to 110º C) can cause "a sympathicotonic effect and, consequently, a peripheral increase in resistance and also of the heart rate". This, they maintain, leads to an increase in load on the heart and thus an increase in its oxygen consumption. The present study therefore does not confirm such results.

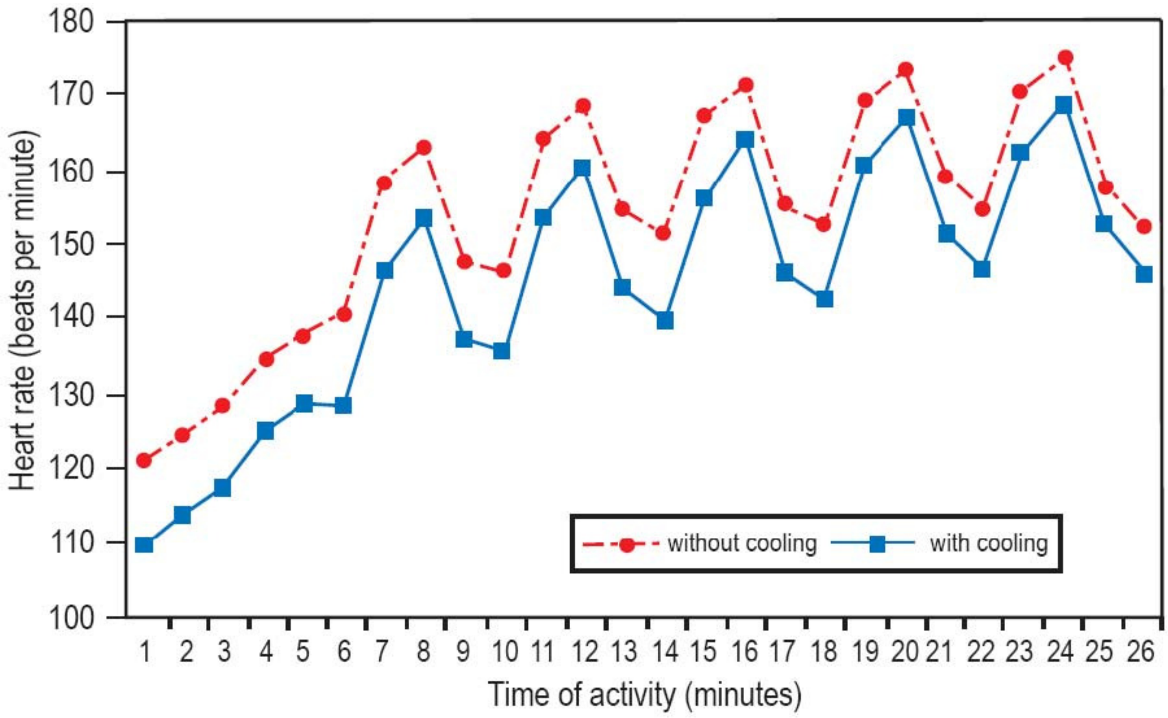

Fig. 2: Heart rate characteristics during an endurance test with recovery intervals (N=17)

3.2 BLOOD LACTATE

Lactate content was measured at the 8th, 16th and 24th minutes of the test, in each case at the end of one of the 250W load phases (c.f. Fig.1). The results indicate that at each measuring point the lactate values are lower after cooling (pWBC) than without cooling (oWBC) (see Fig. 3):

. at the 8th minute the difference value between the result for no previous cooling (oWBC) and that after previous cooling (pWBC) is 0.9 (5.7 to 4.8 mmol/l = very significant: $p = 0.001$);
. at the 16th minute the difference value is 0.8 (7.1 to 6.3 mmol/l = significant: $p = 0.05$);
. at the 24th minute the difference value is 0.4 (6.5 to 6.1 mmol/l = not significant: $p > 0.05$).

These results do not confirm some of the findings of previous research. For example, Lee & Haymes (1995), despite demonstrating advantages of precooling for other factors (heart rate and oxygen intake), were unable to establish any effect on blood lactate content. There is however confirmation that the effect appears to diminish as the duration of loading increases (Marino, 2002).

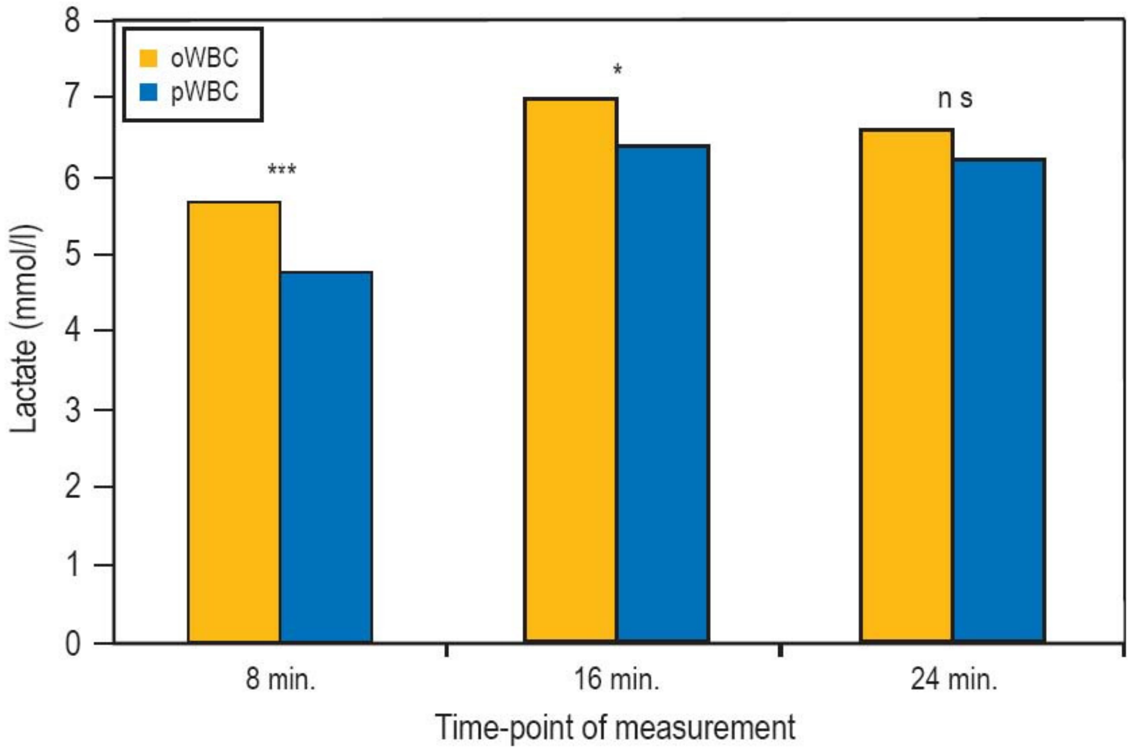

Fig. 3: Blood lactate concentration with (pWBC) and without (oWBC) precooling

3.3 HEART-RATE VARIABILITY

Heartrate variability (HRV) describes the ability of the heart to alter the time interval between beats in response to load (Löllgen, 1999). It thus characterises the timefluctuations in heart rate from one beat to the next and represents an adjustment response by the autonomic control of the heartbeat cycle to loading – both physicosomatic (Hottenrott, 2002) and psychomental (Eiler, 2002) in nature. In this respect it can also be considered a suitable indicator of physical fitness and performance.

Under the influence of cooling (WBC) the timedomain parameters of heartrate variability change highly significantly in favour of a primarily parasympathicotonic activity in comparison to their behaviour under normal temperature conditions (p=0.001) (see Fig. 4):

. RR intervals represent the average heart time interval rate; their increase of 49% in response to wholebody cooling is highly significant.

. s represents the standard deviation of heartrate deviation (from the mean value); after whole-body cooling it increases by 175%.

. sd1 represents the standard deviation corresponding to the vertical diameter of the scattergram of the RR variation; it increases after wholebody cooling by 366%.

. sd2 represents the standard deviation corresponding to the horizontal diameter of the scattergram of the RR variation; it increases after wholebody cooling by 93%.

. The RMSSD value, which represents the square root of the squared mean (r.m.s.) value of the sum of the differences between neighbouring RR intervals, increases by 300%. The higher the value of RMSSD, the higher is the parasympathetic activity.

. The pNN50 value, which gives the frequency in percent of those intervals that show a deviation of 50 ms or more from the preceding interval, increases by almost 100%.

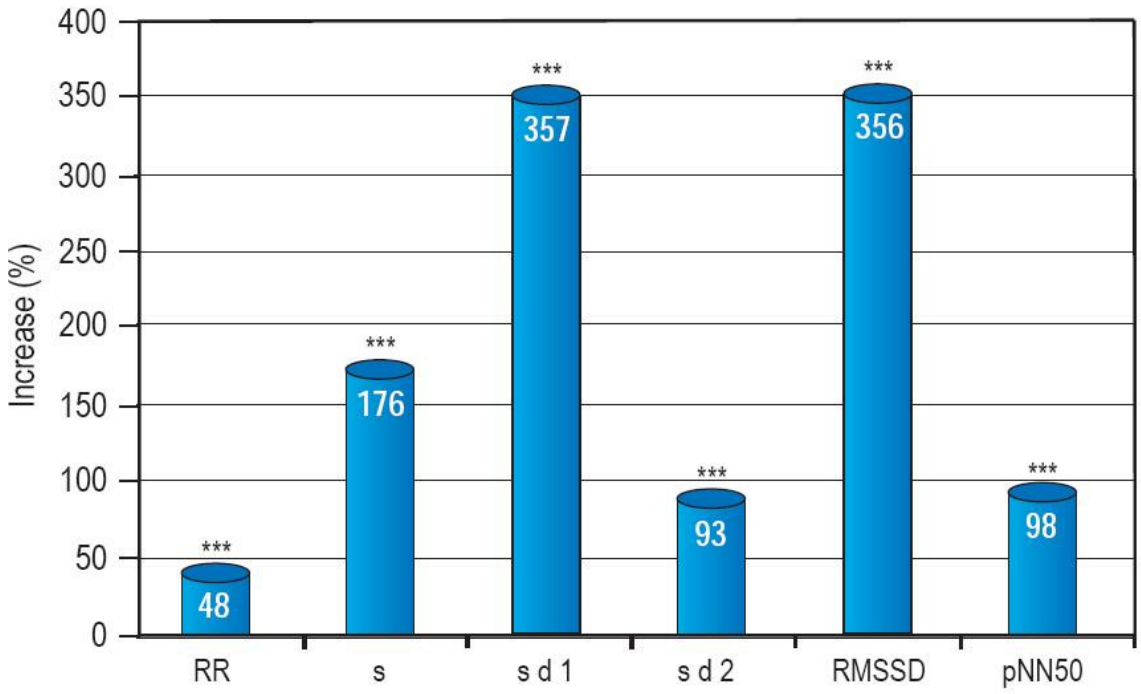

Fig. 4: Influence of wholebody cooling (110º Celsius) on the timedomain parameters of HRV (in percent)

CONCLUSION AND FUTURE PROSPECTS

The application of cold, for a short period (2½ minutes) and at high dosage (110º Celsius) in a cold chamber as a precooling measure has demonstrated significant positive effects on at least three tested loading parameters that have a beneficial effect on performance in endurance activities:

. heart rate is lower throughout the entire 26minute test by between eight and ten beats per minute in comparison with that obtained using a standardised endurance load without precooling;

. blood lactate concentration is lower after precooling the sooner the point of measure after the cooling, the greater the difference;

. heartrate variability shows, for all tested HRV parameters, higher values during highload phases after precooling, which indicates a larger vagotonic proportion of (parasympathetic-nerval) control.

The last aspect, of heightened parasympathetic control after cooling, to the detriment of the sympathetic share, indicates that the effects of cooling also appear important for recovery and regeneration. Research in this area is planned. The relevance to practice of these findings are currently being discussed with trainers (of endurance disciplines) of the German Athletics Association.

5. PREVIOUS PUBLICATIONS BY THE AUTHORS

Joch, W., Fricke, R. & Ückert, S. (2002). Der
Einfluss von Kälte auf die sportliche Leistung,
Leistungssport, 32 (2), 1115.

Joch, W. & Ückert, S. (2003).
Ausdauerleistung nach Kälteapplikation,
Leistungssport, 33 (6), 1722.

Ückert, S. & Joch, W. (2003). Der Einfluss von Kälte auf
die Herzfrequenzvariabilität. Österreichisches Journal
für Sportmedizin 33 (2), 1420.

Ückert, S. & Joch, W. (2003). Der Effekt von Ganzkörperkälteapplikation (110° C)
auf die Herzfrequenzvariabilität. Deutsche Zeitschrift für Sportmedizin, 54 (7/8), 102.

Ückert, S. (2003). Effekte extremer (110°C) GanzkörperKälteapplikation auf das Verhalten von Herzfrequenz und Herzfrequenzvariabilität oder: Kälte als Leistungsund RegenerationsOptimierer. In Hanns-MartinSchleierStiftung, HeinzNixdorfStiftung & TU München (Hrsg.), Gesundheit fördern Krankheit heilen. Neue Wege im Zusammenwirken von Naturwissenschaft Medizin Technik (S. 192193). München.

Joch, W. & Ückert, S. (2004). Auswirkungen der Ganzkörperkälte von 110°C auf die Herzfrequenz bei Ausdauerbelastungen und in Ruhe. Physikalische Medizin, Rehabilitationsmedizin Kurortmedizin (für den Druck 2004 vorgesehen).

Joch, W. & Ückert, S. (2004). Die Herzfrequenzvariabilität unter Belastungsbedingungen nach Kälteapplikation. In K. Hottenrott (Hrsg.), Herzfrequenzvariabilität im Fitnessund Gesundheitssport (erscheint 2004).

Ückert, S. & Joch, W. (2004). Der Einfluss von Kälte auf die Herzfrequenzvariabilität als Regenerationsparameter. In K. Hottenrott (Hrsg.), Herzfrequenzvariabilität im Fitnessund Gesundheitssport (erscheint 2004).

6. LITERATURE

Brück, K. (1990). Wärmehaushalt und Temperaturregelung. In R.F. Schmidt & G.Thews (Hrsg.), Physiologie des Menschen, 24. Auflage

(S. 661682). Berlin u.a.

Eilers, K. (2002). Herzfrequenz und Herzfrequenzvariabilität als Indikatoren psychischer Beanspruchung. Frankfurt u.a.

Hinterecker GmbH (2002).
www.kaeltekammer.at. Stand: 17.12.2002.
Hottenrott, K. (Hrsg.) (2002).
Herzfrequenzvariabilität im Sport. Hamburg.

Joch, W. & Ückert, S. (2003).
Ausdauerleistung nach Kälteapplikation.
Leistungssport 33 (6), 1722.

Kay, D.; Taaffe, Dr.; Marino, F.E. (1999). Wholebody Precooling and Heat Storage During Selfpaced Cycling Performance in Warm Humid Conditions. Journal of Sports Sciences, 17, 937944.

Löllgen, H. (1999).
Herzfrequenzvariabilität.
Deutsches Ärzteblatt, 9 (31/32), 45.

Marino, F.E. (2002). Methods, advantages, and limitations of body cooling for exercise performance. British Journal of Sports Medicin, 36 (1), 8994.

Marsh, D. Sleivert, G. (1999). Effect of Precooling on High Intensity Cycling Performance. British Journal of Sports Medicin, 33(6), 393397.

Schmidt, R.F.; Thews, G. (Hrsg.) (1990). Physiologie des Menschen, 24. Auflage (S. 661682). Berlin u.a.

Taghawinejad, M., Fricke, R., Duhme, L., Heuermann, U. & Zargornzy, J. (1989). Telemetrischelektrokardiographische Untersuchungen bei Ganzkörperkältetherapie (GKKT). Z. Phys. Med. Baln. Med. Klim., 18,3.

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

W. Joch/S. Ückert

ABSTRACT

Treatment with cryotherapy has been known for a long time. Wholebody 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 2225) during a standardised 26minute endurance test and over a fiveminute 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 wholebody cooling may be successfully applied prior to endurance sports activities to optimise energy requirements and recovery.

KEYWORDS

Wholebody cooling cold chamber endurance load rest

[PUBLICATION DATA]

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INTRODUCTION

Bodycooling 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 wholebody 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 24 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 wholebody cooling therapy are "to a large extent still hypothetical" [4]. Taking the example of heartrate 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 heartbeat volume, and an improvement in the uptake of oxygen content from the blood [8].

Both effects gave rise to a temperaturelinked 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 (2½minute) 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 sportrelated 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 wholebody 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 sixminute warmup 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 highperformance Schoberer (SRM) ergometer. The sequence of loading used in the standardised intervallised test can be seen in Fig. 1.

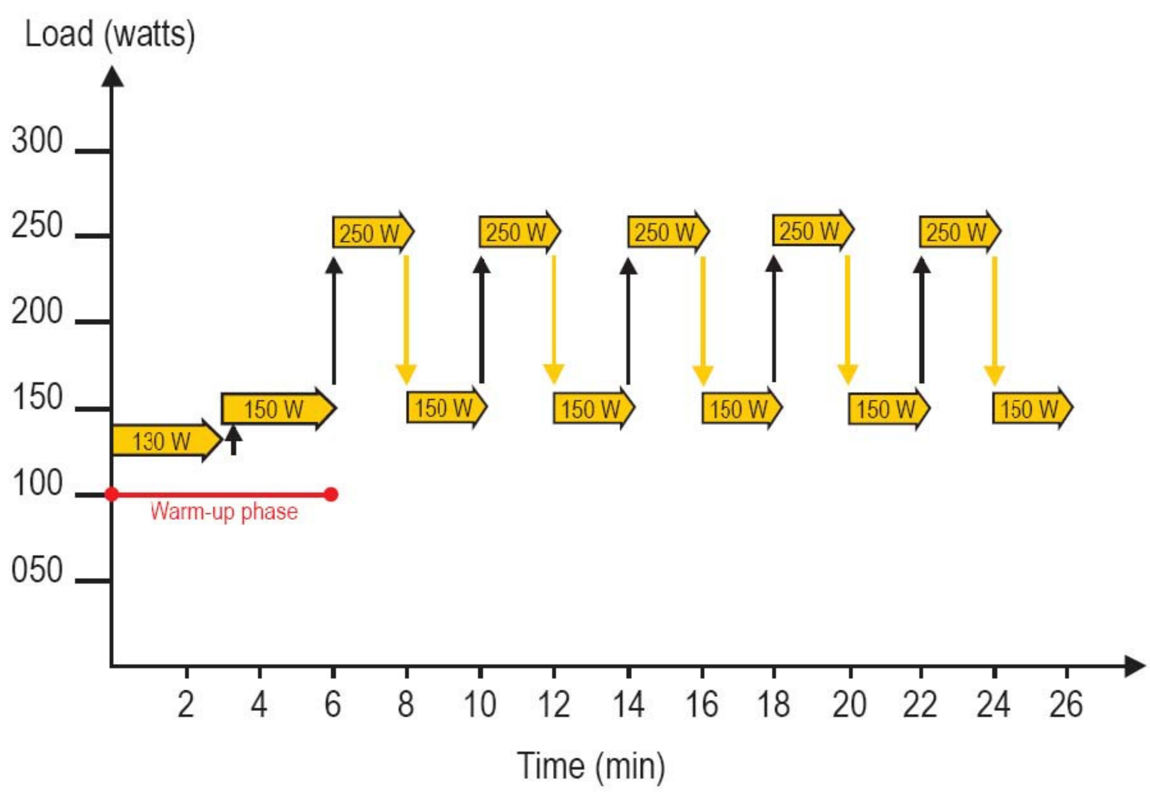


Figure 1: Time and load profile of endurance test over 26 minutes

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 wholebody cooling (pWBC) is on average highly significantly (p= 0.001) lower than is the case without precooling (oWBC) throughout the entire 26minute test period. Under load conditions, then, significantly lower heartrate values were detected than were found in identical test conditions where no preceding exposure to wholebody 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.

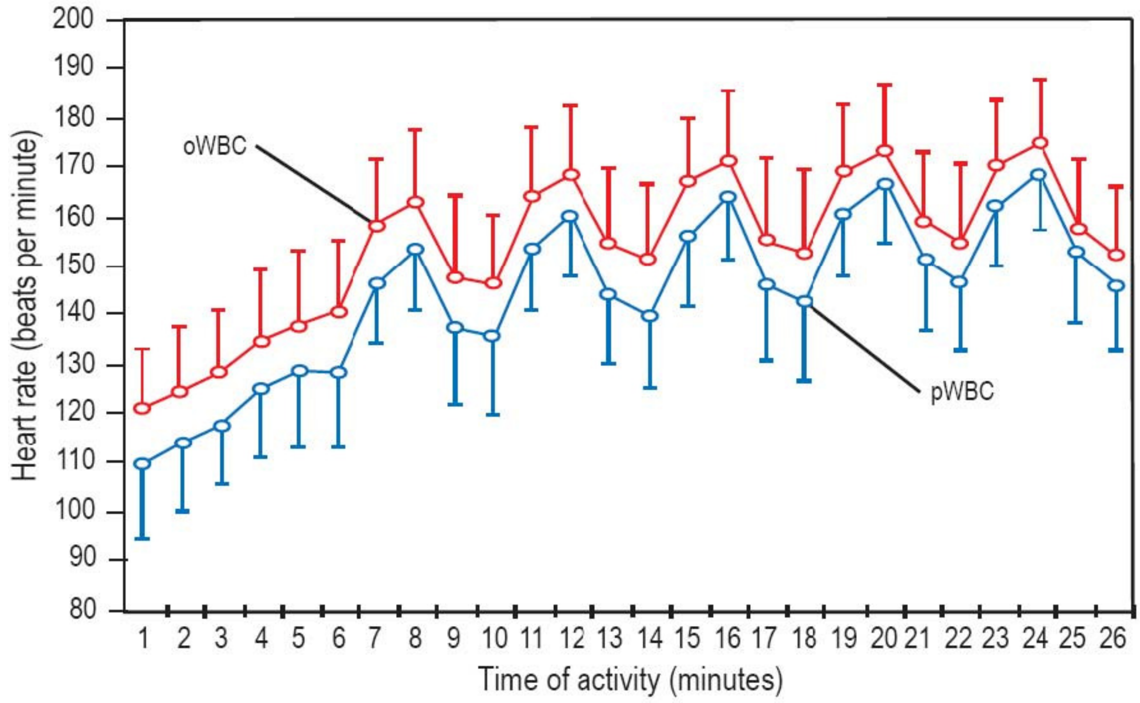


Figure 2: Heart rate (beats per minute) for each minute of the endurance test (after a fiveminute rest phase) without (oWBC) and following (pWBC) wholebody cooling.

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 16 the difference was 8.1% (highly significant), in minutes 716, 6.6% (significant) and in minutes 1726, 4.6% (not significant). In absolute terms the heart rates varied during the actual load phase (minutes 726) 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 78) the difference between oWBC and pWBC was 10.8 beats per minute, while at the end (minutes 2324) 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) wholebody cooling during the endurance test (minutes 16: warmup phase, minutes 726: intervallised load phase)

Heart rate (Beats per minute)

Watts	Minut e	oWBC	pWBC	Diff. o/pWBC	Mean (%-Diff)
	1	120.9	109.6	11.3	**8.8 8.1 7.4 6.6 4.6**
130	2	124.6	113.8	10.8	
	3	128.1	117.4	10.7	
	4	134.6	125.1	9.6	
150	5	138.0	128.6	9.4	
	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	
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	
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 wholebody cooling; pWBC = after prior wholebody 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 ttest 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 highdosage cooling of 110º C could have the effect of a "shock" [15] can therefore not be confirmed [16].

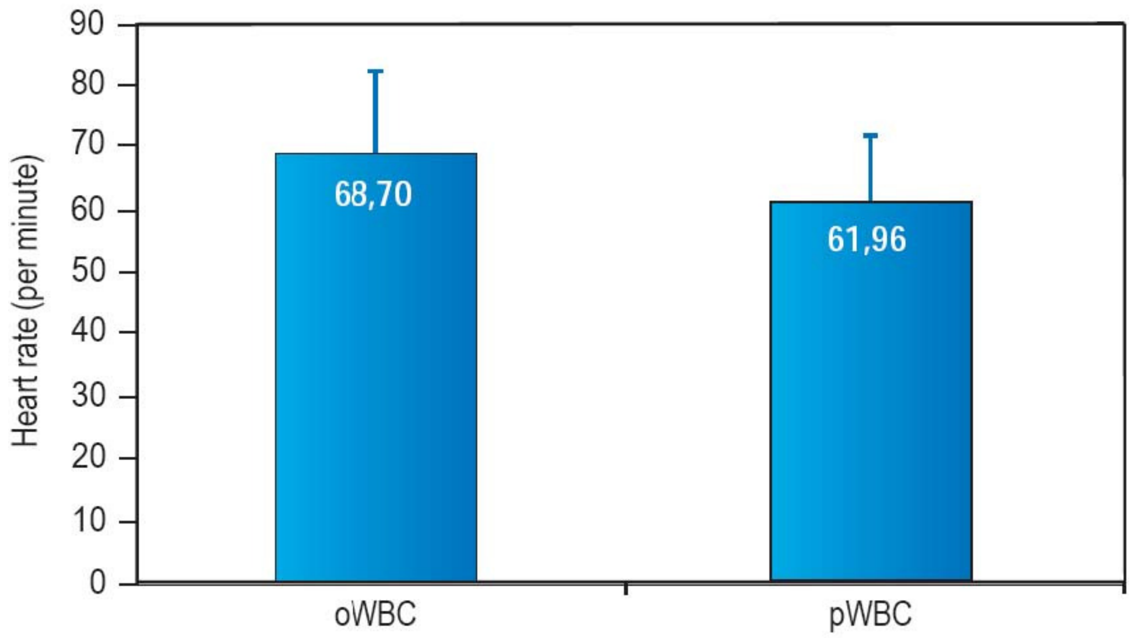


Fig. 3: Behaviour of heartrate curves without (oWBC) and after (pWBC) wholebody cooling during a 26minute intervallised endurance test

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) wholebody 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.

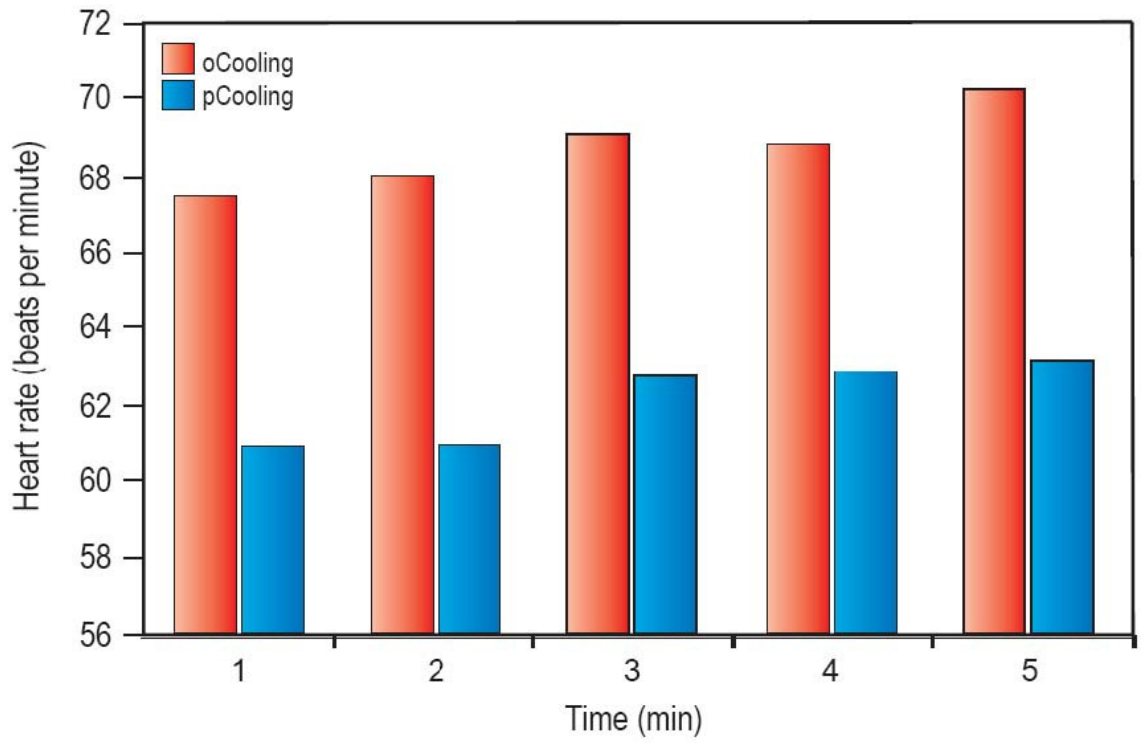


Figure 4: Mean heart rates (beats per minute) in the fiveminute rest period without (oWBC) and after (pWBC) wholebody cooling.

DISCUSSION OF RESULTS AND CONCLUSION

The aim of the research into the influence of shortterm, highdosage cooling (110º C) on heartrate behaviour, under both rest and load conditions, was to test whether and, if so, to what extent wholebody 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 heartbeat 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 warmup, 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 wholebody 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 heartrate variability further confirms these findings [20].

Literature

1 Schröder D, Anderson M. Kryound Thermotherapie: Grundlagen und praktische Anwendungen. Stuttgart: Fischer, 1995.

2 Fricke R. Ganzkörperkältetherapie in einer Kältekammer mit Temperaturen um 110°.
Z. Phys. Med. Baln. Med. Klimat 1989; 18:110

3 Fialka V. Ernst E. Kryotherapie.
Wien med Wschr 1994:144:4244.

4 Kreck C.Saller R. Kältetherapie und Ganzkörperkältetherapie. In: Brüning M, Kemper FH (Hrsg.)r. Naturheilverfahren und unkonventionelle medizinische Richtungen, Kap. 03,06,113, Heidelberg: Springer, 2000.

5 Taghawinejad M, Barwe G, Friche R. Hartmann R. Ganzkörperkältetherapie - Beeinflussung von Kreislauf und Stoffwechselparametern.
Z. Phys. Med. Baln. Med. Klim 1988:18:2330.

6 Badtke G (Hrsg.). Lehrbuch der Sportmedizin.
Heidelberg: JohannAmbrosiusBarth, 1995: 514

7 Hinterecker GmbH, GKKT GanzkörperKältetherapie - 110°C (Kältekammer) www.kaeltekammer.at/infos-profisport.htm

8 Fricke R. Was leistet die Kältetherapie bei rheumatischen Erkrankungen? RheumaJournal, 1999; 1:2829

9 Brück K. Warmlaufen oder Kaltstart? Sportliche Höchstleistungen durch Kälte. Spiegel der Forschung 1987; 5:1316

10 Joch W. Fricke R. Ückert S. Der Einfluss von Kälte auf die sportliche Leistung, Leistungssport 2002: 2; 1115, vgl. auch: Zimmer K. Zagrobelny Z. Influence of extremely low temperatures on skeletal muscle function. Vortrag auf dem III: Internationalen KryotherapieSymposium. Weserland-Klinik. Bad Seebruch am 26.10.2002

11 Joch W. Ückert S. Ausdauerleistung nach Kälteapplikation. Leistungssport 2002: 6; 1719. vgl. auch Castellani JW. Young AJ. Kain JA. Rouse A. Sawka MN. Thermoregulation during cold exposure: effects of prior exercise. J appl Phys 1999: 87; 247252

12 ausführlich in : Joch W. Fricke R. Ückert S. Der Einfluss von Kälte auf die sportliche Leistung, Leistungssport 2002; 2:1115

13 Fricke R. Was leistet die Kältetherapie bei rheumatischen Erkrankungen? RheumaJournal 1999; 1: 2829

14 Fricke R. Lokale Krypotherapie bei chronisch entzündeten Gelenkerkrankungen. Z. Phys Med Baln Med Klim 1988; 17: 46

15 Nöcker K. Heilender Kälteschock 2001 www.fachklinikumbrandis.de

16 vgl.dazu Ückert S. Joch W. Der Einfluss von Kälte auf die Herzfrequenzvariabilität. Öst J Spo Med 2002; 2: 1420

17 Brück K. Warmlaufen oder Kaltstart? Sportliche Höchstleistungen durch Kälte. Spiegel der Forschung 1987; 5: 1316

18 Marsh D. Sleivert G. Effect of precooling on high intensity cycling performance. Br. J Sports Med 1999; 33: 393397

19 Löscher W. Kälte tut Läufern gut. Condition 2003; 3: 30

20 Ückert S. Joch W. Der Einfluss von Kälte auf die Herzfrequenzvariabilität als Regenerationsparameter. In: Hottenrott K (Hrsg): Herzfrequenzvariabilität im Fitnessund Gesundheitssport; Im Druck

ENDURANCE PERFORMANCE AFTER COOLING[1]

W. Joch / S. Ückert

Competitive sport has developed to the point that human performance is reaching its limit. It follows that, in order to further improve performance, new resources must be deployed that were previously unknown or simply not used such as improvements in quality of training, the optimisation of loading and recovery or ways of increasing biological reserves, etc. The conditions of thermoregulation as one such resource able to meet the demands of increased sports performance have, up to now, remained marginal in the area of sport. As a rule they have been confined to the topic of heat production in the body through physical effort, in other words, warming up. The other side of this regulatory system the interplay of heat and cold, the relationship of warming up and cooling down has so far received little attention.

The following contribution, which forms part of a research project funded by the Institute for Sports Science, is concerned with the effect of precooling on endurance performance.

After a brief (2.5 minutes) exposure to a high dosage of cooling (110° Celsius), an endurance test lasting 26 minutes was performed with alternating loads of 150W and 250W on a highperformance bicycle ergometer (SRM). The 17 male test participants were aged between 21 and 24 years and had good endurance capacity, though not in the sense of a developed competitive sports training. From the test data recorded, heart rate behaviour, blood lactate content and energy consumption were compared with the same parameters for an identical test carried out without the prior cooling, under normal temperature conditions (21°C). Here the results will be discussed in the context of selected relevant international literature. The results indicate that the use of precooling can prove an effective means of tapping new performance reserves in highendurance physical activity.

Submitted: 26 May 2000

1. INTRODUCTION

Physical activity generates heat. This process is beneficial to sports performance in that for every degree Celsius of body temperature rise, the biochemical processes necessary for physical activity are accelerated by 13 percent (Lullies 1973, p.372). There is however an upper limit for body temperature which, if exceeded, results in a negative influence on performance[2]. High external temperatures, which cause this limit to be more quickly reached, have a negative effect on performance, as does a lack of external cooling factors. Cooling of the body takes place through sweating (evaporation cooling) and external conditions (temperature, wind etc).

For an optimisation of performance, then, a suitable thermoregulatory balance is required between heat production and heat loss, i.e. cooling. To consider heating alone would be counterproductive, since although the body can cope with an increase in core temperature through physical activity, the necessary cooling from the body surface is not taken into consideration.

1 A research project carried out by the German Institute for Sports Science (Bundesinstitut für Sportwissenschaft), Bonn, in 20012 Project number VF 0407/05/05/2002. 2 In marathon races, for example, body temperatures of over 40° were measured, which without suitable cooling or heatremoval, and often linked to dehydration because of sweating can lead to loss of performance or even collapse.

2. WARM-UP OR A 'COLD START'

The question of thermoregulation in the context of sports performance, that is, the interplay of heat and cold in (endurance) sports performance, was expounded under the somewhat provocative title "Warmup or cold start" (Brück,1987, pp.1316). Brück's argumentation and the basis of his empirical findings consider, in the main, two aspects:

- ➓ the idea that "a (general) rise in body temperature has a favourable effect on performance" does not agree with the physiological facts. Particularly for endurance sports, he maintains, a significant part of the available energy must be expended by thermoregulation on the one hand, for the generation of heat, and on the other, for cooling from the body surface (e.g. skin temperature). Such energy is thus not available for muscular effort and the continuation of the activity. Research carried out in Australia in 1999 quantified this proportion of total energy as 75%: "The human body requires a considerable mount of energy and blood flow to allow cooling. Only about 25% of the energy available is actually used for the sporting activity" (Schmidt & Thews, 1997, p.652). The possibility of cooling the body prior to exercising would thus seem, as regards performance enhancement, not to be without importance.

- ➓ if the body is cooled ('precooled') prior to beginning sport (i.e. the cause of bodily heat production), this would lead to an increase in the 02 pulse (i.e. the quantity of oxygen that can be carried to the body periphery per beat of the heart), with the following effects: an increase in the stroke volume, and an improvement in the uptake of oxygen content in the blood. These two effects would result in an economising of cardiovascular activity on the basis of temperature. Athletes treated in this way would sweat less, that is, the thermoregulatory burden following the socalled "cold start" would be less. A performance improvement of about 17% was claimed over the first fifteen minutes, and body temperature was found to be distinctly lower. Only after about an hour did the results of the two groups converge.

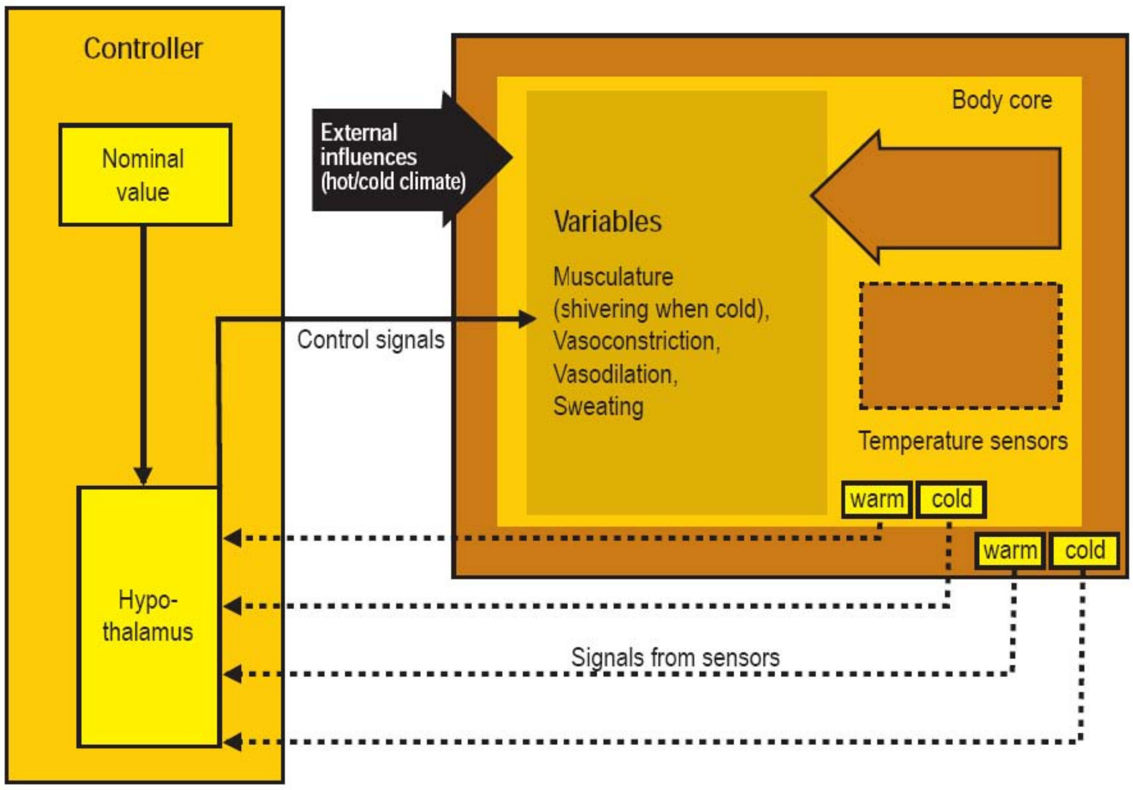
Brück's research shows (in his view) "that the idea that endurance performance can be increased by raising the body temperature ('warming up') has no basis. Rather, it was shown that sustained performance can benefit from lower body temperatures, even by reductions to below resting temperature. This [...] fact is supported by the temperature dependency of many psychological regulation processes, whose demands lead with rising temperature to increasing discomfort, which in turn impairs the ability to maintain sustained performance." (Brück 1987, p.16).

3. PRINCIPLES OF THERMOREGULATION

Man belongs to the homoeothermic group of creatures, i.e. whose bodies' core temperatures are maintained, for the most part, at a constant value. Extremities, however, and skin, behave as poikilothermic - their temperatures are subject to larger fluctuations (Schmidt & Thews 1997, p.649). The primary function of the body's temperature regulation is to maintain an almost constant temperature in the face of fluctuations in heat absorption, heat generation and heat loss by the body. Thermoregulation is a complicated heat regulation system that may be illustrated in simplified form as a closedloop control system (see Fig. 1). In this simplified model, body temperature represents the controlled variable, the hypothalamus the controller, the warm and cold thermoreceptors the sensors and all mechanisms for producing or removing heat the variables. External influencing factors include the ambient temperature, air humidity, wind and radiation, also the time of day; internal influences include the bodily work or physical activity.

Any fluctuation from the nominal value of core body temperature (36.537° C) induces the hypothalamus to take suitable thermoregulatory actions.

Fig. 1: Closedloop system of thermoregulation

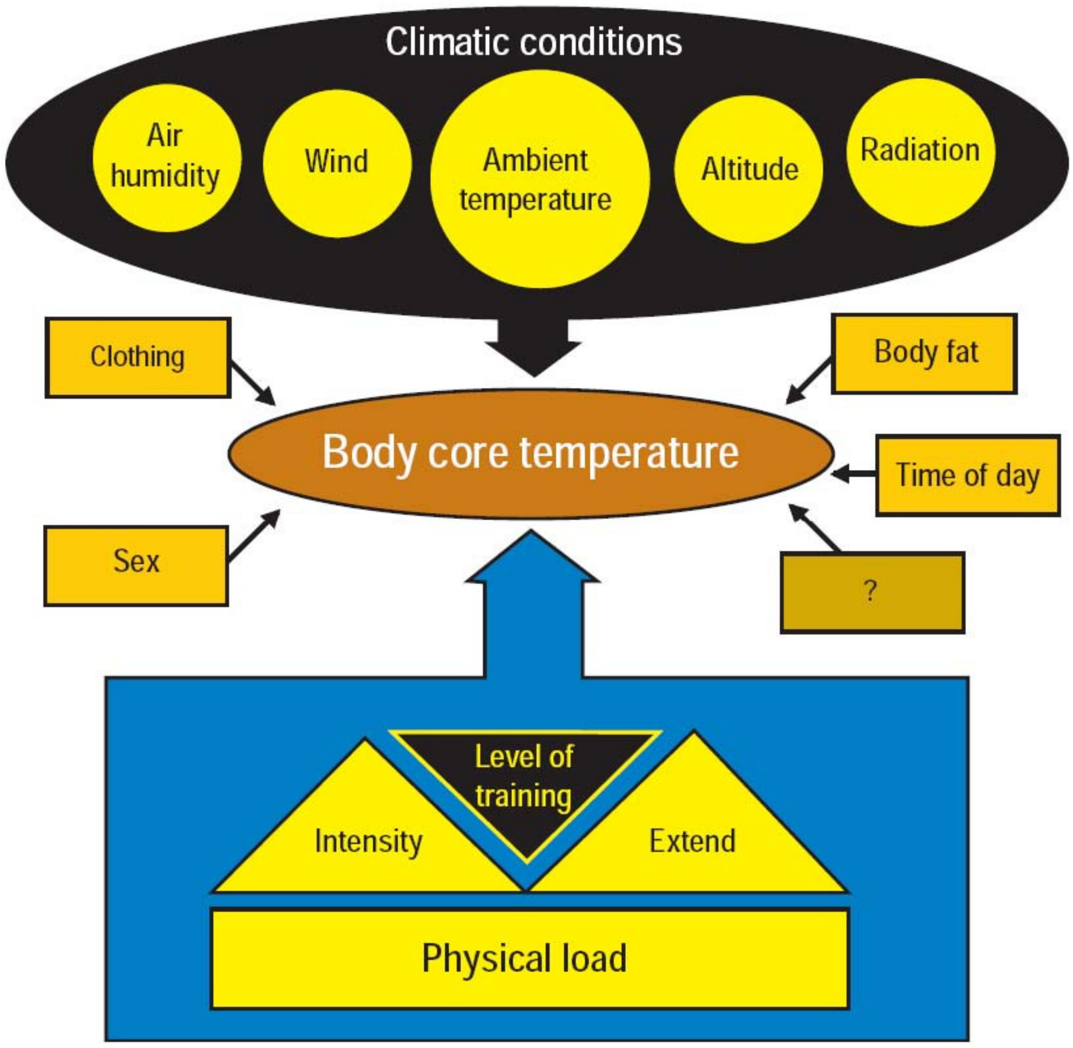


Simplified closed-loop model of human thermoregulation

Temperature zones in the human body

Heat produced in the body is passed to the surface by means of conduction (heat flow through the tissue) and convection (heat carried in the blood). Convection represents the most significant means of heat removal from the muscles (Nadel 1993, p.174). There is thus in general a temperature gradient between the core of the body (where the temperature inside the torso and skull is practically constant) and the periphery (tissue below the skin and the skin itself). The latter serve as insulation for the core. Body temperature decreases both from within to without (radially) and also along the extremities (axially). Heat is produced in the core and conveyed via the primary heat transmitter, blood, across the temperature gradient to the body surface (see Fig.2).

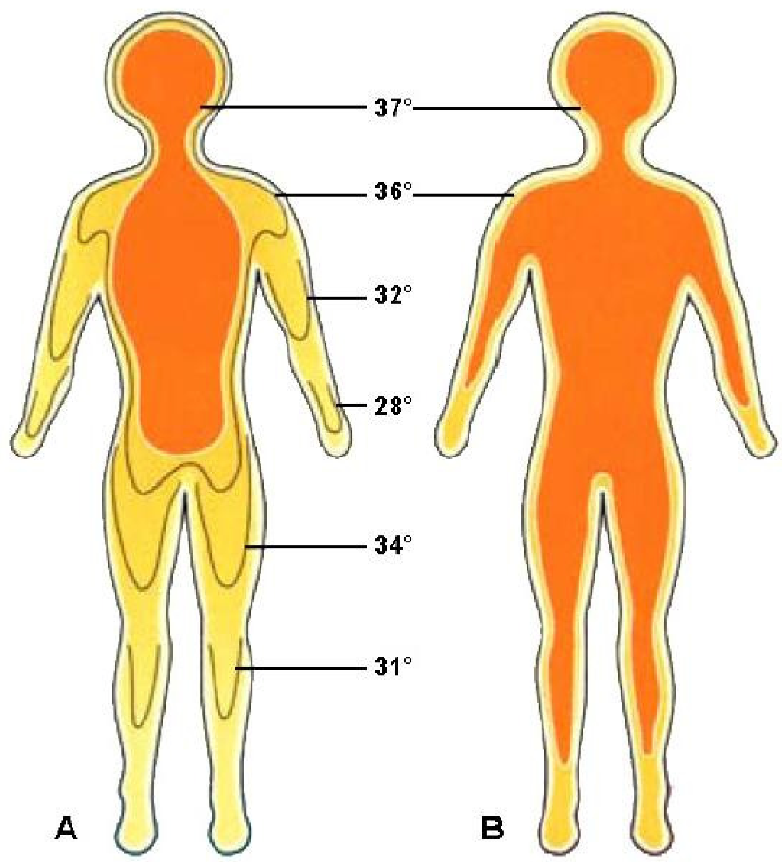
Fig. 2: Main influencing factors on body temperature



COLD AND WARM AMBIENT TEMPERATURES

To protect excessive heat loss in cold environments, blood circulation to the skin is reduced by means of vasoconstriction. This leads to a cooling not only of the body surface but also of deeper tissue layers, resulting in a 'shrinking' of the core and a 'thickening' of the shell. In warm environments, the reverse applies: in order to avoid a critical core temperature increase, heat removal increases. The decrease in sympathicotonic activity owing to a reduction of noradrenalin levels causes vasodilatation, i.e. a widening of the blood vessels. Circulation to skin and extremities increases, allowing greater heat removal from the core and often resulting in sweating one litre of evaporated liquid represents a heat loss of 2418kJ or 580kcal from the body (Silbernagl & Despopoulos, 1991, p.192). The increased secretion of sweat cools the body surface and creates the necessary temperature gradient for heat extraction. The body core expands and the shell is reduced to the skin itself (see Fig.3). The heightened blood circulation to the skin thus benefits circulation to the muscles.

Fig. 3: Temperature zones of the body



Temperature zones in the human body in cold (A) and warm (B) ambient temperatures (after Schmidt & Thews, 1997, 651)

The body's two principal thermoregulatory mechanisms are the production of heat in extreme cold environments and the removal of heat in extreme hot environments. If however the heat imbalance cannot be brought to equilibrium, the result is hypothermia (overcooling) or hyperthermia (overheating). Unlike the core temperature, which remains almost constant, the shell temperature exhibits a greater degree of variability. Hyperthermia caused by physical activity and loading shows that a temperature above 37° C does not generally indicate a response to illness (e.g. fever). The following apply as a rule: the higher the intensity of activity, the higher is the core temperature. the higher the intensity of activity, the lower are the lower and upper comfort thresholds of temperature[3].

The body responds to climatic factors that adversely affect comfort, i.e. extreme cold or heat, in quite different ways according to the level of physical work being carried out. In hot conditions in which the body is engaged in intensive sports activity, discomfort (feeling hot) is greater than where activity is low. On the other hand, in cold conditions, discomfort (feeling cold) is greater where there is little physical activity than where activity is significant.

3 Comfort threshold, also known as the comfort temperature zone, is based on the ambient temperatures in which neither sweat production nor shivering occur and circulation to the skin is sufficient for temperature regulation.

4. COLD AND SPORTS PERFORMANCE: FROM THE LITERATURE

There is comparatively little in the literature that is of help in this area. This section, however, examines contributions from four different sources that are concerned with the effects of cold on performance in sport (in training and competitive situations and also in that of systematic scientific experiments)[4].

Martin, D.R. et al (1998, pp.1-4): Ice jackets are cool

This study describes training undertaken by Australian elite endurance athletes who prepared for the 1996 Olympics in Atlanta using 'cool vests'. A total of 7 trainers and 43 athletes took part, from bicycle road racing, rowing, hockey, athletics and walking. All participants reported a (subjective) positive influence from their training and spoke of improvements in performance that were particularly evident when training was undertaken in hot climatic conditions. The special feature of the training was the cool vest, which allowed sufficient cooling of the thermoregulatory system, without drawing on the athletes' own energy reserves, to prevent overheating. Sweating was also reduced and the threshold of sweating was raised.

Lee, D.T. & Haynes, E.M. (1995, pp. 1971-1976): Exercise duration and thermoregulatory responses after whole-body precooling

The authors describe an experiment in the USA in which the performance of 14 male runners was tested. In each test, two highintensity periods of running took place.

Between these periods was a rest interval of 30 minutes, in which the temperature was either 24° C or 5° C. Afterwards, each runner underwent an enduranceload test whose intensity was set at 82% of his individual maximum aerobic capacity. At 5° C the results were as follows: Oxygen consumption (as gross measurement of sports endurance performance) was significantly

lower; heart rate was somewhat higher under rest conditions, but during the first 15 minutes of exercise it was significantly lower; time to exhaustion was significantly longer by 21%; no significant difference was measured in blood lactate levels. [cont. below diagram]

[Cont. from above] The authors concluded from their results that precooling enables a higher endurance performance and reduced loading of the metabolic and cardiovascular systems.

Marino, F.E. (2002, pp.89-94): Methods, advantages and limitations of body cooling for exercise performance

Marino's studies of precooling substantiate the notion that an increase in body temperature is detrimental to performance in sports activities. It seems that precooling is particularly beneficial for endurance activities of a duration of up to 3040 minutes; it is less effective for activities that are intermittent (i.e. with intervals of rest) and activities of shorter duration.

4 See also A. Krüger (2002): Aktuelles in Kürze. Hitze. Leistungsport 30 (2), 30f.

Olschewski, H. & Brück, K. (1988, pp. 803-811): Thermoregulatory, cardiovascular and muscular factors related to exercise after precooling

Seven men were tested on a bicycle ergometer at a room temperature of 18°C. The load was increased in two steps: in phase 1 (minutes 116) it corresponded to 40% of maximum oxygen intake, and in phase 2 it was raised until oxygen intake reached 80% of the maximum and maintained at that level until exhaustion. In each case the test was conducted twice once with precooling and once without. The results: after precooling, the time to exhaustion at 80% of maximum oxygen intake

was increased by 12%; heart rate was significantly lower; the rate of sweating and heat conduction for the precooled group was 39%

lower in the exhaustion phase.

5. The authors' own research and results

Research methodology

For our research, precooling took the form of wholebody cooling in a cold room held at 110° C for 2.5 minutes[5]. This precooling was followed by an endurance test. The random sample of test persons consisted of 17 male sports students aged 2124 who had an average to good endurance capacity but were not trained specialists in endurance sports disciplines.

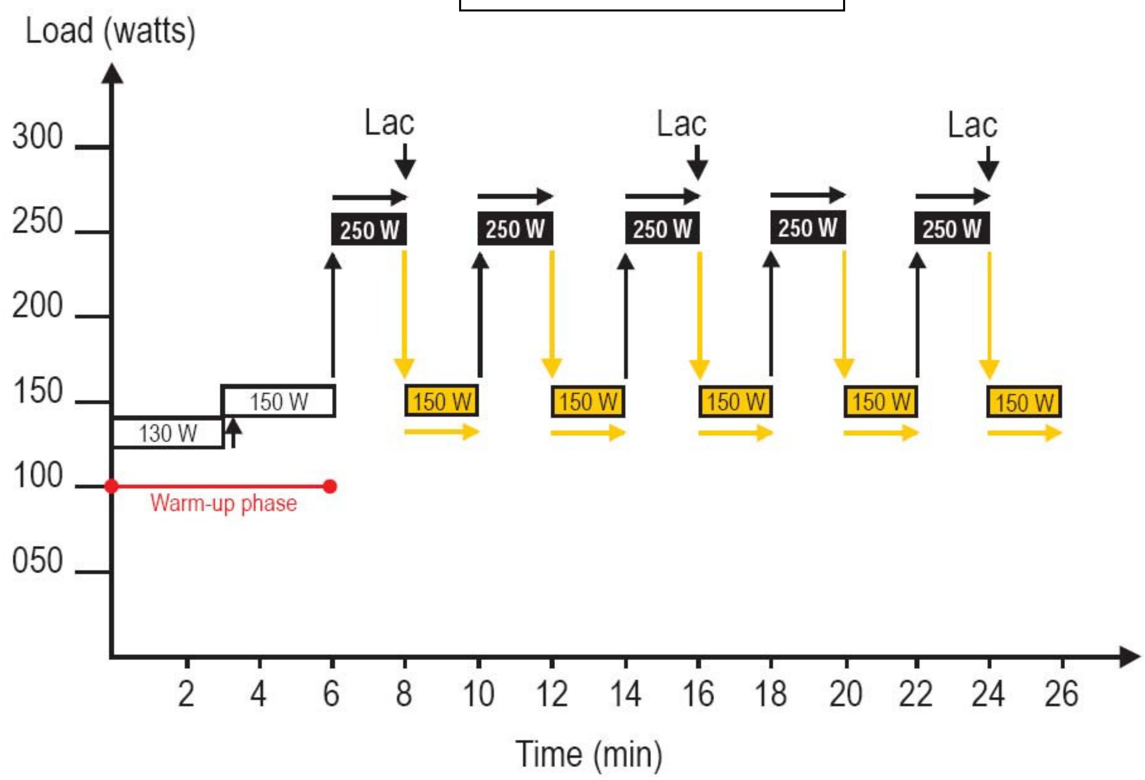
After the cooling in the cold room, the participants were subjected to the following endurance load test using a highperformance Schoberer (SRM) bicycle ergometer: warmup phase of 130 and 150watt loads, three minutes of each, in alternation, twominute intervals of high load phase (250W) and low load phase (150W), controlled automatically. A total of five alternations or 'stages' took place, equalling 20 minutes in total.

The total duration of the test, including the sixminute warmup phase, was thus 26 minutes. The load sequence of the test can be seen in Fig.4. In the test, the following variables were examined[6]: calorific consumption, measured with the Polar S 810 heartrate device programmed with the personal data of each participant (age, sex, body weight, performance level, VO2max) for each test minute; lactate concentration in the blood at the end of the first, third and fifth highload phase (minutes 8, 16 and 24), heartrate behaviour, measured with the Polar S 810 device, throughout the test in both warmup and load phases.

5 There are currently between 70 and 80 coldrooms in Germany. The first was built in Sendenhorst for Prof Dr Reinhard Fricke on the model of the Japanese practitioner Yamauchi and is mainly used for the treatment of rheumatic complaints (cryotherapy). The normal temperature maintained in these cold rooms is 110° C, but may occasionally be lowered to 120° C.

6 As part of the research project, investigations were carried out in addition to the parameters specified here in order to monitor the change in core body temperature, blood gases and variability in heart rate.

Fig. 4. Test profile



Test profile of intervallised endurance test. Warmup phase of 130 and 150W (3 mins each), then 250W high load phase and 150W low load phase, 2 mins each, alternated 5 times

EXPERIMENTAL RESULTS

Calorific consumption

Calorific consumption was measured and recorded for every minute using the Polar device. Below, the results from minutes 8, 16 and 26 (end of load phase) are discussed and evaluated. They demonstrate that calorific consumption is always lower where precooling took place (pWBC) than where it did not (oWBC). The reduction for pWBC was 12% at minute 8, 15% at minute 16 and 32% at minute 26.

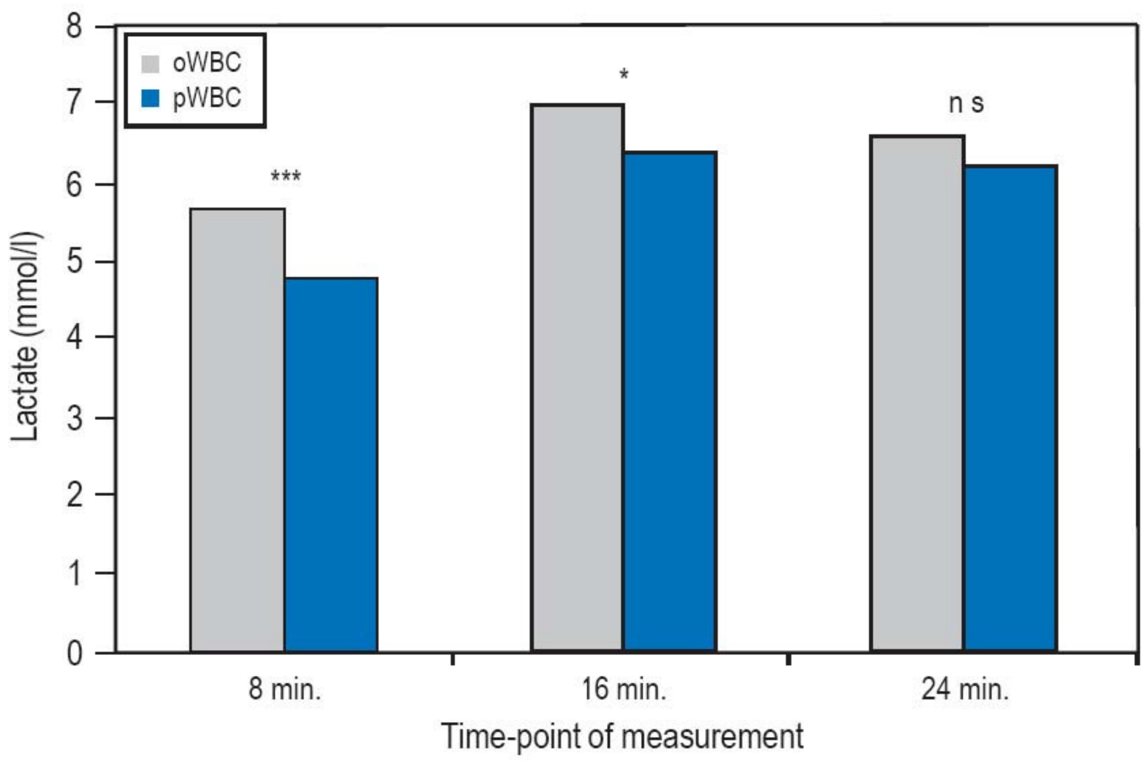
These results are significant, particularly concerning thermoregulatory conditions and with reference to Silbernagl and Despopoulos (1991, p.192), according to whom one litre of fluid evaporated from the skin represents a heat loss of 580 kcal, and to Marsh and Sleivert (1999, pp.393397) who stress that the body requires "a large amount of energy" for cooling, and that this amount increases with the duration of exercise and associated increasing sweating and uses more calories where precooling did not occur.

The grounds would seem to be unequivocal. The wholebody cooling procedure prior to endurance activity reduces as a result of the drastic cooling of the surface layers of the body in the cold room the energy required for thermoregulatory cooling of the biological system relative to that required where cooling has not taken place.

Lactate
Lactate concentration was measured in the 8th, 16th and 24th minutes, in each case at the end of a high-load phase (see Fig. 5). The findings show that at each point of measurement, lactate levels following precooling (pWBC) are lower than those where no precooling occurred (oWBC): in minute 8, the difference value between oWBC and pWBC was 0.9 mmol/l (5.7 mmol/l to 4.8 mmol/l = significant, p= .01); in minute 16, the difference value was 0.8 mmol/l (7.1 mmol/l to 6.3 mmol/l = significant, p= .05) in minute 24, the difference value was 0.4 mmol/l (6.5 mmol/l to 6.1 mmol/l = insignificant, p> .05).

These results do not confirm the research mentioned earlier. Thus, for example, Lee and Hymes (1995, pp.19711976) had been unable to establish a difference in lactate levels despite evident improvements in such variables as heart rate and oxygen intake. It can be confirmed, however, that the effects appear to diminish with increasing duration of activity (Marino, 2002, pp. 8994).

Fig. 5: Lactate concentration

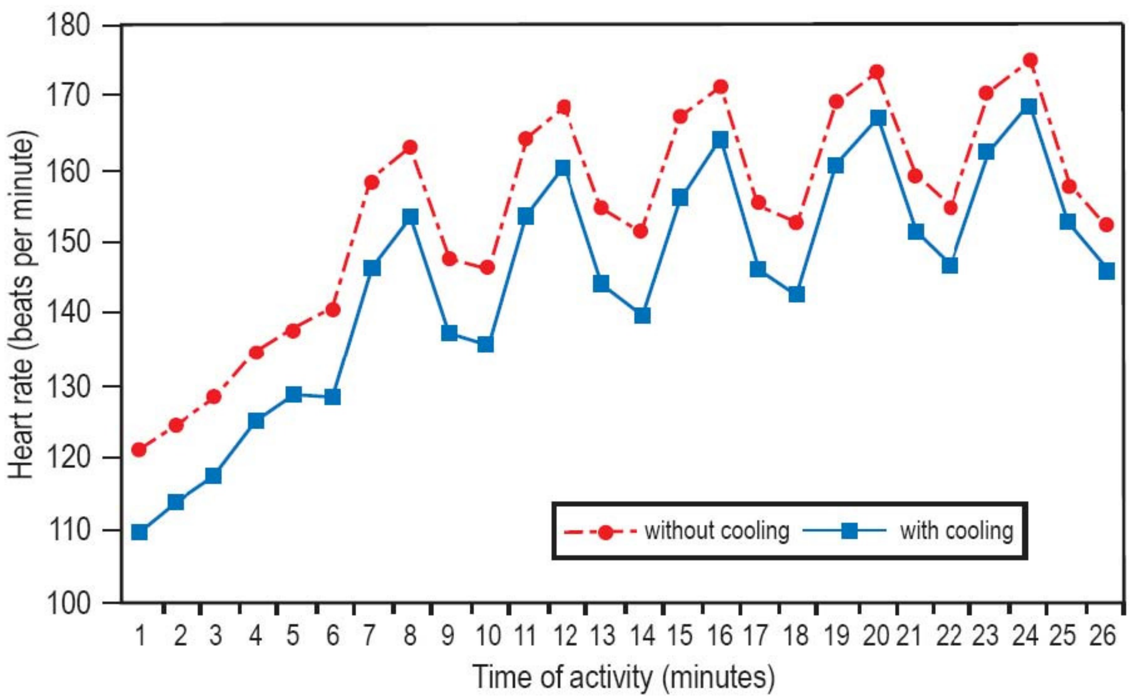


Lactate concentration: comparison between oWBC (grey) and pWBC (blue)

Heart-rate behaviour
Heart rate is an important and convincing parameter of performance that, together with capacity for oxygen uptake, makes it possible to determine the intensity, load and optimal training method of an individual. There are however marked differences between individuals as regards heartrate behaviour, and in this respect there are variations even under standardised test conditions that relate to age, sex and, above all, fitness level. Some research suggests that cooling, in particular wholebody cooling in a cold room, 'stimulates' the heart rate (Hinterecker, 2002).

In a related experiment using electrocardiography it was discovered that the heart rate increases by an average of 24 beats per minute during the cooling itself and by 13 beats per minute following cooling (Taghawinejad et al, 1989, p.33). The authors suggest that the cooling therapy (to 110° C) can cause a "sympathicotonic effect and consequent increase in resistance at the periphery, together with an increase in heart rate". This would then lead to an increase in load on the heart and so increase its demand for oxygen. However, this study was concerned with rheumatism and made no reference to load in the sense of sports activity; it was carried out under rest conditions.

Fig. 6: Heart rate behaviour during endurance test



Heart rate profile during an intervallised endurance test of 26 minutes with 5 phases of alternating 250W and 150W loads and a 'warmup phase' of 6 minutes (n=17)

It can be seen from Fig. 6 that the heart rate after wholebody cooling (pWBC) is lower throughout the entire 26minute test, with on average a high significance (p= .001), in comparison to results for the same test without prior cooling (oWBC) (see Table 2). For endurance load conditions, then, the effect of precooling on heart rate differs from that under rest conditions (Taghawinejad, 1989): under load conditions, heart rate is lower than under the same load where precooling has not taken place (oWBC). What is more, in our experiment two of the 17 test people had to abort the endurance test (minutes 20 and 24) where there had been no cooling, whereas for pWBC all seventeen completed the test in its entirety.

Warming-up phase

At the beginning of the endurance test, during minutes 1 and 6 of the warmup (130W and 150W respectively), the differences in heart rate without precooling (oWBC) and after precooling ranged between 6.8% and 9.3% (see Table 1), with a mean value of 8.1%. If one compares this section with that between minutes 7 and 16 or minutes 17 and 26 (see Table 2), there are in both of these sections, with alternating loads of 250W and 150W, mean differences of respectively 6.6% and 4.6% (see Table 1).

From this it may be deduced that the positive effect of precooling gradually diminishes over time, is greatest at the beginning of the activity and decreases as exercising continues (see also Marino, 2002, pp.8994). This outcome is also confirmed during the warmingup phase: the heart rate differences here amount to a mean of 8.8% in minutes 13 and 7.4% in minutes 46. This difference may be attributable, on the one hand, to the duration of the test; it may however also be due to the increase in load: in minutes 13 this is 150W and in minutes 46 it is 250W. The latter aspect will be further discussed below. In any case our results indicate clearly, for all differences in detail, that the cooling effect, although it diminishes over time, nevertheless is quantatively significant and demonstrable throughout.

Table 1: Heartrate behaviour during the warmup phase

	Heart rate (beats/min) with 125W load			Heart rate (beats/min) with 150W load		
	1st min.	2nd min.	3rd min.	4th min.	5th min.	6th min.
oWBC	120.9	124.6	128.1	134.6	138.0	140.9
pWBC	109.6	113.8	117.4	125.1	128.6	128.9
Diff. o/p	11.3	10.8	10.7	9.6	9.4	12.0
%: pWBC	90.7	91.3	91.6	92.9	93.2	91.5
% Diff.	9.3	8.7	8.4	7.1	6.8	8.5

Rise in fatigue

The pattern of heart rate over the series of five high (250W) and five low (150W) load phases indicates the onset of clear (significant) tiredness (see Table 2). Under oWBC conditions a rise can be seen in the high-load phases from 158.5 (minute 7) to 175.1 (minute 24) beats per minute. After precooling (pWBC) heart rates are lower at all times, by a difference of 11.8 beats/minute (minute 7) and 5.8 (minute 24).

This clearly supports, on the one hand, the positive effect of wholebody cooling on endurance performance. However, it also confirms the fact that the positive effects of precooling decrease over the duration of the test: the differences between oWBC and pWBC values become steadily smaller. This further means that the onset of fatigue under pWBC grows over time (and approaches values between oWBC and pWBC given the appropriate test duration, as indicated by Marino (2002, pp.8994)). If one compares the heartrate difference at the end of the warmup phase (150W) with that of the entire test (150W), then the tiredness factor can clearly be seen. Minute 6: 140.9 beats per minute; minute 26: 152.2 beats per minute. Difference: 11.3 beats per minute. Comparison of pWBC and oWBC indicates, on the one hand, the consistently lower values of pWBC: 128.9140.9 beats per minute, c.f. 146.2152.1 for oWBC, and on the other hand, the decreasing difference between oWBC and pWBC, namely 12 beats per minute (minute 6, 150W) to 5.9 beats per minute (minute 26, 150W). A distinction, furthermore, can be observed between the first and second minute of each of the five highload phases in this respect: the differences between oWBC and pWBC are consistently greater in the second minute than in the first, and in the lowload phases they are constantly greater. This is a clear demonstration that precooling serves to optimise the body's ability to adjust to the load, which is more effective than in the case of oWBC. The question posed above of whether the effects of cooling on endurance performance are a function not only of the duration of activity but also by the intensity of the load, may now be answered: the effects of cooling are not subject to load, only to duration.

Table 2: Heartrate behaviour in the high and low load phases

Watts	Test-minute	oWBC	pWBC	Diff. o/p	% pWBC	% Diff.
250	7	158.5	146.7	11.8	92.6	7.42
	8	163.1	153.4	9.6	94.1	5.92
150	9	147.5	137.4	10.2	93.1	6.9
	10	146.2	135.9	10.3	93.0	7.04
250	11	164.5	153.4	11.1	93.2	6.76
	12	168.7	160.4	8.3	95.1	4.92
150	13	154.6	144.4	10.2	93.4	6.62
	14	151.4	139.9	11.4	92.5	7.54
250	15	167.5	155.7	11.8	93.0	7.02
	16	171.2	164.2	7.1	95.9	4.12
150	17	155.1	146.1	9.1	94.2	5.84
	18	152.9	142.4	10.5	93.2	6.85
250	19	169.2	160.5	8.6	94.9	5.07
	20	173.3	167.0	6.3	96.4	3.64
150	21	159.2	151.5	7.7	95.2	4.81
	22	154.5	146.6	7.9	94.9	5.1
250	23	170.5	162.7	7.8	9.4	4.59
	24	175.1	169.3	5.8	96.7	3.3
150	25	157.7	152.4	5.4	96.6	3.41
	26	152.1	146.2	6.0	96.1	3.92

Heart rate behaviour (n=17) in the high load phases (250W = minutes 78, 1112, 1516, 1920, 2324) and low load phases (150W = minutes 910, 1314, 1718, 2122, 2526); for legend see Table 1

6. CONCLUSION, IMPLICATIONS FOR TRAINING PRACTICE AND PROSPECTS

The results of the present study of the influence of cooling on endurance performance or moren precisely, the influence on this of brief, highdosage wholebody cooling (WBC) applied prior to physical activity have proved, under the conditions of the study, relatively clear. They may be summarised in six points:

In the case of no precooling (oWBC), two of the 17 participants were unable to complete the endurance test. After precooling, however (pWBC), the same test was completed successfully by all participants.

Lactate concentration was significantly lower after precooling, at each of the three sampling points, than it was without precooling. The difference in the first sampling, in minute 8, proved to be highly significant.

Energy consumption by the participants was at all sampling points highly significantly lower after precooling than without.

Throughout the 26minute test, the participants' heart rates after precooling (pWBC) was highly significantly lower ($p= .001$), with a mean difference of 11.84 beats per minute (6.68%), than the rates obtained under identical test conditions without precooling (oWBC). This result adds support to the findings in the existing literature, according to which "the positive influence of cooling during exercise" could be proved in a test conducted without cooling, heart rate rose from 135 to 167 beats per minute, while with precooling it rose to 140 beats per minute, a lower rate by some 16% (Janssen 1996, p.43). The positive effect of cooling on endurance may thus be experimentally proved.

At each point monitored during the test the 'warmingup phase' (minutes 16), high load (250W) and low load (150W), the positive influence of precooling decreased with time. However, the point at which the influence would no longer be demonstrable was not reached within the 26 minutes of the test. At the end of the test the heartrate difference between oWBC and pWBC was still about half of the initial difference.

The assumption that load intensity, controlled in the experiment with systematically alternating loads of 250W and 150W in twominute periods, would be significant for the influence of cooling, was not substantiated.

From the results a number of conclusions may be drawn as regards sports training, which may only briefly be discussed here:

There are examples, albeit isolated, of elite athletes who make use of wholebody cooling to enhance their performance. One of these is the English longdistance runner Paula Radcliffe. The Süddeutsche Zeitung newspaper reported on 6 August 2002 that, following a gruelling 5km run in preparation for the 10km race at the European Championships in Munich, she took an ice bath on the recommendation of her physiotherapist. She explained the cooling in terms of the minitraumas suffered by her muscles, which would heal faster with the aid of cooling. In this respect, then, cooling was used as a therapeutic aid to recovery following a high level of stress to the body. The boxer Darius Michalczewski gave different reasons for his regular visits to a cold room (110° C) during preparations in Poland immediately prior to his fight with Derrik Harmon. In an interview with German TV channel ZDF in April 2003 he explained that the cooling allowed him to save about 20% of his energy, meaning that he could thus either train more intensively than otherwise, or alternatively, could train at the same intensity while saving strength. This, then, is an example of the use of cooling as a training strategy to facilitate the full exploitation of performance potential.

The use of cooling, in the form of a wholebody application of brief, intense cold in a cold room, is a particularly effective training aid where high ambient temperatures could lead to a reduction in performance.

In such a case, cooling would be considered a prophylactic or precautionary measure: the energy required to cool the exercising body (thermoregulation), thus detracting from the sports activity being performed, is less; while sweating occurs at a later stage and with a lower intensity. Both of these aspects imply a saving of energy. A variation on wholebody cooling in a cold room is the use of cool vests during the training itself (Martin et al, 1998, pp.14).

In conclusion it should be pointed out that cooling may be applied during endurance training to aid recovery, in particularly where two training elements must be performed in one day (as is usual in toplevel sport). Such cooling could be provided between the sessions, even with a separation of several hours (owing to the decreasing effect). This would have the advantage that the subsequent training session would benefit from the positive effects demonstrated in our experiment, which would allow either training at a higher intensity or training at the usual intensity with reduced stress. Such an optimisation of endurance training deserves inclusion within the further development of highlevel training that, in consideration of the current exhaustion of quantitative training possibilities, seems to be urgently needed.

About the authors

Professor Winfried Joch is a retired lecturer at the Institute for Sports Science of the University of Münster. He specialises in training theory, training of the young, motor development and the development of talent.

Sandra Ückert is a doctoral candidate in the same area. She specialises in training theory and in performance diagnosis.

WHOLE-BODY CRYOTHERAPY AT -110°C FOR TWO MINUTES INCREASES MUSCLE STRENGTH AND PERFORMANCE

Wholebody cryotherapy at 110°C for 1, 2 and 3 minutes showed the greatest increase in muscle strength and performance in the knee joint after 2 minutes. To find the most effective times for conditioning in sporting applications, 5minute pause intervals were used before and after the coldchamber exposure instead of 2-minute intervals.

METHOD:

One healthy knee joint of 7 female and 7 males was tested after a warmup phase of 5 minutes on the Cybex ergometer. After an interval of 5 minutes, wholebody cryotherapy was carried out at 110° for 2 minutes. Following a further pause interval of 5 minutes, the knee was retested on the Cybex. Results: the investigation of flexion 120°/s, flexion 60°/s. Extension 60°/s demonstrated an increase in peak power of between 2.83% and 3.76% with the exception of extension 120°/s with a value of 3.35%. The investigation of performance yielded an increase of between 3.30% and 18.6%.

DISCUSSION:

The results of the investigations demonstrate a further increase in muscle strength and performance with a 5minute pause before and after exposure to the cold chamber, compared to the prior investigation with a 2-minute pause. The results of investigations carried out on men and women must be evaluated separately on greater numbers of test subjects. Further investigations are required in order to work out the optimum time intervals for cold chamber application aimed at improving conditioning in sport.

LITERATURE:

Fricke R, Grapow G, Knauer G. Steigerung von Muskelkraft und Leistung durch GanzkörperKältetherapie -110°C über 1, 2 und 3 Minuten.

SPRINTING AFTER WHOLE-BODY EXPOSURE TO COLD AT -110°C FOR 2 MINUTES

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Weserlandklinik Bad Seebruch, VLOTHO

DRVSchriften Volume 12 (1999) 166167 Prof.
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The finding that, when working in cool conditions, red muscle fibres especially are activated (fast twitch = FT) more than white muscle fibres, is confirmed by tests investigating the influence of wholebody exposure to cold on red muscle fibres. In an initial investigation, Esslinger noticed an increase in sprint performance (as measured by a stopwatch) in sprint tests carried out after WBCT. To confirm this observation, we measured sprint performance before and after coldchamber exposure at 110°C for 2 minutes using an electronic measuring cabinet. In two test groups, the sprint was measured after 5m, 10m and 15m. The groups of medical students completely two sprint tests on the first day to learn the test conditions. On the following day, a coldchamber exposure at 110°C was carried out after two new sprint tests, and 5 minutes later the sprint performance was remeasured. The results were separated into females and males. A further group of female physiotherapy students and one male PT student ran 3 times on the first day. On the second day, the FBCE was carried out after 3 test runs. 5 minutes later, two further test runs were measured 5 minutes apart and the mean values determined. The results of the sprint tests of untrained men and women demonstrated an increase in sprint performance in both groups, however with different values. While the improvement in performance is only observed in the group of medical students after 10 and 15 m, an improvement in sprint performance was observed at all 3 measuring points among the female PT students. When the medical students were divided into male and female, there was an improvement in all parameters, but in the females this only occurred after 15 m. The differences between the two groups may be due to a difference in training status. One may also assume that physiotherapy students are physically better trained than medical students. The differences between males and females are explained by the relatively greater mass of red muscle fibres in males. In the light of the investigation results, an improvement in sprint performance can be expected following wholebody exposure to cold at 110°C. To clarify the results further, there are plans to further standardise the test conditions in terms of technical requirements and the level of training.

Increased muscle strength and performance through whole-body cryotherapy at -110°C

for 1, 2 and 3 minutes

R. Fricke, G. Grapow, G. Knauer
Weserlandklinik Bad Seebruch, VLOTHO

People who trained at a lower skin temperature demonstrated a significantly greater training effect compared to control individuals (Schuh, 1991). Working under cool conditions activates relatively more red muscle fibres (Brück, 1987). A resting muscle is activated by rubbing it with ice. Wholebody cryotherapy at 110°C offers these conditions for activating muscles. For this reason, tests were carried out to investigate the influence on the strength and performance of healthy muscles in the lower extremities.

Method:

30 test subjects were divided up into three groups of 10. Following a warmup phase, the individuals were treated in a cold chamber at 110°C for 3, 2 and 1 minute. Immediately before therapy, the peak power and performance at flexion 120°/s and flexion 60°/s were tested using the Cybex. Two minutes after cold chamber treatment, these same values were tested on the Cybex based on the group to which the individual belonged.

Discussion:

Wholebody cryotherapy at 110°C leads to an increase in peak power and performance. The best results were achieved after an application time of 2 minutes. Flexion 120°/s and extension 60°/s were the most favoured speeds. The somewhat negative results for flexion 60°/s and extension 120°/s can be put down to unfavourable speeds for the function in question. On the other hand, in untrained individuals, it could be due to varying distribution and activation of the muscle fibres. The therapeutic effect of wholebody cryotherapy can in some cases be explained by the cool corpuscles with the increased aerobic capacity of the muscle metabolism, which makes the ongoing aerobic way of dealing with the work easier. In further investigations, the effects of cold chamber treatment in relation to the intervals from the warmup phase and to testing after therapy will be investigated.

Literature:

Brück, K. (1987): Warmlaufen oder Kaltstart? Sportliche Höchstleistung durch Kälte
Spieg. Forsch 5. 1316. Schuh, A. (1991) Ausdauertraining bei gleichzeitiger
Kälteadaption. Phys. Rehab. Kur. Med. 1. 2228.

WHOLE-BODY-CRYOTHERAPY AT -110°C:

NEW PERSPECTIVES IN THE DOMAIN OF SPORTS MEDICINE AND TRAUMATOLOGY:

Abstract
L. Savalli, P. Trouvé, P.L. Puig, P. Lamaignere
CERSCAPBRETON:

Wholebody cryotherapy (WBC) has been used for several years in the countries of northern Europe and Japan as an adjuvant treatment for inflammatory rheumatic conditions, chronic degenerative conditions and certain neurological conditions characterised by muscular hypertonia. To date, little work has been carried out in the domain of sports traumatology. Method: The preliminary study that we have conducted focuses on evaluating the importance of WBC in precisely this domain. The study population is made of up 36 sportspersons who have been provided with a reeducational stay at the CERSCAPBRETON, following orthopaedic surgical intervention, as part of a “programme of reathleticisation” or “complementary eeducation”. Treatment with cold, associated with a rehabilitation programme, is based on the subject passing through a chamber chilled to 110° for 2 to 4 minutes, twice a day, in a swimsuit, with the subject’s extremities being protected and the subject breathing through a simple surgical mask. Patients are able to stop the session at any time. The presence of preexisting cardiovascular conditions or Raynaud’s syndrome represents a contraindication to cryotherapy. A satisfaction questionnaire was given to each sportsperson at the end of the treatment. Results: The number of sportspersons who had experienced pain during their stay was 21 (58%), of whom 17 stated that they were satisfied or very satisfied with the impact of WBC on their pain. Thirtyone (86%) of these stated that they were satisfied or extremely satisfied with regard to the impact of WBC on their physical condition, 16 (44%) on their sleep and 31 (86%) on the recovery of their muscular effort. Thirtyfive are satisfied or very satisfied with their experience of WBC and 12 (33%) believe that WBC has made a considerable contribution to the functional progress achieved at the end of the stay. Ultimately, for 33 sportspersons (92%), WBC represents a definite or major area of interest in our establishment.

Discussion / conclusion: The preliminary results outlined above need to be confirmed with a larger study population. It seems, however, given these initial results, that WBC is the cause of generally interesting effects relating to better recuperation of sporting effort, notably by increasing muscular tolerance for effort and the quality of sleep. Furthermore, WBC boasts analgesic and antiinflammatory properties, which may encourage tolerance of the reeducation programme, which in turn will increase the benefits obtained from it.

EVALUATION OF WHOLE-BODY-CRYOTHERAPY -110°C ON SPORTSMEN/SPORTSWOMEN

L. Savalli, P. Trouvé, P.L. Puig, P. Lamaignere
CERSCAPBRETON:

The CERS, European Center for Sport Reeducation is a 130 beds inpatient Center, specialised in the rehabilitation and training of sportman and women.

The CERS is evaluating since January 2004 the effects of the 110°C on patients preparing their come back to the sport activity, getting specific, individual trainings. These patients have already been in the past treated 3 weeks for their rehabilitation after their surgery or Trauma.

Patients have been requested to answer a questionnary
90 Patients treated 78 at least with 10 sessions of Whole Body Cryotherapy / WBCT sessions. Quantity average: 22 +/7,5 sessions

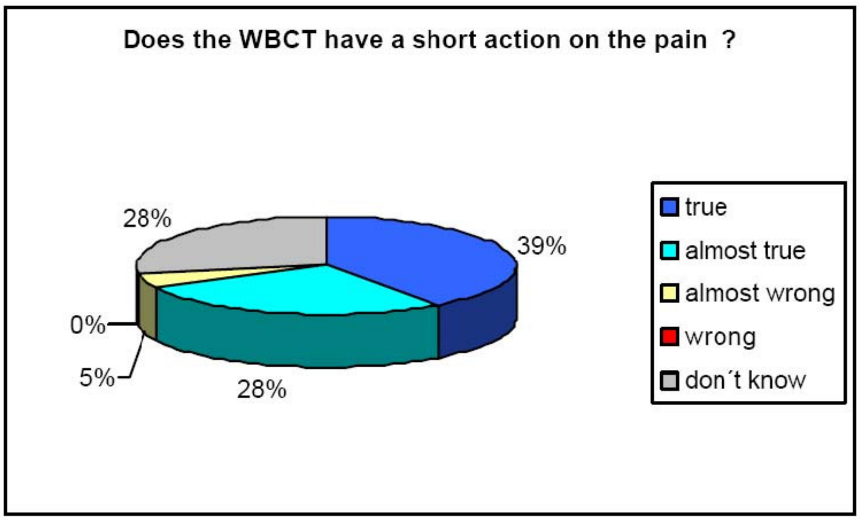
Injured part of the Body :
Knee: 54
Ankle: 8
Shoulder: 7
Spinal cord: 5
Pubis region: 3
Hip: 1

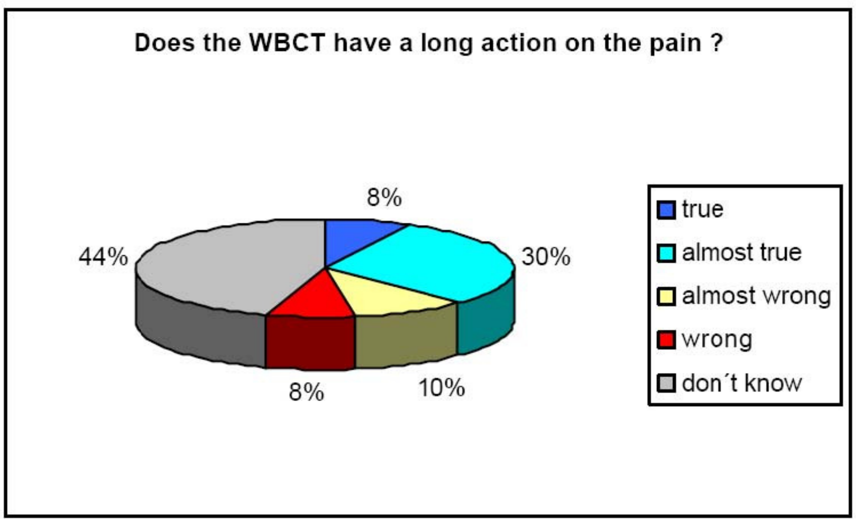
Medical act practiced
Suture: 4
Ostheosysnthesis: 3
Ligamentoplasty: 52
Divers: 7 Without
act: 7

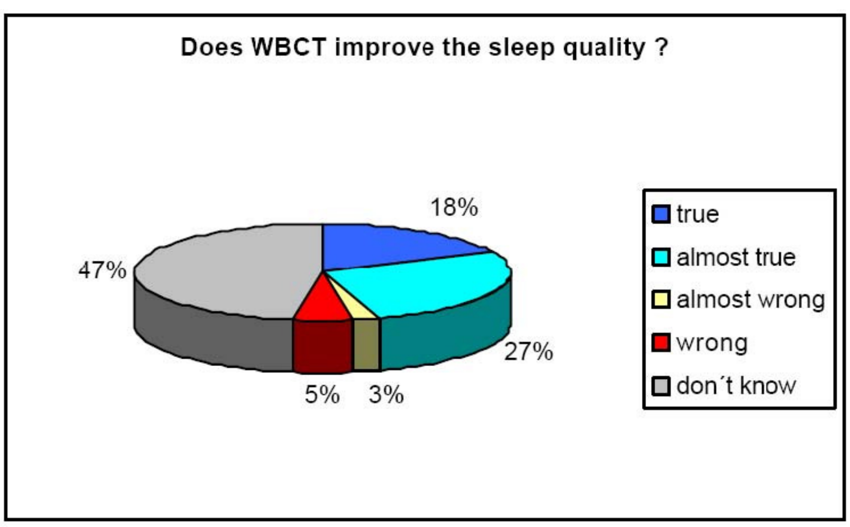
Timing
27 patients get cryotherapy less than 3 months after the med. Act
51 patients get cryotherapy later than 3 months after the med act

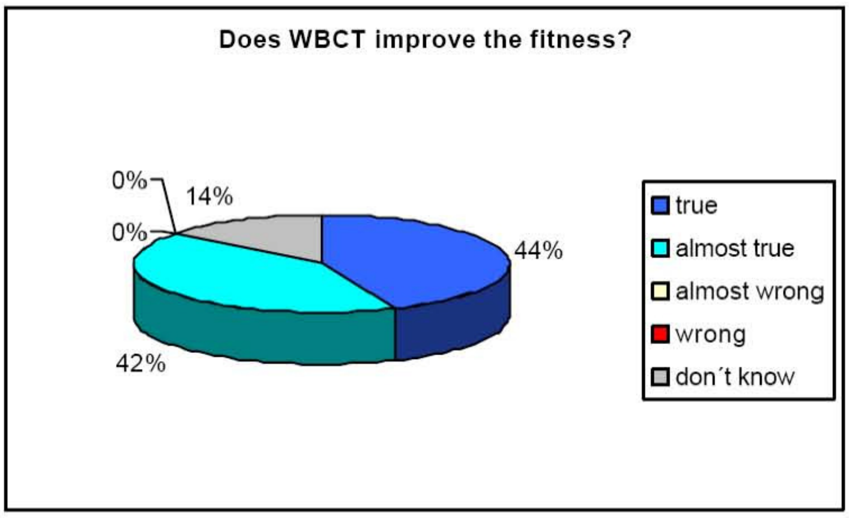
CONCLUSION

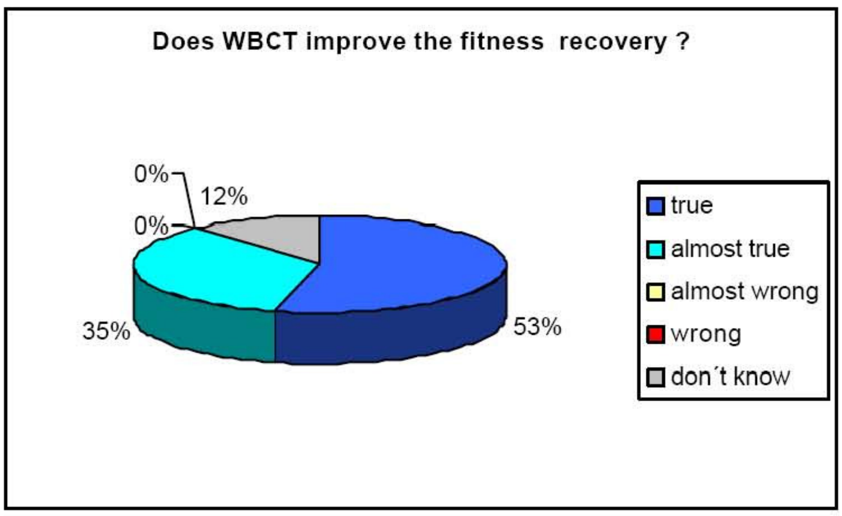
These preliminary presented results should be confirmed through a random study. Nevertheless it seems, considering these results, that the WBCT generates general interesting effects as a better physical exertion recovery, especially in increasing the muscle exertion recovery. Otherwise the WBT has analgesic and anti-inflammatory properties which could improve the tolerance of the rehabilitation program, improving its results.

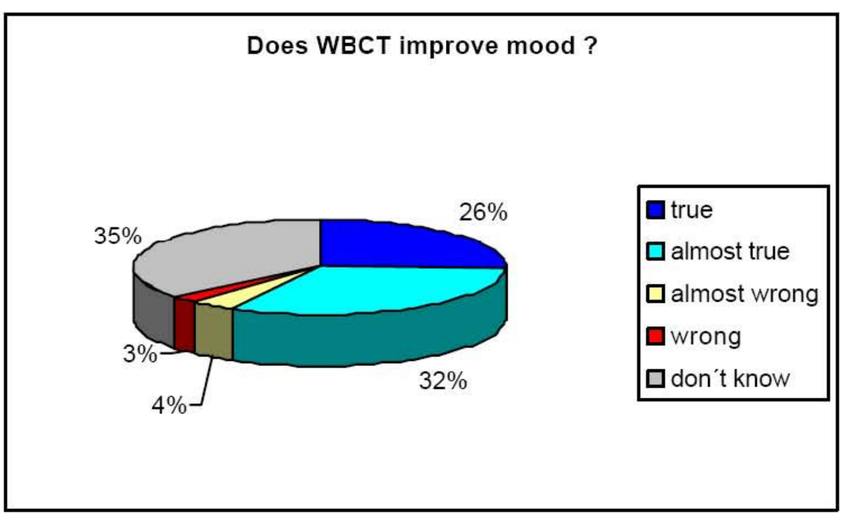

Does the WBCT have a short action on the pain ?
28%
39%
0%
5%
28%
true
almost true
almost wrong
wrong
don´t know

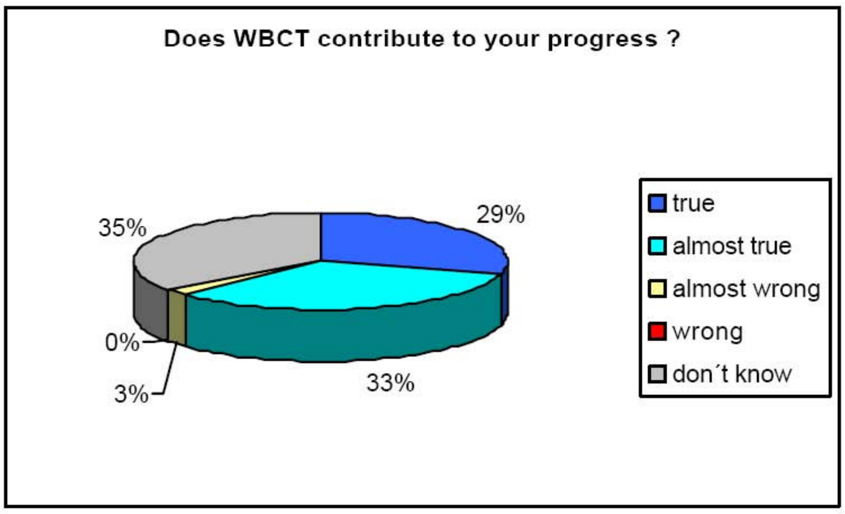

Does the WBCT have a long action on the pain ?
8%
44%
30%
8%
10%
true
almost true
almost wrong
wrong
don´t know

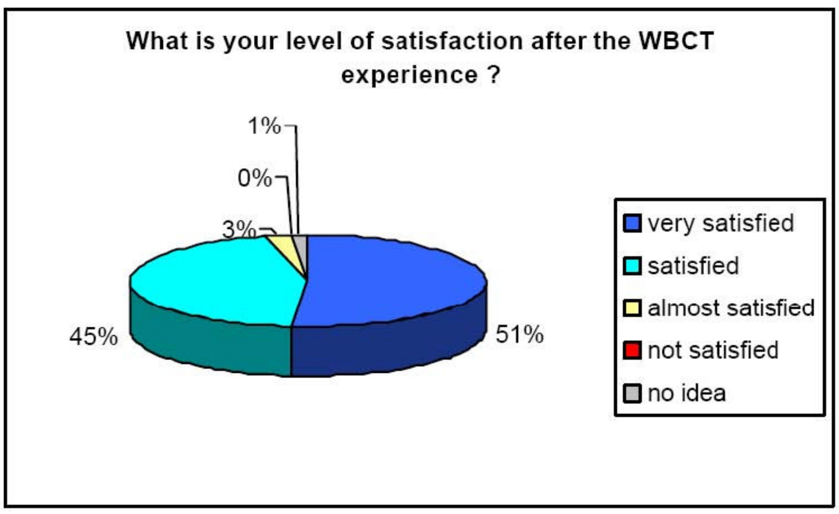

Does WBCT improve the sleep quality ?
18%
47%
27%
5%
3%
true
almost true
almost wrong
wrong
don´t know


Does WBCT improve the fitness?
0%
14%
0%
44%
42%
true
almost true
almost wrong
wrong
don´t know


Does WBCT improve the fitness recovery ?
0%
12%
0%
35%
53%
true
almost true
almost wrong
wrong
don´t know


Does WBCT improve mood ?
26%
35%
3%
4%
32%
true
almost true
almost wrong
wrong
don´t know


Does WBCT contribute to your progress ?
35%
29%
0%
3%
33%
true
almost true
almost wrong
wrong
don´t know


What is your level of satisfaction after the WBCT experience ?
1%
0%
3%
45%
51%
very satisfied
satisfied
almost satisfied
not satisfied
no idea