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BRIEF REPORT

Swimming in ice cold water

B. Knechtle · N. Christinger · G. Kohler ·
P. Knechtle · T. Rosemann

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Abstract

Introduction We investigated two athletes swimming in 4°C for 23 min (1.3 km, swimmer 1) and 42 min (2.2 km, swimmer 2), respectively.

Materials and methods Pre swim, percent body fat was determined; post swim, core temperature was measured.

Results The core temperature of swimmer 2 was: 37.0°C immediately before the start, 32°C 20 min after getting out of the water, and 35.5°C 80 min after finishing the swim.

Conclusion We assume that the higher skin-fold thickness and body fat of swimmer 2 enabled him to perform longer. In addition to this, mental power and experience in cold water swimming must be considered. In any athlete aiming at swimming in water of less than 5°C, body core temperature and heart rate should be continuously monitored in order to detect a body core temperature below 32°C and arrhythmia to pull the athlete out of the water before life-threatening circumstances occur.

Keywords Hypothermia · Rectal temperature · Body fat · Skin-fold thickness

Introduction

Endurance swimming in cold water is limited due to hypothermia. When body core temperature drops below 32°C, there is a progressive risk of spontaneous ventricular fibrillation and death [1].

There are a few reports in the literature about swimmers in cold water. Acevedo et al. [2] described, in a case study, a swimmer preparing in 18°C for the English Channel. Nuckton et al. [3] reported about 11 subjects swimming in 11.7°C. Keatinge et al. [1] characterised eight cold water swimmers in 9.4–11°C and Tipton et al. [4] reported on five athletes swimming at 10°C.

Swimming in water of less than 10°C has not been reported. People immersed after shipwreck in water colder than 6°C usually die of hypothermia within 75 min [5]. However, it is possible to survive in water of 5–6°C when drifting in clothes for 5–6 h [6].

As far as we are aware, up to now no report of elite swimmers in ice cold water at 4°C has been published. We report here about two elite swimmers performing in 4°C.

Methods

Subjects and their preparation for the swim

The anthropometry of the two swimmers, both originating from Cape Town, South Africa, is represented in Table 1. The physical training of both swimmers was swimming for 5–6 days of the week for 1 h covering approximately 2.5 km per session. In the preparation for the event, both swimmers regularly performed sea swims in water of 18°C for 40 min over 1.6 km. Furthermore, swimmer 1 completed ice baths for 3 min at 1.5°C and then another 3 min

B. Knechtle (✉) · N. Christinger · P. Knechtle
Gesundheitszentrum St. Gallen, Vadianstrasse 26,
9001 St. Gallen, Switzerland
e-mail: beat.knechtle@hispeed.ch

B. Knechtle · T. Rosemann
Institute of General Practice and for Health Services Research,
University of Zurich, Zurich, Switzerland

G. Kohler
Radio-oncology, University Hospital, Basel, Switzerland

at 2.5°C. Swimmer 2 spent 3 min at 0.4°C and 7 min at 3°C while swimmer 1 spent 10 min at 3°C. Twelve days before the planned event, they both swam 45 min in the sea at 10.5°C; 9 days before, they did 7.5 km in 2 h 29 min at 11.5°C. Swimmer 2 swam 1 km in 1°C in Antarctica in February 2008, in a time of 22 min. No medical information is available for the swim but it was supervised by experienced polar explorers and a doctor. Both athletes also prepared mentally for the ice swim. Swimmer 1 was reading literature about extreme cold and problems in a cold environment. Swimmer 2 watched movies of ice swimming and ice diving. This gave him a good idea of what these people did and how they reacted. Furthermore, he ran the swim many times in his mind, going over the phase before the swim, the entry into the water, the first few minutes to settle the breathing, dealing with the initial pain and then getting into a rhythm. Two days before the swim, in Lake Zurich, they swam for 10 min on the planned course. They walked on the Lake shore to determine the exact route of the swim and to prepare mentally for the course.

Pre-event measurements and calculations

The day before the swim, red blood cells, white blood cells, platelets, haemoglobin, haematocrit, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were measured using ABX Micros CRP 200 (Horiba ABX Diagnostics, Northampton, UK). Liver enzymes (GOT and GPT) and creatine kinase (CK) were determined using

Table 1 Anthropometric measurements of the swimmers before the event

	Swimmer 1	Swimmer 2
Body mass (kg)	86.5	75.1
Body height (m)	1.79	1.79
BMI (kg/m ²)	27.0	23.4
Skin-fold chest (mm)	5.6	15.4
Skin-fold midaxillary (mm)	14.6	12.6
Skin-fold triceps (mm)	7.4	10.0
Skin-fold subscapular (mm)	14.6	15.8
Skin-fold abdominal (mm)	29.8	29.0
Skin-fold suprailiac (mm)	35.2	33.4
Skin-fold thigh (mm)	11.0	15.0
Skin-fold calf (mm)	6.6	8.6
Sum of eight skin-folds (mm)	124.8	139.8
Mean skin-fold thickness (mm)	15.6	17.4
Body fat (%)	21.0	23.4
Calculated fat mass (kg)	18.2	17.6
Calculated skeletal muscle mass (kg)	43.1	35.1

SpotchemTM EZ SP-4430 (ARKRAY, Amstelveen, The Netherlands). Lung function with functional vital capacity (FVC) and forced expiratory volume (FEV₁) was determined using Easy oneTM diagnostic Spirometer (Ingelheim am Rhein, Germany). Resting electrocardiogram (ECG) was recorded using CARDIOVIT AT-102 (Schiller, Linz, Austria). Blood pressure was measured using a sphygmomanometer to the nearest 5 mm Hg. Body core temperature was measured rectally using an alcohol–mercury thermometer (−10 to +50°C, scaled to 0.5°C) to the nearest 0.5°C. Body mass, body fat percentage [7] and skeletal muscle mass [8] were determined using the anthropometric method. Body fat percentage was calculated using the formula according to Ball et al. [7]. Skeletal muscle mass was calculated using the formula according to Lee et al. [8]. Skin-fold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured using a skin-fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm on the right side of the body. One trained investigator took all the measurements, as inter-tester variability is a major source of error in skin-fold measurements. Circumferences of the upper arm, thigh and calf were measured at the largest circumference of the limb to the nearest 0.1 cm. At the thigh, circumference was determined 20 cm above the upper pole of the patella.

Immediately before the start of the swim, blood pressure, heart rate and rectal temperature were measured. During the swim, heart rate was continuously measured using a portable heart rate monitor POLAR S710 (Polar Electro Oy, Kempele, Finland). The support crew had direct visual contact with the swimmers and recorded the stroke rate every minute.

The event

The swim was held on 30 January 2009 in Lake Zurich (406 m above sea level) and started at 02:00 p.m. The actual local weather conditions at the start time were provided by the Sea Police Zurich. At the start of the swim the water temperature was 4.3°C, the air temperature was 0.8°C, and humidity was 76%. The wind direction was from the north–east (48°) blowing at 4 m/s with a wind chill of −7.5°C and barometric pressure was at 971 hPa. The start of the swim was at ‘Casino Zürichhorn’ and the athletes swam close to the shore in a northerly direction to ‘Bellevue’ in the city of Zurich. About 50 m before the finish, the swimmers had to swim under a bridge and then turn to the right to climb up steps to get out of the water. Each swimmer was followed by a police boat with resuscitation equipment, a diver and medical personal in case of emergency. A swimmer could stop voluntarily, give a hand signal and would then be rescued by his own lifeboat. In

case the stroke rate dropped below 30 beats per minute and the swim style became uncoordinated, the diver would jump into the water and pull the swimmer out of the lake before he lost consciousness. There was no telemetric system to monitor heart rate or body core temperature. The swimmers were wearing a standard Speedo swim suit, a pair of goggles and a standard silicon cap. No greasing was done. No ear plugs or other methods of reducing exposure to cold were used.

Results

Table 1 summarises the anthropometric measurements, and Table 2 shows the laboratory data measured the day before the swim. The ECG of both swimmers showed no abnormalities. Immediately before the start, the blood pressure of swimmer 1 was 180/100 mm Hg and swimmer 2 was 140/90 mm Hg. Body core temperature was at 37.2°C in swimmer 1 and 37.0°C in swimmer 2.

The swimmers started together, swimming side by side and looking at each other. Figure 1 shows the stroke and heart rate during the swim. Swimmer 1 stopped after 23 min having covered 1.3 km. During the swim, he repeated the names of his family members. When he realised that he was not able to continuously repeat the names, he slowed down, lost contact with swimmer 2 and stopped the swim of his own volition. He swam towards the support boat and was pulled out of the water. On the boat, he was conscious. The support crew wrapped him in blankets and transferred him onto shore and back to the

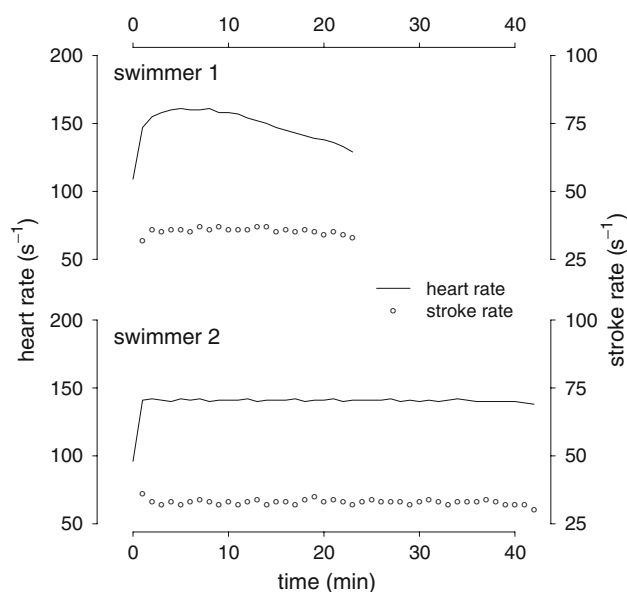


Fig. 1 Time course of heart rate and stroke rate in both swimmers

start where he could enter a heated building and take a hot shower. After full recovery, he complained about numbness in the fourth finger of the right hand. He reported that he had started faster than planned and developed tachy- and dyspnoea. After losing contact with swimmer 2, he swallowed lake water and was unable to continue the swim.

Swimmer 2 finished the 2.2 km after 42 min without external help. When he arrived at the finish, a diver helped him to get out of the water; he was not able to stand without help. He was conscious, but disorientated and practically unable to talk. He started shivering and was covered with blankets and immediately transferred into a heated car which took him to a heated indoor pool. During the 10-min drive, he started hyperventilating. He started to talk but was still disorientated. About 20 min after stopping the swim his body core temperature was at 32°C and he entered the heated pool (31°C). He complained about increasing dizziness, but then walked with help to the showers where he took a hot shower for about 15 min. After the shower he was able to stand without help and started dressing. Eighty minutes after finishing the swim his body core temperature was at 35.5°C. About 3 h after getting out of the lake, the swimmer was completely recovered without any physical or mental after-effects. After full recovery, he reported that he had had increasing difficulties in breathing during the swim and that his hands got increasingly stiff. During the swim he counted from 0 to 100 in order to keep control. He realised in the last minutes—the finish before his eyes—that he was no longer able to count numbers and did not remember how he finished the swim and got out of the water. He did not even realise that a diver had helped him out of the water. A

Table 2 Laboratory data before the event

	Swimmer 1	Swimmer 2
White blood cells ($10^3/\text{mm}^3$)	7.5	8.3
Red blood cells ($10^6/\text{mm}^3$)	5.0	5.7
Platelets ($10^3/\text{mm}^3$)	232	247
Haemoglobin (g/dl)	14.0	16.4
Haematocrit	42.8	50.7
MCV (μm^3)	85.5	88.1
MCH (pg)	28.0	28.4
MCHC (g/dl)	32.7	32.3
GOT (U/l)	19	13
GPT (U/l)	23	14
Creatinine (U/l)	107	52
FVC (l)	5.38	4.53
FEV ₁ (l)	4.61	3.13
FEV ₁ /FVC	0.86	0.69
Blood pressure (mm Hg)	115/70	140/75
Heart rate (bpm)	61	55

major problem during the swim was a stiff neck due to the wind chill.

Discussion

The most important problem of swimming in cold water is hypothermia [3]. The upper limit of hypothermia is accepted as 35°C [1] to 36°C [3]. Swimmer 2 had, 20 min after the swim, a core temperature of 32°C. This was after a drive in a heated car with the athlete wrapped in blankets. We must assume that his core temperature immediately after the swim was lower than 32°C where a progressive risk of spontaneous ventricular fibrillation and death exists [1]. However, we must be aware of the ‘afterdrop phenomenon’ as described by Nuckton et al. [3]. Ten out of their 11 subjects swimming in 11.7°C experienced after-drop defined as continued cooling after removal from cold stress. Presumably, regarding this phenomenon, body core temperature in swimmer 2 was rather higher immediately after the swim.

The drop in body core temperature during swimming in cold water can lead to ventricular fibrillation and death [1]. Telemetry with constant observation of ECG would be desirable to detect arrhythmia. In this actual setting, the only possibility of having control over the swimmers was direct visual contact and observation from the support boat, and calculating the stroke rate. Both swimmers were relatively constant with their stroke rate (Fig. 1). Tipton et al. [4] concluded with their swimmers, at 25, 18 and 10°C, that swimming efficacy and length of stroke seem to characterise swim failure in cold water. We saw that swimmer 2 became unable to concentrate in the last 2 min of the swim and this was also represented by the lower stroke rate. However, we assume that this was not due to impairment of the central nervous function. We rather think that the swimmer was irritated by the dark under the bridge and the change of the support boats when he had to change direction. According to O’Brien et al. [9], cognitive performance should be maintained at a core temperature of 35.5°C.

It is assumed that swimmers with more body fat can perform longer in cold water [1] and an increase in fat mass is recommended [2] before a swim in cold water. In the study of Keatinge et al. [1], the subject with the thinnest skin-fold thickness (mean skin-fold thickness of 4 skin-folds) of 8.56 mm swam for 23 min in 11°C. The subject with the highest skin-fold thickness (21.5 mm) swam for 65 min in 10°C. Swimmer 2 performed twice as long as swimmer 1. The skin-folds of our swimmers might agree with the findings of Keatinge et al. [1]. Keatinge et al. [6] could show in an experimental setting that a large man of 1.93 m, 125 kg weight and an overall mean subcutaneous

fat thickness of 14 mm could stay for 83 min in 5.3°C, and the rectal temperature fell by only 1.15°C. It is obviously possible that body core temperature can also be stabilised in cold water of about 5°C, presumably due to fat thickness.

In a recent study [10], a higher BMI was associated with a decreased risk of hypothermia. However, we had different findings in our athletes. Swimmer 1 had a lower sum of total skin-fold thickness, a lower mean skin-fold thickness and a lower percent body fat. Although BMI of swimmer 1 was higher compared to swimmer 2, he had to give up earlier. Swimmer 1 had a higher muscle mass compared to swimmer 2, the higher muscle mass was responsible for the higher BMI (Table 1) although calculated fat mass was higher in swimmer 1 compared to swimmer 2.

A further important aspect to swimming in ice cold water is mental power. Swimmer 2 was experienced in swimming in ice cold water since he had already swam in Antarctica. After his 22-min swim in Antarctica we wanted to improve his performance and enable him to swim longer. Swimmer 1 knew that up to now a limit of about 22 min had been set in ice cold water by swimmer 2, and probably stopped at this point because of a mental barrier.

Conclusions

A male athlete could swim for 42 min in 4°C and reach a distance of 2.2 km. The thickness of skin-folds was presumably an important factor, not BMI. His final core temperature of 32°C was very close to the risk of spontaneous ventricular fibrillation and death. In any future athlete aiming at swimming in ice cold water for longer than 42 min body core temperature and heart rate should be monitored by radiotelemetry in order to detect a decrease in body core temperature below 32°C and cardiac arrhythmia in order to pull the athlete out of the water before life-threatening circumstances occur.

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