Impact of environmental factors on swim training and performance

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ABSTRACT

HOLMER I. Impact of environmental factors on swim training and performance. *Kinesiology*. Vol. 2, No. 1, pp. 51-55, 1997. The effect of water temperature and other environmental factors on efficiency of training, as well as performance is discussed. Different types of swimming performance are considered, namely competitive swimming, long-distance swimming and triathlon and swimming performance associated with accidental exposure. The effect of altitude is well known and only briefly reviewed. The "hypoxia effect" i.e. the effect of reduced alveolar oxygen pressure due to controlled (reduced) breathing is a controversial factor. The effects may be significant in competitive swimming and synchronized swimming. Water temperature have a profound effect on performance in long-distance events and low temperatures require specific adaptations in terms of morphology and/or behavior (clothing). Ambient climate have little effect on performance in water. A general lack of acclimatisation to heat requires a greater thermoregulatory effort inducing a higher cardiovascular strain and disturbed fluid balance. This may indirectly affect training in terms of dry land exercise and modify water training.

Key words: ACCLIMITISATION EFFECTS, CLOTHING & SWIMMING, SWIMMING VELOCITY & WATER TEMPERATURE

Albeit most swimming events take place under rather constant and homogeneous, environmental conditions in terms of water temperature, this factor per se and other environmental factors may influence efficiency of training, as well as performance itself. Certainly, different types of swimming performance are likely to be more or less susceptible to environmental effects. For the purpose of a general analysis the following activities are considered: competitive swimming, long-distance swimming and triathlon and swimming performance associated with accidental exposure. The following environmental factors are analyzed: ambient barometric pressure, oxygen pressure, ambient climate, water temperature and clothing.

Altitude-low ambient pressure

Research on altitude effects on physical performance continues to attract researchers as long as important sports events are scheduled to locations at high altitudes. The vast literature on the subject contains little information specific for swimming. Recently, a specific meeting was devoted to altitude swim training (Smith 1990). Information about general effects may be found in most textbooks (Astrand and Rodahl 1986, Shepherd 1992).

Acute effects. Typically at an altitude of 2200 m the alveolar oxygen tension is lowered by about 25 %. Upon arrival at altitude immediate physiological adjustments take place, reduced alveolar oxygen tension in proportion to altitude, hemoconcentration and hyperventilation. Heart rate and, presumably, cardiac output is increased at submaximal work to compensate for the reduced oxygen-delivering capacity. However, maximal cardiac output is maintained. The obvious effects in terms of physical work capacity are reduced maximal oxygen uptake, reduced performance in aerobic events (>2 minutes) and maintained maximal anaerobic capacity. Arterial blood will no longer be fully saturated. Compensatory hemoconcentration and hyperventilation is not sufficient and maximal oxygen uptake is considerably reduced. Short lasting events depending merely on muscular and anaerobic power are little affected.

Acclimatisation effects. After 2-3 weeks a significant increase in red blood cell production is seen, raising the blood hemoglobin values and the oxygen transporting capacity per unit of blood flow. Hyperventilation becomes even more pronounced, eventually, increasing the respiratory work. Reduction of carbon dioxide and bicarbonate stores with hyperventilation, eventually, leads to a reduced buttering capacity for lactate. Since maximal oxygen uptake remains well below the sea level value, a gradual reduction of cardiac output -stroke volume takes place. At the end of the acclimation period there is some recovery of VO_2max and reduced or unchanged max anaerobic capacity.

Effects on descent. Several reports in coaching literature claim positive effects of altitude training, at least in terms of sprint performance. However, observations cannot be attributed to altitude per se, since no control group underwent the same training program at sea level. The few studies carried out with control groups report, improved submax performance, lowered lactate and oxygen uptake (Daniels et al. 1991), unchanged max oxygen uptake (Daniels et al. 1991) and unchanged maximal performance (Troup 1991).

The hypothesis behind improved performance is that swimming at the same pace at altitude requires more anaerobic energy yield, since oxygen consumption is significantly reduced. The main problem is to what extent the same pace at all can be maintained at altitude/at least for extended series of training sessions. The high maximal lactate levels reported on descent from altitude camps (Weng et al. 1994), however, need attention and additional investigations with control groups are required.

Oxygen tension

Swimming with controlled (reduced) breathing is popular as a training form and of particular interest for the very short sprint events (50 and 100 m). Studies indicate improved bouyancy and a more favourable body position, on average, when breathing becomes less frequent and, accordingly, more air remains in the lungs (Holmer et al. 1980).

The acute effects of reduced breathing have been reported as (Holmer et al. 1980, Dicker et al. 1980) lowered alveolar oxygen tension, lowered oxygen uptake, lower heart rate, lower lactate and better bouyancy -reduced drag. The reported effects are not readily the expected ones for a training program. Instead of increasing energetic loads, there is a decrease. For adequate use of swim training with controlled breathing the following factors have to be considered:reduced work load (mainly due to improved bouyancy and reduced drag) and improved CO_2-tolerance. For the competitive sprint swimmer controlled breathing may result in reduced drag and improved stroke mechanics (more symmetric strokes).

For synchronized swimming controlled breathing, evidently, is quite important. It is used for the control of bouyancy. However, prolonged stay under water induces an increasing risk of hypoxia and the development of unconsciousness (Davies et al 1995).

Ambient air temperature and humidity

Ambient climatic conditions, in particular heat, have profound impact on physical performance of endurance type. Thermoregulatory adjustments compete with muscular/energetic requirements (Astrand and Rodahl 1986). Swimming preformance, however, is not likely to be affected due to more favorable cooling conditions in the water. On the other hand, training camps under hot environmental conditions may induce additional fatigue due to the added heat load. Land activities become more exhaustive resulting in less effective training and, eventually, also water training.

A heat acclimation program seems justified in order to improve sweating and cardio-vascular capacity to cope with heat and work. In particular, water and electrolyte balance must be checked and adjusted accordingly.

Water temperature

Water conducts heat about 25 times faster than air and this has profound effect on human physiological and thermal responses. Outside a relatively narrow range of water temperatures (24-30°C) most people will suffer from body heat imbalances, eventually, deteriorating physical performance. Albeit most swim events are likely to take place in pool temperatures between 25-30°C, competitive events are held in much colder water, e.g. triathlon and long distance swimming. Several studies have shown that swimming performance is affected by pool temperature. Mougios and Deligiannis (1993) showed improvements in sprint events with increased temperature in the range 20-32°C, more so in the lower range. The cause of this effect is not clear, but may have to do with cardio-vascular and metabolic factors. A slower and less efficient circulation and perfusion of the extremities in the colder water is one possible explanation. Heart rate and, eventually, cardiac output is reduced during maximal swimming in cold water (Mougios and Deligiannis 1993, Holmer and Bergh 1974). A direct effect of subnormal tissue temperature on muscle metabolism and the contraction process is very likely (Blomstrand et al 1984). Lowdown et al (1992) investigated triathlon events in temperatures of 17-30°C and found unchanged performance. Many studies of swimming in cold waters (lower than 20°C) report more or less pronounced reductions in performance. Much of the problem is caused by the instant cooling effect of the water. The first seconds of immersion in very cold water elicits a strong respiratory reflex (gasp-reflex) and a subsequent hyperventilation, which is almost impossible to control (Tipton et al 1991). Accidental immersion in very cold water, therefore, may cause panic and inhalation of water, especially when the sea is rough. Sudden drowning in cold water may be caused by this response.

Once respiration is under control (often within 20-30 seconds) the outcome of the swimming or stay in cold water much depends on conditions for heat balance. Important factors are body morphology (in particular subcutaneous fat), body form (surface area to mass ratio), body position (head out etc.), available protection, e.g. clothing and energetic capacity (metabolic heat production).

Within few minutes extremity cooling becomes significant, muscle temperature drops and muscle function deteriorates (Holmer and Bergh 1974, Bergh, 1980). Hence, long before any major reduction occurs in body core temperature, the extremities have become cold and muscular performance impaired. Even a very fit swimmer may find himself exhausted within few minutes at speeds or distances, normally covered at ease. Figure 1 shows that the margin between maximal capacity and submaximal cost of swimming at a given speed, quickly narrows in cold water.

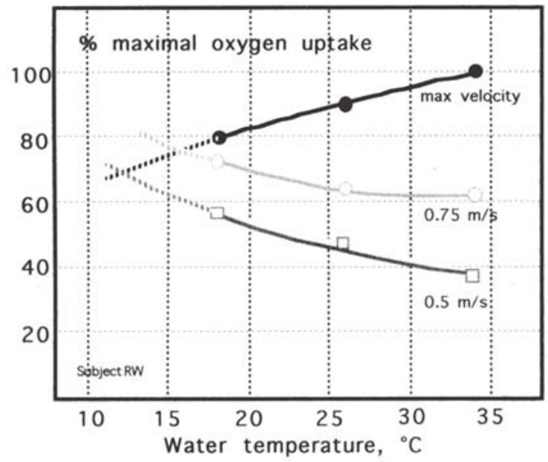

Figure 1. Change in oxygen uptake during submaximal and maximal swimming in water at different temperatures. The increased energy cost of swimming in colder water at unchanged speed in combination with reduced maximal oxygen uptake may quickly develop into «unexpected» and early exhaustion also in trained swimmers.

Some individuals have developed a remarkable capacity to endure long periods of swimming in cold waters. Pugh & Edholm (1955) showed that successful channel swimmers were fatter and had higher than normal skinfold thickness. Apart from good swimming proficiency a long distance swimmer apparently should possess a high surface tissue insulation.

Lynne Cox is a typical representative for this event. Keatinge (Keatinge and Nyboer 1989, Keatinge and Neild 1990) reported about her swims of the Berings strait and Beagle channel in Chile. The latter trip was 6.5 km in water at 9°C and lasted 198 minutes. She finished with a rectal temperature of 34.7°C. Her body build appears to be suitable for cold water swims; weight 92 kg, height 1.68m and mean skin-fold thickness 31mm (four sites) (Keatinge and Neild 1990). Thin people would quickly become hypothermic and, eventually, die before that time.

It is evident that swimming in water at subnormal temperatures (approx. below 20-22°C) becomes increasingly difficult, mainly due to direct cold effects on tissues and functions; reduced circulation, slower cell metabolism and impaired nerve function. This has to be kept in mind and special precautions to be taken, when competitions are held under such circumstances.

Clothing and swimming

The increasing interest in long distance swimming and triathlon has emphasized the problems of swimming in cold water. In triathlon it is allowed to use clothing and several studies have indicated the benefits of using a wet suit.

Lowdon et al. (1992) investigated the effect of different types of swim suits on performance. A wet suit maintained performance unchanged over the range 17-30°C. Chatard et al. (1995) confirmed these results and observed an additional positive bouyancy effect in non-swimmers. They achieved a better body position in the water, thereby reducing drag and improving stroke mechanics.

The merits of retaining clothing in accidental cold water exposures are strong (Keatinge 1969). They help to create boundary layers around the body, slowing down heat losses. Swimming destroys such layers, as do shivering and the resultant heat loss easily overrides the extra heat produced. Body cooling accelerates.

The delicate question remains, under what circumstances swimming to safe landmarks or to nearby floating devices is preferable to waiting still in the water tor rescue. At water temperatures below 10-15°C most people would only have capacity to swim very short distances before exhaustion.

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