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CONCEPTS

Heat Stroke Risk for Open-Water Swimmers During Long-Distance Events

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Open-water swimming is a rapidly growing sport discipline worldwide, and clinical problems associated with long-distance swimming are now better recognized and managed more effectively. The most prevalent medical risk associated with an open-water swimming event is hypothermia; therefore, the Federation Internationale De Natation (FINA) has instituted 2 rules to reduce this occurrence related to the minimum water temperature and the time taken to complete the race. Another medical risk that is relevant to open-water swimmers is heat stroke, a condition that can easily go unnoticed. The purpose of this review is to shed light on this physiological phenomenon by examining the physiological response of swimmers during long-distance events, to define a maximum water temperature limit for competitions. We conclude that competing in water temperatures exceeding 33°C should be avoided.

Key words: body composition, water sport, skin temperature, body temperature, triathlon, swimming

Introduction

The Federation Internationale De Natation (FINA) defines open-water swimming as any competition that takes place in rivers, lakes, oceans, or water channels, and distinguishes between 2 categories on the basis of the distance swum. A long-distance swimming event includes any competition in open water up to a maximum of 10 km, whereas marathon swimming events exceed 10 km.[1] There are more than 6500 open-water swimming clinics, camps, tours, races, and events in at least 158 countries globally, in which many elite and recreational athletes compete, followed by masters athletes.[2,3] This however does not take into account all of the triathlon events in which the first phase of the race is open-water swimming.[4]

Hypothermia is the most prevalent medical risk associated with open-water swimmers during long-distance events. A few recent reviews fully describe the impact of this condition.[5,6] In an attempt to reduce the frequency of hypothermia, the FINA and ITU (International Triathlon Union) have introduced a set minimum temperature of water in which participants are allowed to compete as well as a time limit in which to complete a specific race (calculated from the finish time of the first swimmers and changed on the basis of the distance swum), because lower water temperatures and prolonged swim duration increase the risk of participants developing hypothermia.[7] The temperature limit established by FINA and ITU are 16°C and 14°C, respectively; however, according to the ITU rules, a wetsuit is compulsory when water temperatures are below 20°C.[4] Interestingly, no rules have been introduced to limit a maximum water temperature at which athletes may not compete. Less is known of the risk of developing heat stroke during open-water swimming. This is significant because this condition has previously resulted in the death of a number of elite athletes; for instance, during the 2010 FINA 10-km open-water World Cup in Fujairah (Dubai), an elite athlete of team USA died.[8] Although medical details of the autopsy have not been released, concerns have been raised about the water temperature during the swimming competition. FINA officials claim that the water temperature exceeded 31°C (near its finish at 11:30 AM). This may have been too high when taking into consideration

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that the maximum water temperature during pool competitions is 28°C.

Therefore, the purpose of this review is to describe the medical risk associated with heat stroke during open-water swimming events, a condition that can easily go unnoticed. The aim is also to examine the physiological response of swimmers during long-distance swimming events conducted in warm water.

Potential studies were identified by searching electronic databases: PubMed (1950–2012), Cochrane (1898–2012), Scopus (1960–2012), and Google scholar; the final search was conducted in December 2012. The search terms used included both single words and combinations of words: open water, swimming, swimmers, triathlon, and water temperature. Bibliographies were checked, and experts were consulted for any additional studies. Research studies and case reports available as full papers were deemed eligible if they conformed to the predetermined inclusion (adults 16 years and older, both sexes, any sample size, any distance and time swum, any food or liquid ingested, English language, full paper only) and exclusion (any other physical activity conducted in water, pathological conditions, language other than English, abstract-only conference proceedings) criteria.

Heat Stroke

Heat stroke occurs when the core body temperature rises above 40°C, and it is caused by the failure of the brain's temperature regulatory center in the hypothalamus. Failure is caused by the inability of the body's system to dissipate heat, inducing a dramatic rise in body temperature. This hyperthermic condition results in death of 20% of reported cases as a result of heart failure or cerebral edema.[9] Heat stroke is the second leading cause of exercise-related mortality. Noakes[10] pointed out that heat stroke can only occur when the athlete's rate of heat production exceeds the rate at which the excess heat produced during exercise can be dissipated into the environment, addressing several factors that may affect the capacity of the environment to absorb the heat generated by the athletes during exercise and a few factors that may increase the risk of developing heat stroke.[10,11] These factors can be summarized as high environmental temperature; low potential for convective cooling (during land sports: still wind and high humidity conditions); elevated rate of energy expenditure (higher level of exercise intensity); and greater body mass and percentage body fat. One more component of heat stroke is the excessive heat production by abnormal muscle metabolism in subjects with a genetic disorder of the skeletal muscle.[12]

Land-Sports vs Swimming

Body temperature regulation during exercise on land occurs by dissipating heat via sweat evaporation, a process that does not occur during exercise in water. Moreover, convection and conduction is much greater in the water compared with land-sports, increasing heat loss or gain during physical activity.[13] Thus, during swimming when the water temperature exceeds the temperature of the skin, swimmers will experience heat gain and a consequent rise in body temperature.

Studies on the thermophysiological response of swimmers have been summarized in the Table, although studies that investigate the thermophysiological response of subjects who perform different physical activities (such as running) in water have been excluded in this review[20,21] because of the specificity of the swimming motion and its unique physiological responses.[3,22]

From the Table it is evident that during swimming at high intensities (>50%), sweat evaporation does not occur in water and convection and conduction induce an increase in heat gain when the water temperature is higher than or similar to skin temperature.[14–19] In fact, Costill et al[14] observed a rise in rectal temperature in swimmers who swam 20 minutes (freestyle) at 27°C and 33°C, whereas skin temperature rose in the 33°C trials and decreased in the 17°C and 27°C trials. These data are in contrast to the study conducted by Fujishima et al,[18] who observed a rise in skin temperature but not in rectal temperature in swimmers after 120 minutes (breaststroke) at 33°C. One possible reason that might explain these differences are the different swimming styles used during these studies, although this hypothesis needs explicit testing. Nadel et al[15] showed that the core temperature during 20 minutes of swimming increased with the increase of exercise intensity; core body temperature decreased in 18°C and 26°C water at 40% maximal oxygen consumption ($\dot{V}O_2max$), and it increased in 26°C and 33°C water at 70% of $\dot{V}O_2max$. To our knowledge, we were the only researchers to investigate the thermophysiological response of swimmers during a simulated open-water race (5 km) in a swimming pool maintained at different water temperatures.[19] The rectal temperature of swimmers increased in the 27°C and 32°C trials, although this increase was significantly greater in the 32°C trial.[19]

The phenotype of open-water and pool swimmers appears to be different, and these differences may have an advantage in long-distance events in cold water but may increase the risk of developing heat stroke in long-distance events in warm water. Competitive open-water swimmers have been described by VanHeest et al[23] as shorter and lighter, with lower muscle mass and more fat mass than