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CASE REPORT

Cardiovascular and Perceptual Responses to an Ultraendurance Channel Swim: A Case Study

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Ultraendurance open water swimming presents unique physiological challenges. This case study aimed to describe cardiovascular and perceptual responses during a successful solo channel swim. Investigators followed a female swimmer's Catalina Channel (32.2 km) crossing, monitoring water temperature (T_{water}) and air temperature (T_{air}), distance remaining (DR), average velocity, and heart rate (HR_{swim}) at regular intervals. Every 24 minutes, the swimmer reported perceived pain (on a scale of 0–10), rating of perceived exertion (RPE [scale of 6–20]), perceived thermal sensation (scale 0–8), and thirst (scale 1–9). Data are presented as mean ± SD where applicable. The participant finished in 9 hours, 2 minutes, and 48 seconds; T_{water} averaged 19.1 ± 0.4ºC, and T_{air} averaged 18.6 ± 0.9ºC. Her HR_{swim} ranged from 148 to 155 beats/min, and thermal sensation ranged from 3 to 4. Pain inconsistently varied from 0 to 5 during the swim. The RPE remained between 12 and 14 for the first 8 hours, but increased dramatically near the end (reaching 18). Thirst sensation steadily increased throughout the swim, again reaching maximal values on completion. Physiologically and statistically significant correlations existed between thirst and DR ($r = -0.905$), RPE and HR_{swim} ($r = 0.741$), RPE and DR ($r = -0.694$), and pain and DR ($r = -0.671$). The primary findings were that, despite fluctuations in perceptual stressors, the swimmer maintained a consistent exercise intensity as indicated by HR_{swim}; and during ultraendurance swimming, pain, RPE, and thirst positively correlated with distance swum. We hope these findings aid in the preparation and performance of future athletes by providing information on what swimmers may expect during an ultraendurance attempt and by increasing the understanding of physiological and perceptual responses during open water swimming.

Key words: open water, female, rating of perceived exertion, exercise heart rate

Introduction

Open water ultraendurance swimming presents unique physiological and perceptual stressors including exhaustion, hypothermia, strong ocean currents, and unpredictable weather.[1–5] Long-distance channel swims (in or across open water between land masses or islands) require extensive preparation and acclimatization as durations can exceed 24 hours in water temperatures as low as 11ºC (52ºF).[2,5–8] Notwithstanding these challenges, race performances continue to improve,[9] and new amateur and professional athletes attempt ultraendurance swims every year.[10] For example, the number of English Channel swimmers (arguably the most recognizable channel swim in the world) has increased exponentially in recent years, with more than 1800 successful swims from 1875 to 2013.[11] Female athletes have recently gained attention in ultraendurance sports as their peak performance times progress closer to those of men,[12] especially in long-duration cold water swims for which women may possess favorable physiological advantages over men (eg, smaller body size and greater body fat percentage resulting in less drag and increased buoyancy). Diana Nyad's recent completion of the US-Cuba crossing (180 km) without a shark cage has brought even more public attention to the sport.

Despite the sport's growing popularity, long-distance open water swimmers still represent a relatively small population.[7] Moreover, studying race situations proves difficult as strict rules forbid contact with swimmers during sanctioned events.[13] This combination makes ultraendurance channel swimming an under-researched sport, leaving many unanswered physiological and psychological questions. Most open water swimming

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research has focused on athlete characteristics,[2,14,15] training,[3,16] performance times,[9,10,12] and body temperature responses to cold water,[1,4,5,17] but little physiological or psychological information exists that was obtained during actual events.

Of the few case studies involving channel swimmers,[2,3,8,16,18] none reported heart rate response, perceived pain, perceived exertion, thermal sensation, or thirst sensation during an event. Therefore, the purpose of this case study was to describe the cardiovascular and perceptual responses of a female ultraendurance swimmer during a successful solo crossing of the Catalina Channel (32.2 km [20 miles]) in Southern California. This renowned swim stands as an event in the Triple Crown of Open Water Swimming (www.openwaterswimming.com/community/triple-crown-open-water-swimming), which includes crossing the English Channel and the Catalina Channel and circumnavigating New York's Manhattan Island. The health, safety, and performance of ultraendurance swimmers depends on extensive preparation; research describing physiological and psychological consequences during this demanding event will help guide the planning and training of future athletes.

Case Presentation

PARTICIPANT AND ETHICS APPROVAL

One competitive female swimmer (aged 24 years, height 158 cm, mass 58.2 kg, body mass index 23.2 kg/m^2, body fat 25.0%) participated in the channel swim. The participant reported specifically training and acclimatizing over a 1-year period for this event (Table 1), swimming 6 to 9 times a week (11 to 20 hours per week), enduring cold water (temperature as low as 11ºC [52ºF]), rough seas, night swimming, or overnight sleep deprivation. This study conformed to the requirements of the Declaration of Helsinki, and the work reported was approved by the Institutional Review Board at California State University, Fullerton. The participant read and signed informed consent and medical history forms before data collection.

ANTHROPOMETRIC MEASURES

Investigators measured height with a stadiometer (model 210; SECA Corp., Hamburg, Germany), body mass by electronic scale (model ES 200L; OHAUS, Pinebrook, NJ), and calculated body mass index (BMI) as mass (kg) divided by height (m^2).[19] One trained researcher conducted a 3-site skinfold assessment (triceps, suprailiac, thigh)[20] to estimate body fat percentage, pinching a tissue fold (nearest millimeter) with a calibrated skinfold caliper (Harpenden; British Indicators, West Sussex, UK) and averaging 3 measurements at each site (within 2 mm of each other).

THE CHANNEL SWIM

The participant swam 32.2 km (20 miles) from Doctor's Cove (Catalina Island) to Palos Verdes (mainland California), wearing only a swimming suit, cap, and goggles. She observed Catalina Channel Swimming Federation Rules, which prevent 1) the use of insulating or buoyant material (eg, wetsuits); and 2) unnatural assistance to the swimmer (eg, drafting, touching a kayak).[13] She started at 2353 hours (11:53 PM) owing to favorable currents, following an escort boat with feeding and research kayaks paddling on either side (no vessel was close enough to interfere with Catalina Channel Swimming Federation Rules). At 24-minute intervals, the investigators tracked water temperature (T_{water}) and air temperature (T_{air}), distance remaining (DR), and velocity (by change in nautical position/elapsed time). The participant rested (treading water) every 24 minutes, for 1 minute or less, drinking water ad libitum and typically consuming approximately 175 mL carbohydrate-electrolyte solution; during alternate rest periods, she also ate carbohydrate-electrolyte gels, bread, or banana smoothies.

CARDIOVASCULAR MEASURES AND SWIM INTENSITY

Investigators measured resting heart rate (HR_{rest}) before the swim and recorded swimming heart rate (HR_{swim}) at 5-second intervals throughout the event by telemetric monitoring (E600; Polar Electro, Woodbury, NY). Researchers developed an estimation equation for age-predicted maximum heart rate (APMHR) during swimming ($APMHR_{swim} = [206 - 0.88\ (age)] - 13$) by subtracting 13 beats/min (as swimming elicits a lower HR_{max} compared with running)[21–23] from a maximum heart rate (HR_{max}) equation used specifically for healthy females.[24] The Karvonen formula ($HR_{reserve} = APMHR_{swim} - HR_{rest}$) was used to calculate the swimmer's heart rate reserve.[25] Finally, investigators determined the participant's swim intensity (ie, work rate) during the channel crossing as a percentage of $HR_{reserve}$: swim intensity ($\%HR_{reserve}$) = ([$HR_{swim} - HR_{rest}$] / [$HR_{reserve}$]) · 100.[26]

PERCEPTUAL MEASURES

During each rest period, investigators documented the participant's perceptual responses using 4 scales, shown in Table 2. To evaluate perceived pain, researchers