BRIEF REPORT

Tympanic Thermometry Is Unsuitable as a Screening Tool for Hypothermia After Open Water Swimming

Ian R. Rogers, MB, BS, FACEM; Domhnall Brannigan, MB, BCh, BAO, BA; Amanda Montgomery, MB, BS; Nicole Khangure, MB, BS; Aled Williams, MB, BS, FACEM; Ian Jacobs, PhD, FRCNA

From the Sir Charles Gairdner Hospital, Nedlands, WA 6009 Australia (Dr Rogers, Dr Brannigan, Dr Montgomery, Dr Khangure, and Dr Williams); and the University of Western Australia, Crawley, WA 6009 Australia (Dr Jacobs).

Objective.—Mass participation in competitive open water swimming is becoming increasingly popular. The purpose of this study was to determine whether infrared emission detection (IRED) tympanic temperature measurement taken in participants approximately 1 minute following a long-distance open water swimming event is a suitable screening tool for hypothermia.

Methods.—We studied 15 males and 7 females who completed the 20-km Rottneest Channel Swim off the coast of Perth, Western Australia. Following the swim, each athlete was clinically assessed for hypothermia through the observation of gait, cognitive processing, and demeanor. Approximately 1 minute following the swim, participants underwent temperature measurement using one of two IVAC Core Check 2090 IRED tympanic thermometers set to core equivalent mode. Further tympanic readings and an oral temperature reading were taken at 5 minutes post swim in subjects triaged to the medical tent after the initial clinical screen.

Results.—At 1 minute post event, the average tympanic temperature measurement was 28.9°C (95% CI, 28.3–29.7), while at 5 minutes postevent it was 31.6°C (95% CI, 31.1–32.2). The average oral temperature at 5 minutes post event was 34.3°C (95% CI, 33.7–34.7). The difference between the screening tympanic and oral temperatures was statistically significant ($P = 0.000$)

Conclusions.—Infrared emission detection tympanic thermometry is unsuitable as a screening tool for hypothermia following a prolonged open water swim because it substantially overestimates the incidence and severity of hypothermia in participants.

Key words: tympanic thermometry, hypothermia, open water swimming

Introduction

Hypothermia is an obvious medical risk of open water endurance swimming.^{1–3} Participation and interest in open water swimming is on the increase worldwide, as evidenced by its inclusion in the program for the 2008 Beijing Olympics. For race medical organizers it is a challenge to screen for hypothermia in participants after a mass open water swimming event given the number of athletes involved. Any technique employed must be portable, rapid, cheap, accurate, reliable, and relatively noninvasive. Infrared emission detection (IRED) tympanic thermometry has some of these attributes⁴ and therefore might be considered a suitable tool for hypo-

thermia detection after open water swimming. We set out to test IRED thermometry as a hypothermia screening tool in the setting of the Rottneest Channel Swim, one of the world's largest open water swims, held each year in February off the coast of Perth, Western Australia.

Setting

The Rottneest Channel Swim covers some 20 km of ocean between the west coast of Australia at Cottesloe in Perth to Rottneest Island, which lies to the west. Solo competitors complete the event without a swimming break. In the year studied, the water temperature varied between 19°C and 22°C, and the air temperature ranged between 17°C at the start and 22°C at the finish on the day of the study. A head wind ranged between 20 and 35 knots, and the swell measured up to 3 m. Flotation

Corresponding author: Ian Rogers, MB, BS, FACEM, Post Graduate Medical Education, Sir Charles Gairdner Hospital, Nedlands WA 6009 Australia (e-mail: Ian.Rogers@health.wa.gov.au).

Table 1. Descriptive results for race participants undergoing at least 1 tympanic temperature measurement

	<i>Race time (h:min)</i> <i>N = 22</i>	<i>Tympanic temperature at</i> <i>1 min post finish (°C)</i> <i>N = 19</i>	<i>Tympanic temperature at</i> <i>5 min post finish (°C)</i> <i>N = 10</i>	<i>Oral temperature at</i> <i>5 min post finish (°C)</i> <i>N = 13</i>
Mean	6:09	28.9	31.6	34.3
SD	0:42	1.4	0.8	1.0
95% CI	5:50 to 6:28	28.3 to 29.7	31.1 to 32.2	33.7 to 34.9
Median	6:03	28.8	31.4	34.2
Range	5:01 to 7:31	26.1 to 31.2	30.7 to 33.0	33.0 to 36.6

devices and swimming aids are banned during this swim, which precludes the use of wetsuits. Head protection consists of only a thin latex-rubber bathing cap.

Methods

As part of standard race medical care all swimmers underwent a brief screening assessment within 1 minute of emerging from the water at the race's finish. This assessment was conducted by physicians only and comprised assessment of gait, demeanor, and mentation; physicians sought to identify clinical signs of hypothermia, which was considered the major medical risk of the event. A tympanic temperature reading was also taken at the time of this screen (further details below). All swimmers who were thought to be at risk of hypothermia on the basis of the screening assessment alone (regardless of any available temperature readings) were moved to the race medical tent for a more thorough evaluation. In the tent the competitors temperature was then measured at approximately 5 minutes post finish using a low reading glass thermometer placed in the deep sublingual pocket until reading equilibration occurred (typically 3 minutes).

Both as part of the study protocol and as described above as part of routine medical care, competitors had a tympanic temperature measurement at approximately 1 minute post-race finish. This was performed using one of two IVAC Core Check 2090 IRED thermometers (IVAC Corporation, San Diego, CA) set to core equivalent mode. These thermometers have a manufacturer-specified operating ambient temperature range of 18.3°C to 32.2°C and had been calibrated to the manufacturer's instructions. The thermometers were used according to a previously agreed-upon method: they were held in the operator's dominant hand, placed in the subject's ear on the same side, and aimed at the subject's contralateral temple, with gentle traction on the pinna. For those competitors referred on to the medical tent, a second tympanic temperature was measured after drying the exter-

nal ear and just prior to inserting the oral thermometer (again at approximately 5 minutes post-race finish). The tympanic thermometers were used until they displayed their "return to base" code, which occurs after an automatic number of temperature estimations. This number is manufacturer predetermined and is not user modifiable. The study was terminated at this point. Hypothermia was classified as a tympanic or oral temperature of less than 35°C.

Data were analyzed using SPSS (Version 14.0). Proportions were calculated for categorical data. Means and 95% confidence intervals were derived for age and temperature. Differences between the temperatures recorded by each of the devices were calculated with the 95% confidence intervals being derived for differences between paired observations. The paired *t* test was used to assess statistical significance between the temperatures. The study had the approval of our institutional ethics committee.

Results

At least one tympanic temperature reading was obtained in each of 22 competitors who completed the event, 15 (68%) of whom were male. Males were slightly older (mean age, 33.9 ± 11.3 years; range, 13–51 years) compared with females (mean age, 33.4 ± 12.5 years; range, 16–51 years). Screening tympanic temperatures were recorded at 1 minute postfinish in 19 of the 22 competitors, while the other 3 (of the 22) only had a screening tympanic temperature on arrival in the medical tent at 5 minutes post finish. The summarized results for all available temperature data are described in Table 1.

The tympanic readings at 1 minute and 5 minutes were less than 35°C in all subjects measured. The oral temperature at 5 minutes was less than 35°C in all but 3 of the subjects.

There were 10 participants who had an initial tympanic temperature recorded at the end of the race and an oral temperature recorded on arrival in the medical tent

Table 2. Temperature comparisons between first tympanic temperature measurement and oral reading ($N = 10$)

	<i>Tympanic temperature at 1 min post finish (°C)</i>	<i>Oral temperature at 5 min post finish (°C)</i>	<i>Difference (oral-tympanic) (°C)</i>
Mean	28.8	34.4	5.6
SD	1.1	1.1	1.2
95% CI	28.0 to 29.6	33.7 to 35.2	4.7 to 6.7
Median	28.5	34.5	5.5
Range	27.6 to 31.0	33 to 36.6	4.0 to 7.6

(Table 2). On arrival at the medical tent, the mean oral temperature of these 10 competitors was 34.4°C (95% CI, 33.7–35.2). This temperature was 5.6°C (95% CI, 4.7–6.7) warmer than that recorded on the first tympanic reading ($P = .000$).

Discussion

Our results clearly show that IRED tympanic thermometry is not suitable as a hypothermia screening tool at or soon after the finish of a prolonged open water swim. Used in the manner indicated by this study, IRED tympanic thermometry would grossly overestimate the incidence and severity of hypothermia, which negates any perceived advantages related to its practicality.

The failure of the thermometers in this setting was not entirely unexpected. Previous work^{5–7} has shown that IRED thermometers underestimate and overestimate core temperatures in a range of outdoor settings. Some of this over/underestimation may relate to ambient cooling or warming of the tympanic membrane,⁸ as might be expected to occur with exposure to cool water, such as in the event we describe. Inaccurate temperature readings may also occur as a result of the use of the thermometers in temperatures outside of their specified ambient temperature operating range, though this was not the case in our study.

Our study has some limitations. Ideally we would have liked to collect complete temperature data on all subjects by obtaining 2 tympanic readings and a single oral reading, which would have allowed a more detailed statistical analysis. However, the study was conducted in a real race setting. Competitors were reluctant to undergo repeat temperature readings, and because of the volume of finishers we could not practically ask subjects to undergo further readings after our standard medical screen had not identified any clinical signs of hypothermia. To our knowledge, none of the subjects screened clinically at the finish and released later required medical care for hypothermia or other illness. Similarly, we do not believe that the group in which we achieved all 3

planned temperature readings (tympanic at 1 and 5 minutes, oral at 5 minutes) differed from those for whom we had incomplete data. Our results may not be generalizable to other events with different water temperatures or race times nor to other models of tympanic thermometers.

Arguably we should have allowed a longer time for ear drying and rewarming before measuring temperatures, but this then negates any value of IRED thermometry as a screening tool. Our aim was to test what could be practically achieved in a real race setting, where any screening must of necessity be rapid to allow for processing of large numbers of finishers. At race finish only tympanic thermometry is rapid enough to meet this requirement. Oral temperature readings require time for equilibration, which means moving the swimmer to an area outside the finish lane (in our case the medical tent). A priori our objective was only to compare formally the 1-minute tympanic (race finish) and 5-minute oral (medical tent) temperatures. The descriptive results in Table 1, with both tympanic readings, are provided only to give an idea of the warming of the ear canal that may occur if temperature readings are delayed to the medical tent. We took particular care to use a standardized technique to eliminate this as a possible variable in the differences in tympanic temperatures.

Our use of oral temperature as a gold standard can be challenged. Unlike tympanic thermometry, an oral temperature reading requires time for equilibration and so cannot be achieved immediately after race finish. There is debate about the most appropriate site to measure a true, representative core temperature⁹; however, our aim was to make a comparison with a practical, clinical gold standard. Rectal temperatures may have been more indicative of true core temperature but were not practical within the constraints of privacy in a beachfront environment. Allowing more time for sublingual/core temperature equilibration might more truly measure core temperature but negates any value as an early screening test and introduces the potential confounder of body rewarming. The rewarming possible in the 4-minute inter-

val between our initial tympanic reading and oral temperature readings would likely only minimally impact our results, as rewarming rates with passive rewarming are not usually greater than 3°C per hour.¹⁰ A logical future research direction is to measure temperatures in such an event using ingestible temperature measuring capsules, which may allow researchers to circumvent many of the problems identified above.

On the basis of our study, IRED tympanic thermometry does not appear to be a suitable screening tool for hypothermia after a prolonged open water swim. We believe that at present clinical screening is the best option, but this theory warrants further prospective validation.

References

1. Nuckton TJ, Claman DM, Goldreich D, Wendt FC, Nuckton JG. Hypothermia and afterdrop following open water swimming: the Alcatraz/San Francisco Swim Study. *Am J Emerg Med.* 2000;18:703–707.
2. Tipton M, Englin C, Gennser M, Golden F. Immersion deaths and deterioration in swimming performance in cold water. *Lancet.* 1999;354:626–629.
3. Keatinge WR, Khartchenko M, Lando N, Lioutov V. Hypothermia during sports swimming in water below 11 degrees. *Br J Sports Med.* 2001;35:352–353.
4. O'Brien DL, Rogers IR, Holden W, et al. The accuracy of oral predictive and infrared emission detection tympanic thermometers in an emergency department setting. *Acad Emerg Med.* 2000;7:1061–1064.
5. Weiss SJ, Hanhart EJ, McBride R, Johnson H, Denninghof K, Johnson WD. Tympanic membrane thermometry in out-of-hospital patients. *Ann Emerg Med.* 1995;25:41–47.
6. Roth RN, Verdile VP, Grollman LJ, Stone DA. Agreement between rectal and tympanic membrane temperatures in marathon runners. *Ann Emerg Med.* 1996;28:414–417.
7. O'Brien D, Rogers I, Smith A, Lopez D. Infrared tympanic thermometers are unreliable in low ambient temperatures. *Emerg Med.* 1998;10:313–316.
8. Rogers IR, O'Brien DL, Wee C, Smith A, Lopez D. Infrared emission detection tympanic thermometers cannot be relied upon in a wilderness setting. *Wilderness Environ Med.* 1999;10:201–203.
9. Giesbrecht GG. Cold stress, near drowning and accidental hypothermia: a review. *Aviat Space Environ Med.* 2000;71:733–752.
10. Rogers IR. Which rewarming therapy in hypothermia? A review of the randomised trials. *Emerg Med.* 1997;9:213–220.