How cold is too cold? Establishing the minimum water temperature limits for marathon swim racing

Jane Saycell, Mitch Lomax, Heather Massey, Mike Tipton

Department of Sport and Exercise Science, University of Portsmouth, Portsmouth, UK

Correspondence to
Professor Mike Tipton, Department of Sport and Exercise Science, University of Portsmouth, Portsmouth PO1 2UP, UK;
michael.tipton@port.ac.uk

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ABSTRACT

Objectives To provide a rationale for minimum water temperature rules for elite and subelite marathon swim racing and highlight factors that make individuals vulnerable to excessive cooling during open water swimming.

Methods 12 lean competitive swimmers swam for up to 2 hours, three times in different water temperatures between 14°C and 20°C, wearing standard swimming costumes and hats. Rectal temperature (T_{re}), oxygen consumption, perception of cold and performance were measured.

Results In 16°C, half the swimmers did not complete a 2-hour swim; four became (or were predicted to become) hypothermic within 2 hours. In 18°C, three-quarters completed the swim; three became (or were predicted to become) hypothermic. In 20°C, one swimmer was predicted to become hypothermic in under 2 hours. The mean linear rate of fall of T_{re} was greater in 16°C (−1.57°C/hour) than 18°C (−1.07°C/hour) ($p=0.03$). There was no change in swimming performance during the swims or between conditions. Most of the cooling rate could be explained by metabolic heat production and morphology for both 16°C ($R^2=0.94$, $p<0.01$) and 18°C ($R^2=0.82$, $p<0.01$) conditions. No relationship was observed between T_{re} and perception of thermal sensation ($r=0.25$, $p=0.13$), and there was a weak correlation between T_{re} and thermal comfort ($r=0.32$, $p=0.04$).

Conclusion We recommend that 16°C and 18°C water are too cold for elite marathon swim racing. FédérationInternationale de Natation rules were changed in 2017 to make wetsuits compulsory below 18°C and optional below 20°C.

INTRODUCTION

Open water swimming in cold water is an increasingly popular leisure and sporting pastime. However, as evidence by a spate of deaths of otherwise healthy young people in the UK over the summer of 2018, such swimming is not without its risks. These range from cardiorespiratory problems on initial immersion to hypothermia during longer exposures.

Hypothermia is defined as a deep body temperature of below 35°C[1]: swimmers should keep their body temperature above this level for safety. Also, swimming performance usually deteriorates due to peripheral neuromuscular cooling before rectal temperature reaches 35°C, evidenced by shorter strokes, higher stroke rate, increased swim angle and reduced efficiency, all of which are precursors to swim failure.[2] It is unclear, but thought doubtful, whether swimmers are able to judge their own deep body temperature in order to withdraw from events before becoming hypothermic.[3]

Humans vary widely in their ability to maintain body temperature at or close to 37°C in cold water; some can maintain body temperature while swimming in water at 10°C,[4] but others cannot at 18°C.[2 3] The main factor in maintaining deep body temperature when swimming is the amount of body fat, with thinner swimmers showing more rapid falls in temperature due to lower levels of insulation.[2 4]

The Fédération Internationale de Natation (FINA) governs all swim racing. Elite marathon races may be held over distances from 5 km to 32 km. The Olympic race distance is 10 km, and this exposes elite athletes to cold water for approximately 2 hours. Marathon swim racing has minimum water temperatures rules; when we undertook the present study, wetsuits were prohibited for elite racing, and the minimum water temperature for racing was 16°C.[5] There were no scientific data underpinning this rule. We aimed to: (1) study factors that make swimmers vulnerable to cooling and (2) recommend a safe minimum water temperature limit.

METHODS

Participants

Twelve participants (six men and six women) were recruited to the study. All gave written, informed consent, were physically fit and healthy, aged 17 years or over, endurance-trained swimmers and competing as youth elites or open water masters. Detailed characteristics are included in table 1.

Athletes wore their own swimsuits and goggles throughout the study and were provided with a standard silicon swimming hat. On each test visit, participants were asked to arrive well rested and refreshed as though for a race.

Procedures

Familiarisation with the swimming flume and other equipment was carried out on a separate day prior to testing: participants swam for as long as they wished to ascertain the flume speed that they felt most approximated their 10 km race pace; this was then used as the initial speed for test visits.

On each visit, participants were instrumented with a rectal thermistor (Grant Instruments [Cambridge] Ltd, UK), self-inserted 15 cm beyond the anal sphincter. Heart rate was monitored using a chest strap heart rate monitor and watch (Polar, UK), recorded at 5 min intervals. Participants then entered the water and waited for 3 min to allow breathing and heart rate to recover from the cold shock response before swimming for 2 hours in a

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Table 1 Characteristics of study participants ordered by least-to-most skinfold thickness

ID	Sex	Age (years)	Height (m)	Mass (kg)	Sum of seven skinfolds (mm)
1	Male	17	1.80	65.58	43.15
2	Male	41	1.74	75.73	50.60
3	Female	41	1.74	56.40	51.05
4	Female	33	1.65	55.81	60.75
5	Male	32	1.87	84.00	77.90
6	Male	28	1.76	76.00	83.55
7	Male	34	1.76	81.90	92.90
8	Female	45	1.72	64.96	92.25
9	Female	43	1.81	65.59	95.60
10	Male	45	1.77	71.48	101.70
11	Female	26	1.67	63.09	106.75
12	Female	31	1.84	73.42	139.65
Mean (SD)		35 (8)	1.76 (0.06)	69.50 (8.74)	83.24 (26.94)

temperature-controlled flume (SwimEx 600-T Therapy Pool, length 4.2 m, width 2.3 m and depth 1.5 m). The swim was self-paced, and athletes were asked to maintain 10 km race pace, but they could change the speed at any time by signalling the researchers. The speed of the flume was measured by a current meter (Braystroke Model 001 Open Channel Flow meter, Valeport, UK), positioned 10 cm from the surface of the water immediately in front of the swimmer's outstretched hand when above their head. Distance swum was calculated from duration at each speed.

All participants attempted swims at 16°C (the minimum race temperature) and 18°C. Participants completed these in a random order at the same time of day (with a minimum rest of 24 hours between swims). Those who successfully completed a 16°C swim then attempted a swim at 14°C, while the remaining participants swam at 20°C. Ambient air temperature was maintained at 18°C.

Every 20 min, the number of complete stroke cycles in 1 min was counted to assess changes in swim efficiency.

Before the start of the swim, and every 30 min during the swim, expired air measurements (ventilation [$\dot{V}_E$] and oxygen consumption [$\dot{V}O_2$]) were taken for 5 min using the MetaSwim metabolic cart (Cortex, Germany). After each set of expired air measurements, participants rested upright at the side of the pool in the water for 1 min and were allowed to drink water at ambient temperature ad libitum. At this time they were asked to note their perceptions of cold on thermal comfort and thermal sensation scales.[6] The swim was stopped before the end of 2 hours if the swimmer requested to finish, or if the swimmer's T_{re} reached 35°C (laboratory safety withdrawal criterion). In this situation, the swimmer was warmed in a bath (40°C). If T_{re} did not fall to 35°C during the swim, the swimmer exited the water after 2 hours and dried and dressed themselves. T_{re} was monitored after the swim until it started to rise. Participants were permitted to eat and drink during this time to simulate a postrace situation.

Data analyses

The objective criteria used to decide that a water temperature was safe for marathon swimming were:

1. Swimmers were able to maintain T_{re} above 35°C for 2 hours.
2. Swim performance was not impaired (based on swim speed and stroke efficiency).
3. Swimmers were able to judge when they were becoming too cold.

Calculations

Rectal temperatures

T_{re} was normalised and change in temperature was plotted against time from entry into the water. Where T_{re} fell during the swim, the time at which the fall became linear was noted, and the linear rate of change (RoC) of T_{re} (°C/hour) was calculated from the gradient of the plotted linear line. Where a swimmer was not withdrawn due to hypothermia, the RoC was used to predict how long the swimmer would be able to continue before becoming hypothermic using the formula: Time to hypothermia=a + (35–b)/c

Where a=time for T_{re} to start falling linearly; b=T_{re} at start of the linear fall; c=RoC.

The prediction was compared with actual time to hypothermia (T_{re}=35°C) for participants who were withdrawn. As this only happened on three occasions, numbers did not allow for statistical analysis, but in each case the predicted time was within 2 min of the actual time (2.21%–5.61% of actual time).

Physical characteristics calculations

Body surface area (BSA) was estimated according to the formula[7]: BSA (m^2)=0.007184 × mass$^{0.425}$ (kg) × height$^{0.725}$ (m).

Sum of skinfolds (SSF) and mean heat production (MHP) divided by BSA were combined into a single measure (SSF × MHP/BSA), as this gives a single figure that indicates MHP, insulation from subcutaneous fat and heat loss through convection/conduction (major routes for heat loss in water). Leaner individuals tend to have smaller values for SSF × MHP/BSA, while larger individuals with more body fat have higher values.

Performance

Mean swim speed (m/s) was calculated from time (s) spent swimming at each speed. Distance per stroke cycle was calculated as a measure of efficiency by swim speed (as metres per minute)/number of strokes per minute.[2]

Heat production calculations

$\dot{V}_E$ and $\dot{V}O_2$ were averaged from breath by breath data over the final 3 min of each collection and used to calculate MHP, according to the following formula[8]: Heat production (watts)=-mechanical efficiency × energy input

Where energy input was calculated from expired air measurements based on the Weir method,[9] and mechanical efficiency was calculated using the efficiency values of Toussaint *et al*.[10]

Statistical analyses

Data were tested for normality using Shapiro-Wilk test, and p was set at equal to or less than 0.05 and calculated using IBM SPSS V.22.

Paired t-tests were used to compare linear RoC of T_{re} and predicted (or actual) time to hypothermia, mean swim speed and distance per stroke cycle at the end of the swim for participants between 16°C and 18°C conditions, and between 18°C and 20°C for those who participated in this condition. Numbers completing the 14°C condition were too low for statistical comparison.

Effect sizes were calculated using Cohen's *d* to assess the impact of the water temperature on each variable. Cohen's *d* scores were valued as follows[11]:0.2=small effect; 0.6=moderate

Table 2 Participants who attempted a 2-hour swim in each condition and the outcome, ordered by least-to-most skinfold thickness

	1	2	3	4	5	6	7	8	9	10	11	12	Total completed
14°C						C	S (66, unwell)	W (78)				C	2/4
16°C	S (34)	W (60)	S (64)	S (42)	S (106)	C	C	C	S (111)	C	C	C	6/12
18°C	S (64)	W (90)	C	S (49)	C	C	C	C	C	C	C	C	9/12
20°C	S (95)	C	S (65, injury)	S (47, cramp)	C						C		3/6

C, completed condition; S, stopped swim early (time and reason if not due to cold); W, withdrawn due to T_{re} falling to 35°C (time in minutes).

effect; 1.2=large effect; 2=very large effect; 4=extremely large effect.

Forward linear regression was used to assess the correlation between TC and T_{re} and TS and T_{re}, and the correlation between SSF × MHP/BSA and linear RoC of T_{re} for 16°C and 18°C conditions.

RESULTS

Completing conditions

Table 2 shows the outcome of each condition attempted by participants.

Deep body temperature

The number of participants whose T_{re} fell and the number becoming (or predicted to become) hypothermic during each condition are shown in table 3. Six out of the 12 swimmers were unable to complete a 2-hour swim at 16°C, and 4 out of 12 either became hypothermic or were predicted to become so in less than 2 hours. In 18°C, three swimmers were predicted to become hypothermic within the 2 hours. One swimmer was predicted to become hypothermic in the 20°C condition.

For those whose T_{re} fell during the condition, the linear RoC of T_{re} and actual or predicted time to hypothermia for each condition are shown in table 3. There was a significant difference in linear RoC between the 16°C (−1.57°C/hour) and 18°C (−1.07°C/hour) conditions (p=0.03).

Swim performance

Mean swim speed and distance per stroke cycle for each condition are shown in table 3. There was no difference in swim speed or distance per stroke cycle between conditions, and no participant was withdrawn due to swim failure, although two swimmers stopped due to cramp, and in eight cases, swimmers stopped before 2 hours stating that they were too cold to swim (time and reason shown in table 2).

Thermal perception

Figure 1 shows thermal sensation and thermal comfort scores plotted against T_{re} for all participants in all conditions. There was no correlation between T_{re} and thermal sensation (r=0.25, p=0.13) and a weak significant correlation between T_{re} and thermal comfort (r=0.32, p=0.04).

Factors in cooling

Figure 2 shows the calculated variable SSF × MHP/BSA plotted against the linear RoC of T_{re} for 16°C and 18°C conditions. There was a very strong correlation for both conditions (16°C: r=0.98, p<0.01; 18°C: r=0.92, p<0.01), indicating a very high degree of the variance could be explained by SSF × MHP/BSA (16°C: R^2=0.94; 18°C: R^2=0.82). Most of the variance was explained by SSF (16°C: R^2=0.57, p<0.01; 18°C: R^2=0.61, p<0.01), with the model improved by including MHP/BSA (change in R^2 16°C=0.24, p=0.01; change in R^2 18°C=0.25, p<0.01).

Table 3 Comparison of change in T_{re} and performance between conditions

	14°C	16°C	18°C	20°C	P value†	Effect size†	P value‡	Effect size
n	4	12	12	6		Cohen's *d*		Cohen's *d*
No. of whose T_{re} fell	3	11	10	4	–	–	–	–
No. reaching 35°C in under 120 min (actual and predicted times)	1	4	3	1	–	–	–	–
Shortest time to fall to 35°C (min) (actual or predicted)	80.76	50.71	72.00	98.27	–	–	–	–
Mean (SD) linear rate of change of T_{re} (°C/hr)	−1.34 (0.31)	−1.57 (1.08)	−1.07 (0.75)	−1.38 (0.58)	0.03*	0.57§	0.43	0.56¶
Mean (SD) time for T_{re} to fall to 35°C (min) (actual and predicted)	128.46 (38.27)	222.34 (197.43)	408.43 (580.53)	153.09 (74.27)	0.34	0.4§	0.30	0.9**
Mean (SD) swim speed (m/s)	1.17 (0.06)	1.24 (0.10)	1.26 (0.08)	1.32 (0.07)	0.22	0.25§	0.78	0.24¶
Mean distance (SD) per stroke cycle (m) at 20 min	2.52 (0.20)	2.57 (0.29)	2.63 (0.27)	2.78 (0.40)	0.36	0.19	0.34	0.24¶
Mean (SD) distance per stroke cycle (m) at finish	2.39 (0.16)	2.51 (0.35)	2.47 (0.23)	2.58 (0.30)	0.58	0.17	0.47	0.2 1¶

*Significant difference between conditions (p≤0.05).
†Between 16°C and 18°C conditions.
‡Between 18°C and 20°C conditions.
§Small/medium effect of water temperature between 16°C and 18°C conditions.
¶Small/medium effect of water temperature between 18°C and 20°C conditions.
**Medium/large effect of water temperature between 18°C and 20°C conditions.

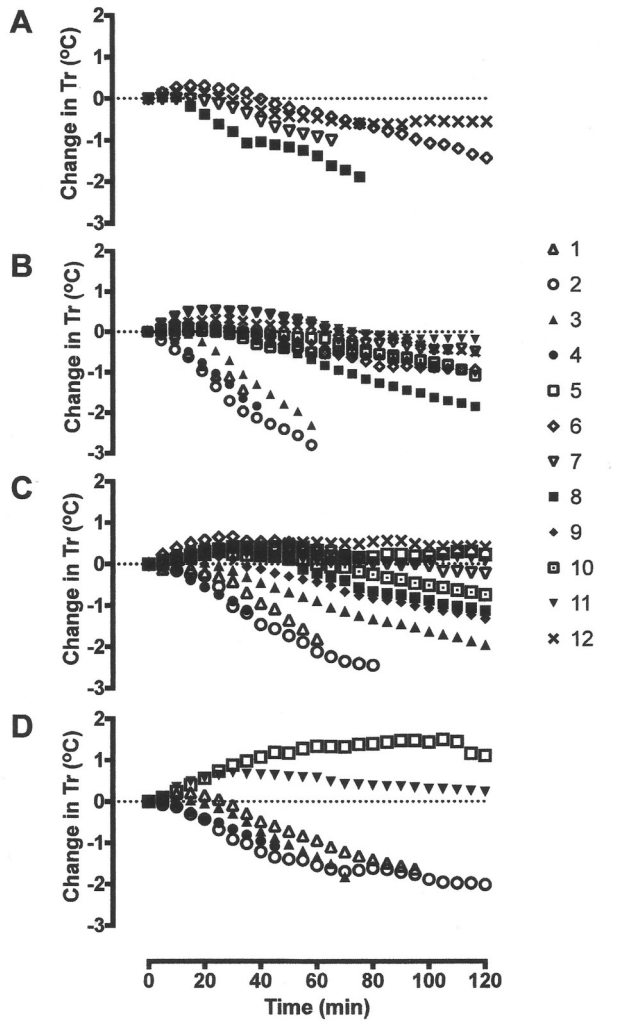

Figure 1 T_{re} (°C) for all participants during the swim. A=14°C; B=16°C; C=18°C; D=20°C. Participants numbered by skinfold thickness (least to most).

The model was very good and not improved by distinguishing between sexes (16°C male: R^2=0.94, p<0.01; female=0.97, p<0.01. 18°C: male R^2=0.77, p=0.03; female R^2=0.83, p=0.02). The low number of participants did not permit statistical analysis of the correlation with age or acclimatisation status.

Where swimmers completed a 2-hour swim, T_{re} was monitored postswim until it began to rise. Where swimmers stopped early they were warmed in a bath.

DISCUSSION

We aimed to ascertain the safe minimum water temperature limits for elite marathon swim racing. It is the first study to quantify the deep body temperature and performance responses of junior elite and masters open water swimmers while swimming in cold water. As participants were lean competitive swimmers, the results are relevant to elite racing and provide evidence for rule changes. Our findings suggest that 16°C and 18°C water is too cold for elite marathon swimming. As a result of our study, FINA rules for elite marathon swim racing were changed in 2017 to make wetsuit use compulsory in water below 18°C and optional in water below 20°C.[12 13]

To decide whether a water temperature (T_w) was safe for marathon swimming, we considered three criteria: (1) whether swimmers could maintain T_{re} above 35°C for 2 hours, (2) whether swim performance was impaired and (3) whether swimmers were able to judge when they were becoming too cold. We also explored the factors that may influence how vulnerable an individual swimmer is likely to be to cooling.

Maintaining deep body temperature

The swimmers most vulnerable to cooling were those with the least subcutaneous fat (ie, with a sum of seven skinfolds of about 60 mm or less); the four leanest participants in the study cooled rapidly (rate of fall of T_{re}) while swimming in 16°C, reaching 35°C in 50–73 min (Figure 3 and table 3). These results extend the existing literature, which indicates that maintaining deep body temperature in cold water is a substantial challenge for thin individuals due to the high heat capacity and thermal conductivity of water.[14] As expected, the rate of cooling was related to T_w, with swimmers in 16°C losing heat more rapidly than in 18°C (a). There was no difference in RoC of T_{re} between 18°C and 20°C water, but the number swimming in 20°C was small and only four of the swimmers showed any fall in T_{re} during the 20°C swim, so the statistical power was poor (power=0.46). The fall in T_{re} in both resting and exercising individuals in water has previously been shown to be proportional to T_w,[15] as conductive/convective cooling increases in line with the temperature gradient between the body and water. However, this relationship is particularly strong at low water temperatures when the physiological heat production and conservation mechanisms are swamped by the cooling power of the water. In warm water, the thermal and metabolic physiological response can, in some individuals, balance heat losses. This explains the wider variation seen in the thermal responses of different individuals in warmer/cool water, and the exponential increase in estimated survival time in water above 15–18°C.[15 16]

Heat loss in water is increased by exercise due to: increased peripheral blood flow and loss of the 'variable' insulation provided by otherwise unperfused muscle; heat from the exercising muscle transmitting directly to the skin surface; and increasing convective heat loss at the surface of the body.[3 17] This effect is greater when using the arms, or arms and legs together, rather than leg-only exercise,[18 19] and so swimmers are at particularly high risk of hypothermia in cold water. Swimmers who are lean are likely to cool more rapidly due to lower levels of the 'fixed' insulation from subcutaneous fat.[20]We found that swimmers with the largest amount of subcutaneous fat were able to swim for longer (without becoming hypothermic) in 14°C water than could the leanest swimmers in water at 18°C.

This is highly relevant to elite marathon swimming. Traditionally, open water swimmers had greater levels of subcutaneous fat than pool swimmers,[21] but since the inclusion of marathon swimming in the Olympic Games programme, the body type of modern elite open water swimmers has moved towards them being lean, more like indoor swimmers.[22] As a consequence, there is an argument for adjusting minimum water temperatures to protect the health of the athlete.

Swimming capacity

Tipton *et al*[2] noted the reduced swimming capability of moderately skilled swimmers; slower speed and stroke efficiency were associated with swim failure during 90 min swims. Such gradual performance decrements did not occur in the present study with elite swimmers. We noticed a binary pattern: swimmers either swam normally or, frequently, chose to stop before completion,

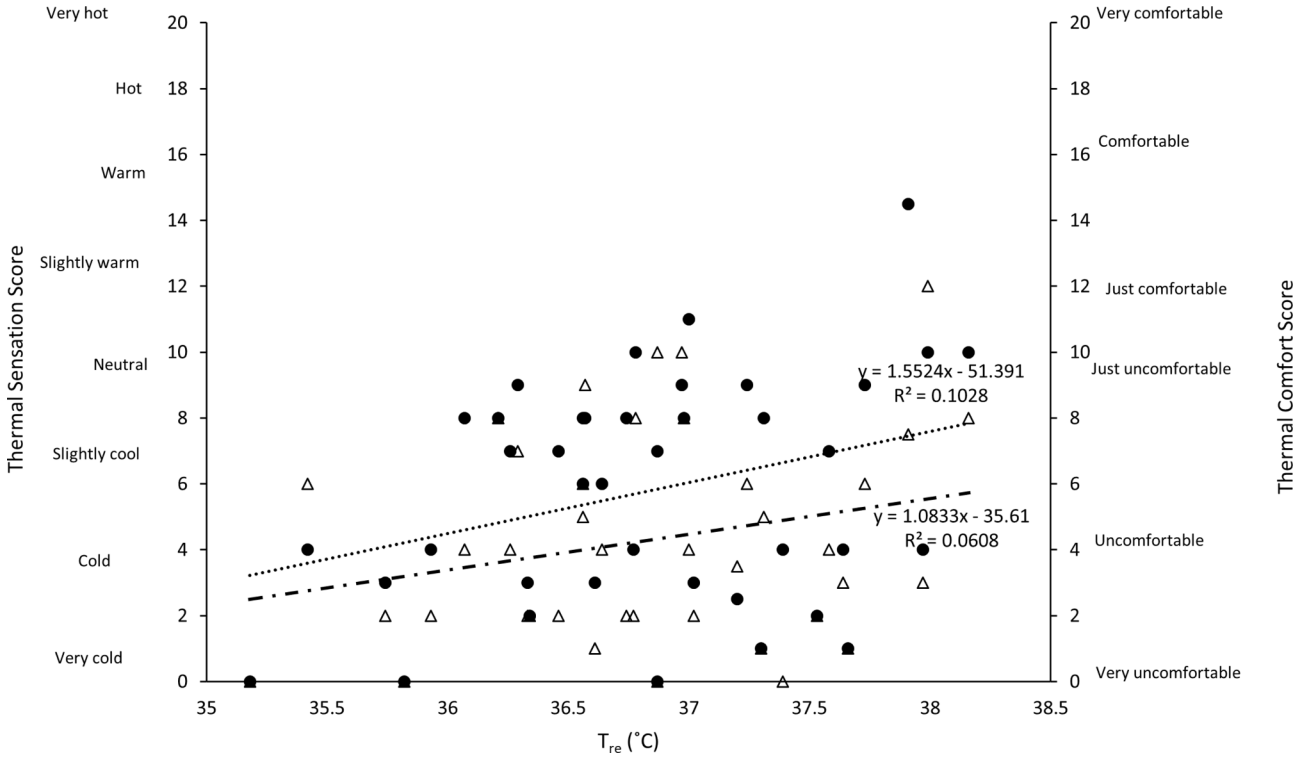

Figure 2 Thermal sensation and thermal comfort scores plotted against T_{re} for all participants in all conditions. n=12. Triangles=thermal sensation scores; circles=thermal comfort scores; dashed line=linear regression for thermal sensation; dotted line=linear regression for thermal comfort.

while some had to be withdrawn as their T_{re} reached 35°C. The most common reason given for stopping was feeling 'too cold to swim', but it is unclear whether the swimmers would have stopped in a race with its greater incentive to continue. We speculate that highly trained, motivated swimmers, with well-established swimming motor programmes, are more able to maintain performance when cold. This hypothesis requires testing.

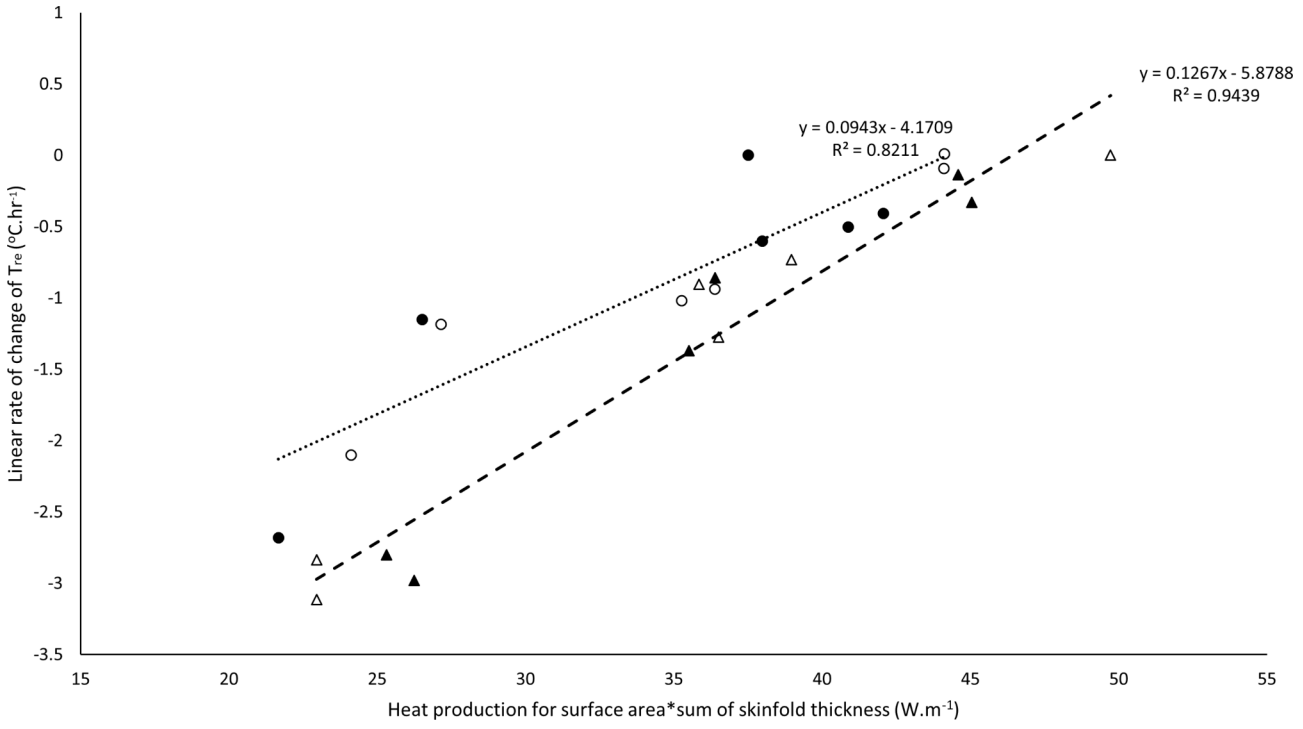

Figure 3 Sum of skinfolds * heat production for surface area plotted against linear rate of change of T_r. Triangles: 16°C condition; Circles: 18°C condition. Dashed line: linear regression for 16°C condition; dotted line: linear regression for 18°C condition. Open shapes: female swimmers; closed shapes: male swimmers. Leaner swimmers tend towards the lower end of the x-axis.

Thermal perception

If swimmers are able to judge their own deep body temperature, they may be able to choose to withdraw from events before they become too cold. However, in the current study, swimmers' perception of their own deep body temperature was unreliable (Figure 1 and Tipton *et al*[2]). This contrasts with a similar study into upper water temperature limits, where swimmers were able to judge if deep body temperature was too high.[23] There may be differential inputs into the perception of cooling and warming when in water.

In cool environments thermal perception arises from an unequal combination of skin and deep body temperature inputs, with skin temperature normally predominating.[24 25] The perception of cold on initial immersion in cold water is dominated by the dynamic response of the skin thermoreceptors; at this time, deep body temperature remains stable. The fact that there are roughly four times more cold receptors in the skin than warm receptors, but few direct cold receptors centrally, helps explain why cold perception depends on skin afferent input. By the time deep body temperature is falling and potentially contributing to the perception of body temperature (usually via the shivering evoked by such a fall—not present when exercising), skin temperate is clamped at about water temperature and contributes little to thermal sensation. In contrast, warm perception when in tepid/warm (as opposed to hot) water is more determined by increasing deep body temperature and mean body temperature as increasing peripheral blood flow exteriorises the core. In addition, warm receptors are abundant in deep body sites and relatively rarer in the skin.[26] Cold habituated swimmers typically have a poor perception of their thermal state because cold acclimatisation makes the already poor relationship between thermal perception and thermal status worse.[3 21 27] Although the mechanism for this is unclear, the habituation occurs more centrally than the peripheral cold receptors[28]; it may relate to the process of hypothermic adaptation where a blunted sympathetic activation, with reduced levels of noradrenaline after a period of cold habituation, has been observed.[29 30] The current study supported these suggestions, with one very well-acclimatised swimmer withdrawn from a 14°C swim when her T_{re} reached 35°C, while her perception was that she was 'cool' and 'comfortable'. This would suggest that acclimatised open water swimmers cannot be relied on to assess their own deep body temperature while swimming.[3] There are cases of swimmers swimming to unconsciousness (see Tipton *et al*[2]).

Factors involved in cooling—who is at risk?

MHP reflects the heat a swimmer is producing, BSA indicates the surface area through which heat is lost by convection/conduction, while SSF indicates the amount of insulation from subcutaneous fat available to a swimmer.[14 17] By combining MHP, BSA and SSF into one number, it was possible to see what proportion of heat loss could be explained by these factors and how much might be caused by other variables, such as peripheral blood flow. There was a strong correlation between SSF × MHP/BSA and the linear RoC of T_{re}, indicating that between 82% and 94% of the RoC in T_{re} can be explained by these factors alone (Figure 2).

Swimmers with a low SSF × MHP/BSA score were most vulnerable to cooling—this was clear and predicted. This phenotype is very lean, tall and with low muscle mass or fitness (which will reduce the capacity for MHP). It is unknown how much MHP would change in a competitive situation. The most important element in explaining the variance in the change in T_{re} was SSF (in 16°C: R^2=0.57; in 18°C: R^2=0.61). The equation could (where MHP is known or accurately predicted) make it possible to predict how long a particular swimmer would be able to swim in 16°C and 18°C water, but the validity and predictive power of the equation needs to be confirmed in a different cohort of swimmers.

Previous studies have suggested that older people, women and those more acclimatised to cold might be more likely to cool quickly, although these studies largely involved passive immersion rather than swimming.[31–33] Having already accounted for SSF, MHP and BSA, distinguishing between sexes did not improve the correlation between SSF × MHP/BSA and linear RoC of T_{re}. This suggests that in the cohort tested, sex per se was not an important factor in cooling rates. Our power was limited (0.64) as we had only six swimmers of each sex. Additionally, there may also be less difference between the sexes in elite swimmers than in the non-athletic population.

The low number of participants and wide variation in age and acclimatisation status prevented useful statistical analysis of these factors; these could account for the small amount of the variation not explained by SSF × MHP/BSA.

PRACTICAL RECOMMENDATIONS

- The 16°C and 18°C water are too cold for many elite lean swimmers to complete a 2-hour swim based on objective safety criteria applied to the athletes' performance in each condition.
- The minimum temperature for elite marathon racing should be changed to 20°C.

Implementation

After being provided with these data, and taking other evidence into account, FINA amended the rules for racing in low water temperatures. In September 2017, FINA made wetsuit use compulsory in water temperatures below 18°C and optional in water temperatures below 20°C from 2017.[12 13]

What are the findings?

- Most swimmers could not complete a 2-hour swim in 16°C water without becoming hypothermic.
- In 18°C water, a quarter of swimmers could not complete the swim without becoming hypothermic.
- Swimmers have a poor perception of their own deep body temperature.
- Rate of change of deep body temperature could be predicted by morphology and metabolic heat production.

How might it impact on clinical practice in the future?

- Fédération Internationale de Natation rules changed in 2017 to allow wetsuits in elite marathon swimming.
- Wetsuits are now compulsory in water temperatures below 18°C and optional below 20°C.

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Contributors All coauthors contributed to the study design and data collection. JS processed and analysed the data and wrote the draft of the manuscript. All authors contributed to revising the draft of the manuscript.

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Competing interests None declared.

Ethics approval The study was approved by the University of Portsmouth Science Faculty Research Ethics Committee (code 2014–075).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All unpublished data are available on request to the corresponding author.

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