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Original Research

Brief report of core temperature patterns in triathletes while swimming in warm open water with and without a wetsuit

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Abstract

International Journal of Exercise Science 19(6): 6005, 2026. This exploratory study investigated the effects of wetsuit use on core temperature patterns in triathletes in warm open water swimming (27.9–28.3°C). Methods: Participants (males (2), females (2), 49.5±7.8 years, body fat 16.3±5.56%) completed two 700-meter open water swims at self-selected submaximal paces: 1) wearing a full sleeve wetsuit (WS) and 2) no wetsuit (NWS). Core temperature was measured using an ingestible temperature pill (sample rate: 15-seconds). To explore the core temperature vs. time patterns, each data set was fit with a 1st, 2nd, and 3rd order polynomial. The sum of residuals squared was calculated to evaluate the goodness of the fit of each line. As a descriptive study, patterns of core temperature changes were qualitatively determined. Results: Swim performance was faster in the WS condition (742.5±148.2 s) vs. NWS condition (907.5±246.6 s) (p=0.02). For core temperature vs. time patterns, of the 8 data sets (i.e., four participants, two conditions), there was general improvement with the line of best fit in at least 5 data sets using the 2nd vs. 1st order polynomial and no appreciable improvement using a 3rd order polynomial. Interestingly, there was no improvement of fitting the data using higher order polynomials for two participants – both during NWS. However, there was improvement of fit using at least a 2nd order polynomial for all participants during WS. Conclusion: Overall, inspection of the residuals seems to indicate that the linear or nonlinear rate of change of core temperature is individualized. Furthermore, there was no risk of hyperthermia in either condition.

Keywords: Triathlon, open water swimming, thermoregulation, heat stress

Introduction

Triathlon is a popular sport which attracts participants from all over the world. Triathlon is generally a safe sport with risk of death being about 1.74 deaths per 100,000 participants; however, the majority of triathlon deaths happen during the swimming portion of the race.[1] Harris et al[1] reported that 67% of deaths in a triathlon occur as a result of cardiac arrests during the swimming segment of the race. The exact mechanism of factors triggering cardiac arrests during swimming in a triathlon is not fully understood. Harris et al[1] presented several hypothesis including the possibility of hyperthermia related to wetsuit use. It may be that the insulating properties of wetsuits, while beneficial in colder waters, could exacerbate heat retention in warmer conditions, potentially leading to hyperthermia.

Unlike land exercise, where heat can be dissipated through sweat evaporation, body temperature regulation in water depends on water temperature, with heat gain occurring when the water temperature exceeds skin temperature.[2] Specifically, heat generated by the swimmer is dissipated

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through convection and conduction.[2] The wetsuit provides a layer of insulation between the skin and water but at the same time allows for water trapped between the skin and wetsuit to warm, further providing insulation from water temperature. Even though the wetsuit is not a closed system and the trapped water is exchanged to some extent, it may be that use of a wetsuit when swimming in warm water leads to less ability to dissipate heat generated by the swimmer. As such, regulations pertaining to the use of wetsuits in warm open water have been established. For example, according to the World Triathlon Competition Rules,[3] when water temperature exceeds 24.6 °C, athletes are prohibited from wearing wetsuits for swim distances of 1501 meters or longer if they wish to remain eligible for awards. For shorter swim distances 1500 m or shorter, the temperature threshold for wetsuit use is 22 °C.

Several studies have focused on examining the impact of wetsuits on core body temperature when exposed to cold water or swimming in the pool.[4-7] Overall, the findings consistently indicate that wetsuits provide a protective effect of body heat loss. However, there is limited data while swimming in warm water.[7-9] Trappe et al[7] investigated the thermal responses of individuals continuously swimming for 30 minutes in water at a temperature of 25.6 °C. The researchers noted that core temperature increased. Interestingly, a smaller temperature increase of 0.89 ± 0.13°C was observed when swimming in a wetsuit, compared to 1.22 ± 0.24°C without a wetsuit.[7]

In a similar study conducted by Swafford et al,[9] swimmers completed a 1000 meter swim while core temperature was monitored using an ingestible sensor. There was no difference in core temperature when swimming in a 25.5°C indoor pool with or without a wetsuit.[9] Interestingly, Swafford et al[9] reported that the core temperature vs. time patterns were more variable when swimming with a wetsuit vs. without. Morton et al[10] reported that core temperature patterns were tri-phasic when swimming in open water temperatures ranging between 8.4-24.5°C. This tri-phasic pattern included an initial rise, a plateau, and then thermal decompensation in core temperature during the course of the swim. In contrast, when swimming in warm water, the core temperature patterns presented by Swafford et al[9] qualitatively either increased linearly or non-linearly when swimming with or without using a wetsuit. A limitation noted by the authors was that swimming in a pool required a turn every 25 m, so it was unclear whether colder water entered the wetsuit during each turn and what impact that may have had on core temperature.[9] Thus, the understanding of core temperature patterns when swimming in warm water is largely left unexplored. This type of information is important when setting guidelines for swimming competitions. Furthermore, the intensity of the swim would likely be an important factor in understanding the influence of swimming in a wetsuit in warm water. USA Triathlon (USAT) allows athletes to wear a wetsuit if water temperature is between 25.6°C to 28.8°C but these athletes are not eligible for age group awards or ranking/qualification points.[11] Nevertheless, very little is known about swimming in warm water using a wetsuit for any level of athlete.

Therefore, the present study aimed to explore core temperature while swimming in warm water during open water swimming with and without a long sleeve wetsuit at self-selected moderate paces. The long sleeve wetsuit was selected as it represents the most thermally insulating type commonly used in open water swimming. Since there is limited work on core temperature swimming in a wetsuit in warm water, this study was also done with the approach of safety of participants. Specifically, a conservative approach to swim intensity and duration was used in order to explore whether or not core temperature would reach a hyperthermic state when swimming in a wetsuit in warm water at a moderate intensity. It was hypothesized that core temperature would increase more when swimming in a wetsuit vs. no wetsuit.

Methods

Participants

Participants (2 males, 2 females 49.5 ± 7.8 years; body mass 73.4 ± 17.3 kg; height 176.4 ± 8.12 cm; body fat percentage 16.3 ± 5.56%) volunteered to participate in this study. Prior to the data collection all participants were asked to review and sign an informed consent and Physical Activity Readiness Questionnaire (PARQ). All participants previously participated in long-distance open water swimming with and without a wetsuit and all had triathlon experience. Participants did not have any injury that would interfere with swimming. All participants provided written informed consent with the study approved by the university Institutional Review Board. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science.*[12]

Protocol

The study was conducted in two phases. Phase 1 involved participants visiting the laboratory for anthropometric assessments and receiving an activated core temperature pill. Body composition was measured through bioimpedance analysis (InBody 570 Body Composition Analyzer, InBody USA, Inc., Cerritos, CA). At least 8 hours before the data collection (Phase 2), the participant swallowed an ingestible core temperature pill (eCelsius Performance pill, BodyCap USA, Inc., Boerne, TX) recording data at 5 min intervals. Validity and reliability of the ingestible core temperature system has been established.[13]

Phase 2 was conducted at the open water swimming location, during which participants completed swims under two conditions: wearing and not wearing their personal long sleeve wetsuit. Prior to the beginning of the data collection the weather conditions were recorded (Kestrel 3500 Weather Meter, Kestrel Instruments, Boothwyn, PA, USA). The water temperature was measured using a digital thermometer with an electronic probe designed for water temperature measurement (VLEJEARI, indoor/outdoor thermometer, range: -50 – 70±1˚C). All participants used their personal long sleeve wetsuits which met standards to use in competition.

When the participant arrived to the swim location, the sample rate of the core temperature pill was changed to 15 s. One participant was tested initially when the water temperature that day was 28.2°C prior to the initial wetsuit (WS) condition and 28.3°C before the second no wetsuit (NWS) condition. Three participants were tested on a subsequent day. The water temperature that day ranged between 27.9°C and 28.1°C across all data collection periods. The air temperature fluctuated between 24°C and 28°C on both data collection days and wind speed was negligible.

For each condition, participants completed an approximately 700 meter open water swim following a single out-and-back course marked with buoys at the start/end and turn points (Figure 1). Event time marks were made in the core temperature system for the start and end of the swim. Participants swam from the shore to the start buoy (~150 m) as a warm up. Upon reaching the start buoy, the participant would treadwater until the researcher gave a 'go' signal. The 'go' signal was given after making sure the swim support was ready, the instruments were ready, and the participant was ready.

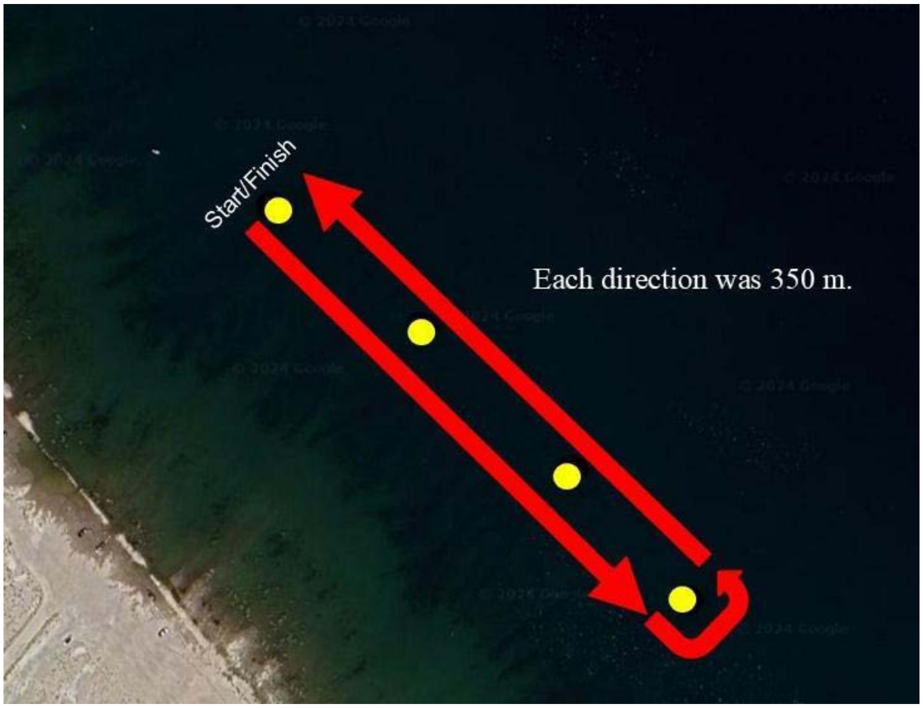

Figure 1. Illustration of the out-and-back swim course.

During the first condition, the participants wore their personal full sleeve wetsuit. All wetsuits were produced by different manufacturers. The thickness of the wetsuit varied by body region, thickest point was within the 5 mm range, aligning with the World Triathlon rules.[3] During the second condition, the participants swam in their regular practice swimsuits (i.e., NWS). Specifically, male participants wore tightfitting practice style swim jammers, while female participants wore two-piece practice swimsuits. The participants were instructed to perform both conditions at a submaximal pace, specifically aiming for a speed they would maintain during a 30 minute race. Each participant was accompanied by a water safety person on a standup paddle board. The water safety person was instructed to stay behind the participant to prevent pacing and participants swam individually without drafting.

Swim performance time was determined from the start-end time points entered into the data logger. After the first condition, the participant returned to shore to prepare for the second condition. Rest duration was determined based on the initial core temperature measured on the shore prior to the first condition. Efforts were made to ensure that participants' core temperature prior to the second condition remained within 1% of the initial measurement. The average rest time between two conditions was about 40 min. After the completion of both conditions, core temperature data were downloaded to a handheld monitor and subsequently uploaded to a computer.

Statistical Analysis

To explore the core temperature vs. time patterns further, each data set was fit with a 1st, 2nd, and 3rd order polynomial. The sum of residuals squared was calculated to evaluate the goodness of the fit of each line. In addition, maximum temperature was identified as the greatest temperature observed during a swim. Average core temperature was calculated as the mean of all temperature data during each swim. The change in temperature was calculated as T_{end}-T_{start}.

The dependent variables were residuals, maximal core temperature, average core temperature, change of core temperature, and swim performance. Effect size (ES) was calculated using Cohen's d, defined as the difference between group means divided by the pooled standard deviation, to quantify the magnitude of differences for each dependent variable between wetsuit and no wetsuit conditions and interpreted as small (0.2), Medium (0.5), Large (0.8), or Very Large (1.3).[14] Statistical analysis was performed using a paired samples t-test to compare each dependent variable between conditions (α=0.05) using IBM SPSS version 28 (IBM Corp, Armonk, NY). As a descriptive study, group statistics were followed up with detailed inspection of individual responses.

Results

As a descriptive study, raw core temperature vs. time data are presented for each participant in Figure 2.

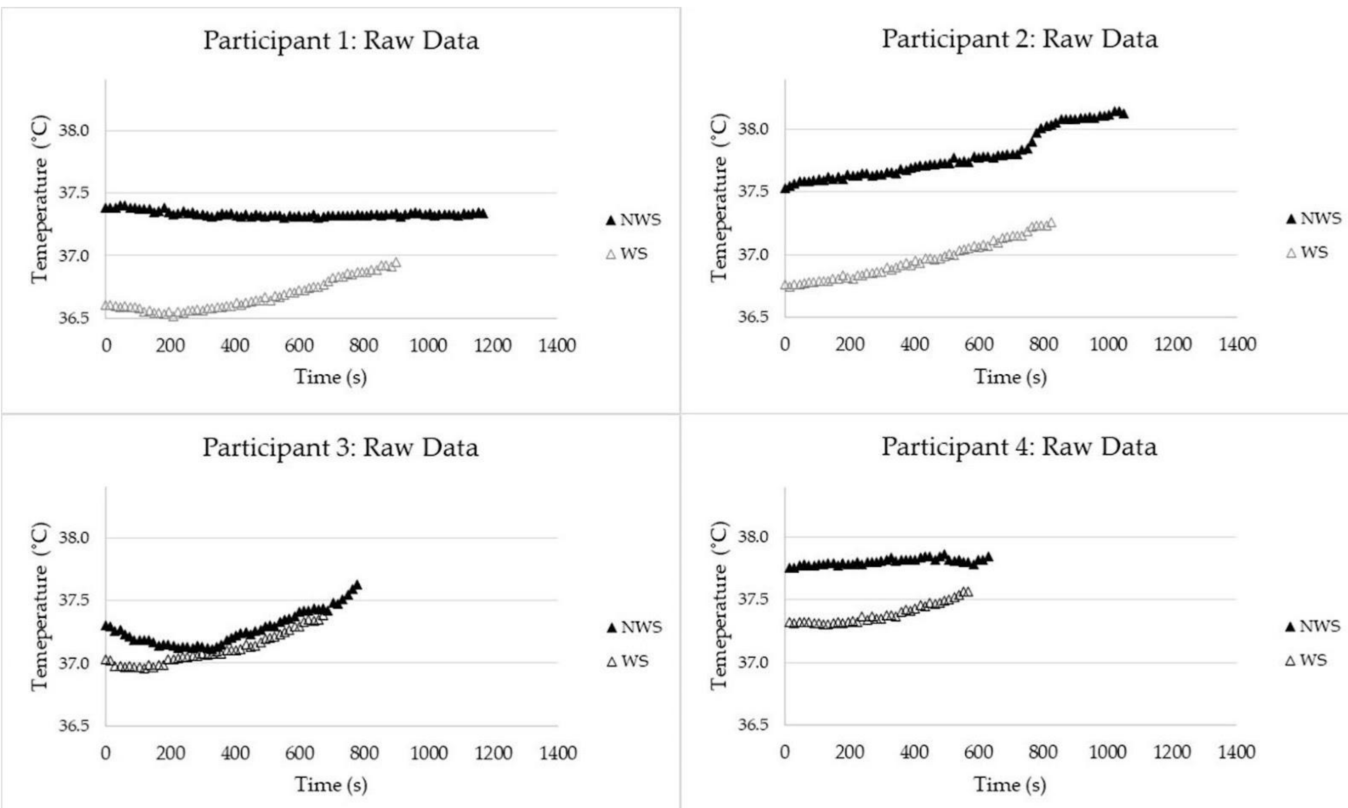

Figure 2. Raw core temperature vs. time data for all 4 participants for wetsuit (WS) and no wetsuit (NWS) conditions.

The group statistical results of the limited data set (i.e., n=4) of discrete variables are presented Table 1. Swim performance was faster in the WS condition (742.5±148.2 s) compared to the NWS condition (907.5±246.6 s) (t(3)=3.342, ES=0.81, p=0.02). Maximum temperature was different between WS (37.3±0.3°C) and NWS (37.8°±-0.3°C) conditions (t(3)=3.24, ES=1.67, p=0.048). Average core temperature was different during WS (37.0±0.3°C) vs. NWS (37.6±0.3°C) (t(3)=3.56, ES=2.00, p=0.038). Change in core temperature was not different during WS (0.36±0.1°C) vs. NWS (0.24±0.3°C) (t(3)=-1.15, ES=0.80, p=0.059).

Table 1. Means and standard deviations for each dependent variable.

Dependent variable	No Wetsuit	Wetsuit
Swim Performance (s)	907.5±246.6	742.5±148.2*
Average temperature (°C)	37.6±0.3	37.0±0.3*
Maximum temperature (°C)	37.8±0.3	37.3±0.3*
Change in temperature (°C)	0.24±0.3	0.36±0.1
Temperature at start (°C)	37.5±0.3	37.0±0.3*

Note: * indicates a difference between conditions (p<0.05)

Since the temperature at start was different between conditions, for illustration purposes, core temperature data were normalized such that the beginning data point for each condition was set to 100% (Figure 3).

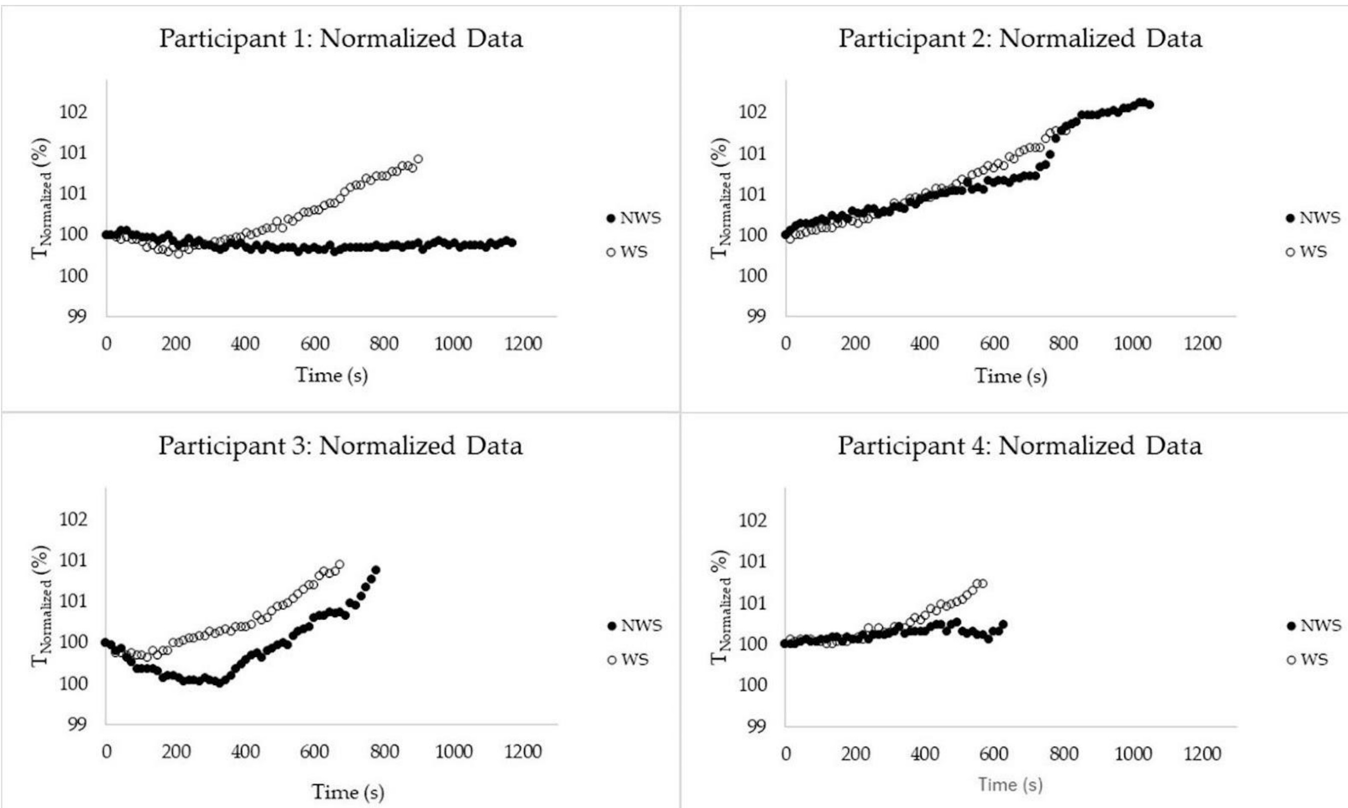

Figure 3. Normalized core temperature vs. time data for all 4 participants for wetsuit (WS) and no wetsuit (NWS) conditions.

The analysis of the residuals indicated that the order of polynomial influenced the residuals regardless of the wetsuit condition (p<0.05). However, the contrasts (i.e., 1st vs. 2nd order, 1st vs. 3rd order) only trended to be different (p<0.10).

Discussion

This descriptive study aimed to understand the impact of wearing a wetsuit on core temperature patterns while swimming in warm water. Given the limited number of participants (n=4), the limits in generalizing the observations made are fully recognized. Nevertheless, this exploratory study established the safety and feasibility of measuring core temperature during swimming in warm water in a wetsuit at a self-selected pace swimming in water temperature that ranged between 27.9°C and 28.1°C. Although we did note group differences in maximum and average temperatures between conditions, this is largely explained by the higher starting temperature of the wetsuit condition. This is further evident by the lack of difference in change in temperature between conditions. This observation led us to refute our hypothesis that there would be a greater change in core temperature when swimming in a wetsuit vs. no wetsuit in warm water.

Given the focus of this study was on core temperature patterns, individual core temperature vs. time data sets were fit with a 1st order, 2nd order, and 3rd order polynomial. The residuals for each line of best fit were calculated. The group statistical results indicated that the higher the order the polynomial, the better the line of fit. This generally applies in data sets that have some type of curvature. However, we noted high variability of which order polynomial best fit a participant's data set. In general, of the 8 data sets (i.e., four participants, two conditions), there was general improvement with the line of best fit in at least 5 data sets using the 2nd vs. 1st order polynomial and no appreciable improvement using a 3rd order polynomial. Interestingly, there was no improvement of fitting the data using higher order polynomials for two participants – both during NWS. Inspection of the residuals seems to indicate that the linear or nonlinear rate of change of core temperature is individualized.

Different patterns of change in core temperature were identified and categorized as 1) linear, 2) a decrease in core temperature followed by an increase, or 3) no change in core temperature followed by an increase in core temperature at some point during the swim (Figure 3). The nonlinear temperature response during swimming has also been observed in other studies.[4,9,10] Interestingly, Morton et al[10] reported that core temperature patterns were tri-phasic when swimming in open water temperatures ranging between 8.4-24.5°C. The tri-phasic pattern included an initial rise, a plateau, and then thermal decompensation in core temperature during the course of the swim. In the present study, when swimming in a wetsuit, we observed patterns that either decreased or increased after the start. For the data sets in which core temperature decreased at first, temperature eventually started to increase. However, we did not observe any plateau in core temperature. It is not clear what would happen if the duration of the swim was longer. Rois et al[8] reported that core temperature while swimming in a wetsuit increased linearly until reaching a plateau at the 30 minute mark. However, it is important to note that their study was conducted in cooler water (25.1°C).[8] compared to the present research, which may have influenced the temperature dynamics reported.

Nevertheless, for the present study, the time to reach a hyperthermic state (39.0°C) was estimated in the context of the swim continuing at the same pace. Using the line of best fit (either 1st or 2nd order polynomial depending on participant), the time to reach 39.0°C was calculated. It was estimated that if temperature continued to increase during a swim, it would take about 19-137 mins for subjects to reach a hyperthermic state. The wide range in times is because some participants had a low rate of change of core temperature (which would yield a longer time to reach 39°C) and others had a high rate of change of core temperature (which would yield a shorter time to reach 39°C). This is further evidence of the individual nature of change in core temperature.

The length of time to reach a hyperthermic state highlights the marginal gains in core temperature during swimming with a wetsuit in warm water for ~700 m at a somewhat hard, self-selected pace as well as the highly individual response of rate of change of temperature. That being said, it is not known if, for the participants in the present study, temperature would plateau at some point and/or if the rate of change in core temperature varies with intensity. If temperature plateaued, the time to hyperthermic state would be longer. During a 30-min swim in 25.6°C in a wetsuit and no wetsuit, Trappe et al[7] reported that core temperature increased for both conditions but noted a smaller temperature increase when swimming in a wetsuit compared without a wetsuit (wetsuit 0.89 ± 0.13°C; no wetsuit 1.22 ± 0.24°C).[7] In the present study, we observed no difference in change in core temperature when swimming in a wetsuit vs. no wetsuit. Like Trappe et al,[7] the present study had swimmers self-select a swim pace for each condition. It may be that the change in core temperature that Trappe et al[7] observed was related to swim time and/or intensity. It is interesting to note that the change in core temperature was more subtle during the wetsuit condition and Trappe et al[7] concluded that participants were not at risk of hyperthermia. They did, however, note that qualitatively, participants subjectively felt warmer during swimming in a wetsuit during the warmest water temperature condition (25.6°C).

In the present study, the variability in individual responses of core temperature vs. time suggests that factors such as body composition, gender, age, and training level, for example, may influence physiological reactions. Furthermore, issues such as wetsuit fit, swim performance time, and perceived effort all point to the importance of individual analysis of change in core temperature during swimming in a wetsuit.

We included a group analysis of discrete core temperature values but fully recognize the limitation of our small sample size (n=4). However, we believe this information is helpful to subsequent studies and the results are in line with previous research. Average core temperature during swimming was 37.0±0.3°C with a wetsuit and 37.6±0.3°C without a wetsuit, which are within a reasonable range and are not indicative of hyperthermic temperatures. For instance, Swafford et al[9] reported an average core temperature of 37.50°C in the wetsuit condition and 37.66°C in the no wetsuit condition. Similarly, Rois et al[8] observed a mean core temperature of 37.46 ± 0.39°C with a wetsuit. However, in that study, in the no wetsuit condition, the average temperature was slightly lower (36.59 ± 1.31°C) than what we observed; likely due to a lower water temperature (25°C) than what was observed in the present study (27.9-28.2 °C). Rois et al[8] also reported that core temperature never reached hyperthermic levels when swimming 75 mins in a wetsuit in 25°C water. To our knowledge, the present study is one of the first studies to continuously monitor (15 s interval) core temperature responses to wetsuit use in warm water during open water swimming. Overall, it is remarkable how core temperature was only marginally affected when swimming in warm water with a wetsuit.

A confounding factor was that the starting core temperature was different between conditions. Although a standard was set for starting core temperature on the shore while the participant was out of the water, each participant had to swim about 150 m to the start buoy and then tread water prior to being given the signal to start swimming. Unfortunately, even with using the ingestible core temperature pill system, the pill cannot transmit data while the person is in the water. Instead, data are downloaded when the participant exits the water. Due to this, it was not possible to check the starting temperature when the participant was at the start buoy. It is likely that the warm up swim out to the start buoy combined with treading water influenced the starting core temperature. That is, participants may have had to work harder during the warm up as well as treading water prior to the start of the swim when not wearing a wetsuit vs. wearing a wetsuit.

A primary limitation of this study was the relatively small sample size. With four participants, the ability to generalize the findings of a group analysis to a broader population is limited. A larger and more diverse sample would enhance statistical power and improve the reliability of the results. Future studies should aim to include participants of different ages, genders, body compositions, and fitness levels to better understand individual variability in physiological responses. It is important to note that in order to conduct this study in open water, there was a date range during which the body of water was sufficiently warm to conduct the investigation. Unfortunately, the window to collect even four participants was small. Nevertheless, with only 4 participants, it was possible to identify the highly variable nature of core temperature vs. time patterns. This needs to be accounted for in studies with a larger sample population.

Another limitation was the focus on core temperature as the primary physiological measure. While core temperature is crucial, other factors such as skin temperature, heart rate, oxygen consumption, sweat rate, and perceived exertion are important to consider. Gay et al[15] compared the metabolic demands of swimming in cold (18°C) and normal temperature (26°C) water. They reported that total energy expenditure, blood lactate levels, rate of perceived exertion, and maximal heart rate were all higher in warmer water. However, they did not examine real time changes in body temperature during swimming. Future research would benefit from simultaneously tracking both metabolic responses and core temperature to provide a more comprehensive understanding of physiological adaptations in different water temperatures.

The present study used a fixed order of conditions (i.e., WS followed by NWS) which was done from a practical sense in that putting on a wetsuit when wet is extremely difficult. Hostler et al[16] reported that core temperature can increase during rest when wearing a dry suit (vs. a wet suit) at high air temperatures above body temperature. From pilot testing, the effort to put on a wetsuit had the effect of increasing core temperature. Given the test was done outdoors in an area with no shade, it was decided to complete the WS condition first in order to minimize the rest time between conditions. For a future study, it would make sense to have a trailer or recreational vehicle with air conditioning that would allow participants to rest and prepare for the next condition. In that case, it would have been pragmatic to counterbalance the order of conditions between participants. Unfortunately, the research team did not have access to such a vehicle.

Finally, the study is limited due to a relatively short swim duration. It is unclear how core temperature would continue to change over longer swim distances or in different pacing strategies. However, given the limited research on core temperature during swimming in warm open water with a wetsuit and given the present study was a descriptive study, the intent was to get an initial understanding of core temperature response during moderate, shorter duration swimming. At this point, future research should explore the effects of wetsuit use over extended periods to determine if core temperature continues to rise or eventually stabilizes as well as different swim intensities. It is also important to recognize that the participants in this study were representative of an age group athlete and not elite. The intensity that elite athletes race at may yield entirely different results. Nevertheless, it is important to study a range of athlete performance abilities in order to best understand the influence of wearing a wetsuit in warm water. By addressing these limitations, future research can offer a more complete picture of how wetsuits impact thermoregulation and physiological performance in various swimming conditions.

In summary, this descriptive study examined the effects of wetsuit use on core temperature patterns during warm open water swimming at a self-selected moderate pace. Participants swam faster when wearing a wetsuit compared to no wetsuit while core temperature was only marginally affected by wetsuit use in warm water with no participants reaching a hyperthermic state. Since the present study only had four participants, future research should employ larger sample sizes and include additional physiological measures to better characterize individual responses to wetsuit use in warm water, with particular focus on variability in core temperature between participants.

An important observation from this exploratory research was that when analyzing core temperature patterns during swimming, it is important that both 1st and 2nd order polynomial lines of best fit be considered for individual participants. Even with a small sample size, distinct patterns of core temperature over time were observed among participants during the wetsuit and no wetsuit conditions, which may have implications for understanding the physiological impact of wetsuit use beyond performance enhancements. Furthermore, it is concluded that the change in temperature during moderate intensity swims in warm water by age group level triathletes was not different when wearing or not wearing a wetsuit. Given the small sample and the unique rate of change of temperature patterns, additional research is warranted.

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