TITLE:

The effects of a land-based warm-up and accompanying passive heat retention on core body temperature, hormones, and subsequent performance in elite surfers.

RUNNING TITLE:

Warm-ups and performance in elite surfing.

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ABSTRACT

Surfing is a high participation sport, yet little sport science research exists surrounding competitive performance in surfing. Given surfing's inclusion as an Olympic sport from the 2020 Tokyo Olympics onwards, examination of performance would seem useful. In numerous land-based sports and in swimming the importance of warm-up and muscle heat is well documented. Here, we discuss the importance of warm-up in the context of expression of 'power' on waves in competitive surfing – a key criteria which surfers are scored for; and, also, how warm-up may enhance overall readiness. This research adopted a repeated measures pre- and post- design whereby participants engaged in several simulated surfing competitions in an artificial wave pool; once after an active warm-up followed by passive heat retention strategy (i.e., wrapping themselves in survival blankets – treatment), and once after no warm-up (control). Saliva samples were collected prior to and after-the active warm up, or equivalent time under control conditions, for measurement of the hormones testosterone and cortisol. Increases in these hormones have previously been associated with increased readiness to compete. Our results demonstrate a clear thermoregulatory benefit to the treatment, and small magnitude upward change to hormones following the active warm-up. In every participant warm-up was associated with improved wave performance compared to control treatment. We argue that the improved thermal profile may have influenced power and as such, surfing performance was enhanced.

KEY WORDS:

Surfing; Warm-up; Testosterone; Cortisol; Performance

1. INTRODUCTION

In Australia, and across the world, surfing is a rapidly growing sport. In Australia alone, between 2019 to 2021 196,000 new participants registered as competitors with formal surfing clubs(1) . Furthermore, from 2016 to 2023 there was a surfing population increase of 46% amongst people aged 18 years or older(2). Currently, in Australia nearly 730,000 adults engage in surfing, and it is believed these numbers align with worldwide participation rates where it is thought that more than 50 million people engage in surf sports(2). Despite these high participation rates, and increased interest in competition in the sport, a paucity of research exists surrounding competitive performance in surfing. Given Surfing's inclusion as an Olympic Sport from the 2020 Tokyo Olympics onwards examination of performance would seem a prudent approach to improving the sport.

Surfing requires physical exertion both above and below water; with padding through water, surfing on water, disembarking board and duck diving under waves being required. In competitive surfing a major judging criterion is 'power', where the surfer uses aspects of the board (fins, rails) to drive into and out of the water often producing spray (which anecdotally judges use visually to help assess power). In power demanding sports warm muscles, achieved both actively and passively, appear to contribute to ability to express power and speed. This has been repeatedly observed in bob skeleton, swimming, rugby union, rugby league, weightlifting and other sports and across both males and females(3-7). As muscle temperature gradually falls this advantage diminishes. Interestingly, even in very warm climates muscle warmth particularly legs and when combined with torso precooling can give marked advantage in power (with the cost of heat fatigue(8). Limited data suggests that development of land-based power contributes to surfing prowess(9). Thus, a warm-up is important for subsequent performance, including in surfing, and this notion is supported by a meta-analysis which shows 79% of research demonstrated improvement in performance with warm-up(10-12). However, for surfing, further data is needed to observe to establish how closely other sport knowledge in aspects of warm-up translates to the sport.

Two further features, in addition to demonstration of power for judging criteria, of competitive surfing make the warm muscle hypothesis attractive. Firstly, surfing is a limited timed event judged by the total of the best two scored waves (number of waves allowed varies depending on competition from 10 to unlimited). A common and reasonably robust strategy is to try and gain two wave scores early following entry into water. An early advantage over opponents of warm muscles, and associated power, would support this strategy. Secondly, competitive surfing is undertaken in water temperatures as low as seven degrees Celsius and up to 32 degrees Celsius, thus an understanding of muscle and body warmth would be advantageous to warm-up planning. Surfers often complete their main warm-ups somewhat in advance of water entry and anecdotally like to observe water conditions. In other sports where holding times intervene between warm-up and event passive heat retention has proven very useful at maintaining muscle warmth and as such may have benefit to competitive surfing. In an earlier study we demonstrated considerable thermal gain to recreational surfers entering relatively cold water by the combination of active warm-up and passive eat maintenance(9). This also had some positive outcomes to the way they surfed (e.g. more maneuvers per wave, better pop ups)(9).

An important component to warm-ups is not just increasing temperature and the potential related muscle power, but also enhancing overall readiness; with readiness being defined as a complete state of physical, behavioural and psychological preparedness to compete(13). In research, readiness has been linked to stress hormones – cortisol and testosterone, possibly as biomarkers, however some direct effects may also occur. Cortisol has been reported to be arousing, and has been linked to performance in short duration sporting events such as in Judo in males(14), Olympic Weightlifting in males and females(15), and Rowing performance (in some contexts) in females(16). However, elevations in cortisol can also lead to aggressive behaviours, and increased fatigue and anxiety(13, 14, 17). Testosterone has been linked to enhanced motivation, motor control, neuromuscular expression of speed and power, assertiveness, and collaborative competitiveness(13, 18-20). Testosterone increases have been linked to performance in longer duration events and team sports in both males and females including Rugby union(21, 22), Rugby 7's(23), and Hockey(24). The linkage of testosterone, in particular, to speed and power may be of value to power elements in surfing(25). Testosterone and cortisol may therefore related to readiness to compete and are often considered relative to each other using the testosterone-to-cortisol ratio(13, 17, 18, 26, 27) and this ratio may have some flow on effect on recovery. Therefore, warm-up protocols associated with elevations in testosterone may potentially contribute to performance.

The aims of this study were to explore, under simulated competition and in elite level competitive surfers, if judged criteria performance was influenced with or without a structured warm-up combined with passive heat retention. We hypothesised that the warm-up and heat retention strategy would elevate core body, and hence muscle temperature, enabling surfers to express more power early in the session and garnish higher judged scores. In addition, we collected saliva before and after an active warm-up and subsequently assayed for testosterone and cortisol to observe is there were any potential links of hormones to warm-up protocols.

2. MATERIALS AND METHODS

2.1. Study Overview

This research adopted a repeated measures pre- and post- design. Participants attended an artificial wave pool (UBRN Surf, Victoria, Australia) on several occasions – each session was 24 hours apart, one attendance was for familiarization, once was for experimental conditions, and once for 'control' conditions. For the 'experimental' surf, participants entered the wave pool following a combined active and passive warm-up; for control they entered the pool without completing a warm-up. Thus, participants acted as their own control. For both control and experimental conditions participants swallowed a thermometer pill (BMedical, Paris, France), and core body temperature was measured every 30-seconds for the duration of data collection. A saliva sample was also collected from each participant immediately prior to, and 15-minutes after, the active warm-up (or equivalent amount of time under control conditions) for measurement of testosterone and cortisol. Finally, performance in the subsequent surf sessions (control and experimental conditions) was scored by two Australian State level qualified surfing judges, blinded to treatment conditions. Hormones, core body temperature and performance were compared between sessions, and relationships for core body temperature and hormones with performance was explored.

2.2. Participants

Nineteen participants (n = 15 males; n = 4 females) were recruited to this study. The mean (± SD) age, height and weight for the entire group was 24.5 ± 11.6 years, 174.7 ± 9.1 cm, and 67.7 ± 10.2 kg respectively; and specifically - the male participants were 22.3 ± 10.3 years, 177.6 ± 7.8 cm, and 69.7 ± 10.6 kg respectively, and females 32.8 ± 14.2 years, 164.5 ± 5.3 cm, and 60.0 ± 0.3 kg respectively. All participants were advanced level surfers (i.e., they were capable of executing aerial maneuvers, and competitive at state level in Australia). Ten of the surfers were goofy footed (i.e., they stood on a surfboard with right foot forward; n = 9 males and n = 1 female), and nine surfed with a natural stance (i.e., they stood on a surfboard with left foot forward; n = 6 males and n = 3 females).

2.3. Procedures

Approval to conduct this research was granted by the University of New England Human Research Ethics Committee (protocol number HE22-141). Prior to commencement of data collection voluntary informed consent to participate was provided by each participant following briefing of the research aims and protocols.

For familiarization, participants surfed at the artificial wave pool in their own time prior to commencement of the experiment. Thereafter, on two separate occasions, 24 hours apart, participants attended the wave pool at approximately 7:00 am and swallowed a thermometer pill. On the control day participants were instructed to prepare for a surf as they normally would and entered the pool at 9:00am. On the experimental day, at 8:20 am participants commenced a land-based warm-up in their wetsuits before covering themselves with a survival blanket until they were entered the wave pool at 9:00am (note, participants all wore a minimum 3/2 combination wetsuit – that is, they wore a wetsuit with chest and back panels of wetsuit made of 3 mm neoprene foam, whereas limb panels are made of a 2 mm neoprene foam. They were instructed to wear the same wetsuit on both occasions). Survival blankets are low-weight, low bulk blankets made of thin plastic heat-reflective sheeting. The warm-up was similar to that described elsewhere(13), and consisted of 2-5 minutes of general mobility, 2-3 minutes of upper body and lower body reactive strength exercises, 2-3 minutes of upper body and lower body elastic strength exercises, and 2-3 minutes of upper body and lower body mechanical power exercises. The warm-up took 12-15 minutes, therefore participants remained under survival blankets, remaining reasonably still, for 15-20 minutes. Saliva samples were collected for hormone measurement from participants at approximately 8:20 am and 8:50 am on both days (i.e., just prior to commencement of active warm-up, and approximately 15-minutes after the active component of the warm-up, on the experimental day; and same times on control day). Core body temperature was analyzed from 8:20am to 9:40am on both experimental and control days (i.e., from commencement of warm-up to end of surfing session), and data was compared with and between days from the full minute at commencement of active warm-up (8:20am), completion of active warm-up (~8:35am), completion of passive warm-up (8:55am), when participants entered the pool (9:00am), at the start of the first competition block (~9:07am), and at the start of the second competition block (~9:20am), at completion of the surf (9:40am). Magnitude of change between data points was also compared between days. Note, water temperature in the wave pool was a consistent 13-16 degrees Celsius each session. A schematic of the research protocol can be seen in figure 1.

2.4. Core Temperature Measurement

Thermometer pills were activated prior to ingestions using and eCelsius Performance Activator (BMedical, Paris, France) and swallowed by participants between 90 and 60-minutes prior to commencing the warm-up. Participants were instructed to not consume and drinks between swallowing the pill and entering the pool to not affect core temperature readings while the pill was in their stomach. All temperature readings were transferred wirelessly from participants soon after completion of the surf using and eCelsius Performance Monitor (BMedical, Paris, France) and downloaded to ePerformance Manager (BMedical, Paris, France) and exported to Microsoft Excel for later analysis.

2.5. Hormone Measurement

Testosterone and cortisol were measured from saliva samples collected from participants immediately prior to commencement of the active warm-up, and 15-minutes after completion of the active warm-up. It is well known that a lag time exists for hormone change from plasma to saliva(28, 29), with the time being individual and context dependent, but allowing for a lag time of approximately 10-15-mintues is generally acceptable, hence the second saliva sample was collected 15-minutes after completion of active warm-up. Saliva samples were collected from participants in sterilized cryovials and stored in a -20ºC freezer until analysis. They were then assayed for cortisol and testosterone using commercial enzyme immunoassay kits (cortisol catalog number 1-3002; testosterone catalog number 1-2402; Salimetrics LLC, State College, PA). Intra- and inter-assay variability was <5.0% for testosterone and cortisol. Samples were analyzed in the same assay to eliminate inter assay variance.

2.6. Scoring of Performance

An advantage of using an artificial wave pool is the ability to control the ‘type’ of wave participants surfed, and when they surf it. As such, the waves each participant surfed on each occasion were standardized as ‘advanced’ level waves; with wave face height always being 1.6 to 2.0 m, and wave length 12 to 16-seconds. Participants were scored in two 'blocks' of three waves (waves three to five, and waves six to nine) by two experienced Australian State level qualified surfing judges for 'flow', 'speed', 'style' and 'power' across the entire wave from 'pop-up' to exit according to standardized Surfing Australia protocols(30). The best two scores for each scoring block were also added for an overall score. Thus, three scores were subsequently given – performance in first scoring block, performance in second scoring block, and overall performance (which was best two scores across both scoring blocks). Where scoring differed in this study compared to Surfing Australia protocols is that scores were given on a scale of zero to ten with increments of 0.5, as opposed to scores being continuous in nature between zero and ten; making data somewhat categorical in nature. Scores between judges were averaged, and when the average sat between increments of 0.5, the score was rounded up (e.g., a score of 5.75 was rounded to 6.0). Note, all scored waves were completed within 25 minutes of getting into the wave pool.

2.7. Statistical Analysis

2.7.1. Core Body Temperature

Data was first assessed to establish if it met the assumptions of parametric statistical analysis (i.e., Shapiro-Wilks test for normality, Levene's test of equality). These assumptions were not met by all data; as such, a Friedman's test was performed on all data combined, on male only data, and on female only data, to establish if a difference existed between sessions and within sessions for core body temperature. Where significant differences were identified, Wilcoxon sign-ranked tests were applied to establish where significant differences exist within and between sessions. We also applied Wilcoxon sign-ranked tests to magnitude of differences.

2.7.2. Hormones

Similarly to core body temperature, data was first assessed to establish if it met the assumptions required for parametric statistical analysis. Again, the assumption were not met, therefore a Friedman's test was performed on all data combined, on male only data, and on female only data, to establish if a difference existed between sessions and within sessions for testosterone, cortisol, and testosterone-to-cortisol ratio. Where significant differences were identified, Wilcoxon sign-ranked tests were applied to establish where significant differences exist within and between sessions.

2.7.3. Performance

Given the categorical nature of the data a non-parametric statistical analysis was most suitable for this data set. As such, a Friedman's test and Wilcoxon sign-ranked tests were also applied to performance data.

All statistical analyses α = 0.05, and all were performed Statistical Package for the Social Sciences software version 29.0 (IBM, New York, NY)

3. RESULTS

Median and interquartile ranges can be seen for core body temperature data in table 1. The Friedman's test on data for all participants for core body temperature revealed a significant difference exist $\chi^2(13) = 141.11$, p = <0.001. Similar was observed for the men's only data $\chi^2(13) = 103.39$, p = <0.001, and for the women's only data $\chi^2(13)$ = 33.47, p = 0.001.

Wilcoxon signed rank tests revealed that for entire group data core body temperature under warm-up conditions was greater compared to control conditions at the end of the active warmup (Z = 2.22, p = 0.03), at the start of the first competition set of waves (Z = 2.74, p = 0.01), and at the start of the second competition set of waves (Z = 2.95, p = <0.01). When exploring men only data the difference was only observed at the start of the first competition set (Z = 2.59, p = 0.01), and at the start of the second competition set (Z = 2.28, p = 0.02). For women only data, no significant differences between conditions were observed. When looking at experimental group differences within session, core body temperature increased following active warm-up (Z = 2.48, p = 0.01). Core body temperature was also greater at the start of the first competition block, the second competition block, and at the end of the surfing session compared to the end of the active and passive warm-ups, and pool entry pool entry (Z = > 3.46, p = < 0.01). It also increased from the start of the first competition set to the second competition set, and from the start of the first competition set to the end of the session (Z = > 3.15, p = < 0.01. Similar observations were made under control conditions (Z = 2.72, p = 0.01) when comparing competition sets and end of surfing session to start, end of active warm-up, passive warm-up, and pool entry (Z = > 2.64, p = < 0.01). Core body temperature was also greater at start of second competition block and at the end of the surfing session compared to first competition block (Z = > 2.64, p = = <0.01). Interestingly, though, core body temperature was greater at the end of the session compared to the start of the second competition wave set under control conditions (Z = 2.12, p = 0.03), but not under experimental conditions. Broadly speaking, similar observations were made for the male only data (Z = > 2.24, p = < 0.05). Comparisons within sessions did not reach statistical significance for women only data (table 1).

When exploring differences in magnitude of increase in core body temperature, data from all participants combined showed that magnitude of increase in core body temperature from pool entry to the first competition set was greater following warm-up compared to control (Z = 2.84, p =<0.01). This was similarly observed in the men's only data (Z = 2.43, p = 0.02), but women's only data did not reach statistical significance (figure 2).

For hormone data, the Friedman's test on all participant's data revealed a significant difference exist for testosterone ($\chi^2(3) = 11.19$, p = 0.01), and cortisol ($\chi^2(3)$ =

18.35, p = < 0.001), but not for testosterone-to-cortisol ratio. Similar observations were made for the male only data ($\chi^2(3) = 8.15$, p = 0.04 and $\chi^2(13) = 14.12$, p = < 0.01 respectively), but, again, no statistical significance was reached for female only data. Wilcoxon signed-rank tests revealed that for all participants testosterone was greater at the start of the day prior to the warm-up compared to the start of the day under control conditions (Z = 2.25, p = 0.02), and post active warm-up compared to pre active warm-up (Z = 2.54, p = 0.01). Cortisol was also greater under warm-up conditions compared to control conditions pre (Z = 2.90, p = < 0.01) and post (Z = 3.10, p = < 0.01). Finally, testosterone-to-cortisol ratio was greater post warm-up compared to pre-warm-up (Z = 1.93, p = 0.05), and post compared to pre under control conditions (Z = 1.81, p = 0.05). Similar observations were made for male only data (Z = 1.99, p = 0.05; Z = 2.39, p = 0.02; Z = 2.56, p = 0.01; Z = 2.61, p = < 0.01; Z = 2.25, p = 0.03 and Z = 1.99, p = 0.05 respectively). See figure 3.

Finally, Friedman's test for the performance data for all participants combined also revealed a significant difference exist for the first competition set, second competition set, and overall score for warm-up compared to control conditions ($\chi^2(5)$ = 49.70, p = < 0.001). This was similarly the case for male only data ($\chi^2(5)$ = 38.51, p = < 0.01), but statistical significance was not reached in women on data. Wilcoxon signed-rank tests showed performance for the first wave set, second wave set, and overall score for the first wave set was better than for the equivalent in the second wave set (Z > 2.41, p = < 0.02). Similar observations were made for male only data (Z > 1.95, p = < 0.05). See figure 4.

4. DISCUSSION

The purpose of this study was to explore whether surfing performance was influenced by a structured warm-up combined with passive heat retention. We anticipated that the warm-up and heat retention strategy would elevate core body, and hence muscle temperature enabling surfers to express more power earlier and achieve higher judged scores. Our results demonstrated a clear thermal advantage to an active warm-up and passive heat retention. Interestingly, this advantage lasted across more than 25-minutes of surfing in relatively cool water. This was similar to the thermal profiles we reported for recreational surfers at comparable water temperatures(9).

In the present study, magnitude of core body temperature increase was greater and 'more rapid' following warm-up compared to control conditions after participants entered the water, and were active paddling, but reached a plateau earlier. This was further highlighted by the fact that under control conditions there remained a significant difference in core temperature from the start of second competition block to the end of the session, but not under warm-up conditions, and by the end of the pool session core temperature for both conditions was similar. Our study also demonstratated that, secondary to the improved thermal advantage, there was a small change in hormonal profile following active warm-up; with an increase in testosterone being observed and a clear decline in cortisol being demonstrated following active warm-up, along with significant differences within subjects between conditions. Finally, performance, as judged by surfing Australia criteria using two independent and blinded to treatment judges, showed a consistent difference across both competition sets of waves blocks and subsequent overall best two wave scorewith warm-up and passive heat retention being associated with higher scores.

Our results were not unexpected given the thermal effect of active warm-up and the passive heat retention properties mirror results presented in other sports(3-7, 31); and our active warm-up protocol also achieved similar results, in terms of hormonal change, elsewhere (9, 13). In fact, other sports studies, where appropriate warm-up has been explored, have produced quite compelling evidence which was instrumental in forwarding an argument for both warm-up and understanding the effect of thermal profiles on surfing performance(31). Surfing competition can also occur in warm water, and on land when ambient conditions are hot and humid precooling can influence performance positively. Recent research has shown that in repeat sprint land models in very hot environments where precooling can have a positive effect on performance, combining concepts of warm legs (through active and passive warming) and cool body (precooling) may offer competitive advantage greater than either alone, suggesting this is worthy of exploration in surfing performance(8).

A novel finding from this present study was that the gain in thermal properties mirrored performance improvement across waves; and the advantage lasted at least 25-minutes in the water; given the small number of participants this was a strong finding. Generally, in land based sports the thermal advantages of warm-up dissipate 10-15 minutes into competition(31). However, surfers are both above and in the water; and in this case were wearing a minimum of 3/2 mm combination wetsuits. Both (water exposure and wetsuit) offer slightly different properties to those seen on land. Such a period of thermal gain therefore has strong implications for the entire period of a competitive heat duration (normally 15 to 30-minutes) in surfing.

As noted earlier, there were some small differences in hormone levels between warm-up and control treatment with both testosterone and cortisol tending higher in the warm-up protocol. There are several possible reasons for the increase in hormone magnitude; firstly, athletes may have been more anticipatory aroused prior to knowing they were doing a warm-up protocol and the warm-up itself is short and intense which can activate hormones (4). Potentially one benefit of this may be increased availability of power and speed(25, 32, 33); which could conceivable have also influenced surf power performance. Changes in hormones may also facilitate mental states of assertiveness, self-belief and competitiveness in both males and females (34, 35). Finally, it is worth noting that testosterone-to-cortisol at conclusion of competition in other sports has been linked to more rapid and 'better' recovery(36). The magnitude of change we observed in this study was possibly too small to effectuate these changes however further investigation is merited.

Despite our research demonstrating value of warm-ups for surfing performance, it is worth noting that in work in bob skeleton athletes adopted warm-ups and passive heat strategies that had thermal advantage but also best suited them(3). As such, sometimes adoption of practice was not necessarily the optimal in terms of enhancing measured sprint – power performance, but it did give participants the best sense of overall performance. In fact, all took some advantage speed and power wise from their own adapted warm-up. This highlights the point that most sport have other elements aside power and speed that must be balanced into a successful performance equation, and why it remains valuable to monitor hormonal response to warm-up (as they may indicate mental state). For example athletes are often anecdotally fashion conscious(37-39), and choose their performance clothing with this in mind so good clothing design incorporating elements of thermal gain will likely be an important contributor longer term to any strong broad compliance.

There are several caveats in this study, fatigue being one. Although the athletes did not report any fatigue across the different sessions this remains a confounder that in our study which we did not adequately dissect out due to practical limitations such as athlete availability and cost of study. Additionally, hormone differences between treatments were small and preliminary in data nature only, and underpowered in female number. They simply suggest an avenue for more exploration. We believe that both gender and BMI may be important particularly in clothing design. We did not have the numbers or spread in our study to elucidate if this is so. In particular, our female numbers were under-powered; more female studies are clearly needed. The ability to measure actual power or speed would further the science of this study, although ultimately, in sport, impact on measured performance (in this case wave scores) is primary. As mentioned, athlete compliance, adoptability and practicality are essential features in a true competitive ecological environment. Our data provides some foundations to further this and suggests understanding both active warm up, passive heat retention and any associated physiological changes such as hormone status may have considerable performance benefit in surfing.

5. CONCLUSION

In a simulated competition context, this study showed a clear thermoregulation benefit of adopting a land-based warm-up with passive heat retention (i.e., being wrapped in a survival blanket) strategy prior to surfing. Unsurprisingly, therefore, we saw a better performance in surfers following the land-based warm-up with passive heat retention likely due to muscle power availability that has been associated with body warmth. Surprisingly the benefit lasted longer than observed in land-based studies and was observed in every participating athlete. Secondary to this we saw small magnitude differences in the hormones testosterone and cortisol that speculatively could relate to readiness to compete. These findings have clear implications for competitive surfing, and also, potentially, for product development (e.g., wetsuits and other warming garments). Further research to improve numbers, specifically females, would be useful.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

Partial funding for this project was awarded by the University of New England Academic Pursuit Fund for CJC.

ACKNOWLEDGEMENTS:

We wish to thank the participants for donating their time to participate in this study.

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Table 1. Core Body Temperature in Degrees Celsius of Participants During Warm-Up (or Control) and Surfing Session. Values are median ± interquartile range

	Start of Warm-Up	End of Active Warm-Up	End of Passive Warm-Up	Pool Entry	Start of 1st Competition Set of Waves	Start of 2nd Competition Set of Waves	End of Surf Session
All Participants							
Warm-Up	37.38 ± 0.53	37.45 ± 0.38[a,b]	37.33 ± 0.36	37.39 ± 0.41	37.78 ± 0.41[a,c]	38.13 ± 0.55[a,c]	38.25 ± 0.32[d]
Control	37.10 ± 0.42	37.26 ± 0.48[b]	37.25 ± 0.43	37.25 ± 0.43	37.45 ± 0.51[c]	37.84 ± 0.49[c]	38.02 ± 0.71[e]
Males							
Warm-Up	37.24 ± 0.56	37.38 ± 0.42[a,b]	37.33 ± 0.38	37.32 ± 0.41	37.72 ± 0.35[a,c]	38.00 ± 0.41[a,c]	38.15 ± 0.37[d]
Control	37.02 ± 0.40	37.25 ± 0.42[b]	37.18 ± 0.36	37.17 ± 0.24	37.38 ± 0.37[c]	37.76 ± 0.54[c]	38.02 ± 0.68[e]
Females							
Warm-Up	37.45 ± 0.17	37.52 ± 0.18	37.41 ± 0.24	37.45 ± 0.34	37.86 ± 0.27	38.33 ± 0.14	38.30 ± 0.14
Control	37.30 ± 0.27	37.49 ± 0.12	37.45 ± 0.53	37.44 ± 0.34	37.79 ± 0.10	37.99 ± 0.26	37.95 ± 0.48

NB. **[a]=**significantly greater than same time point compared to control ($p < 0.05$). [b]=significantly greater than start of warm-up ($p < 0.05$). [c]=significantly different to all time points prior ($p < 0.05$). [d]=significantly greater than all prior time points but not start of second set of competition waves ($p < 0.05$). [e]=significantly greater than all time points prior including second competition set of waves ($p < 0.05$).

FIGURES

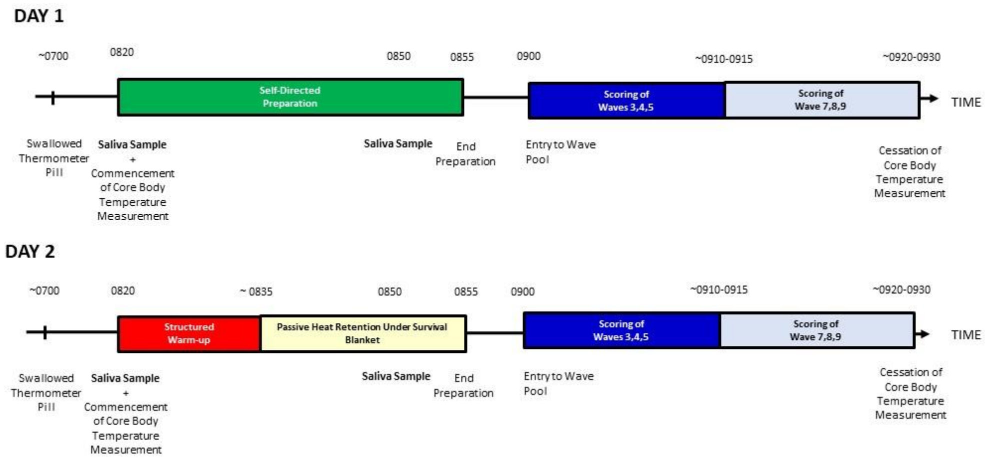

Figure 1. Schematic of research protocol. Note, sessions were completed 24 hours apart.

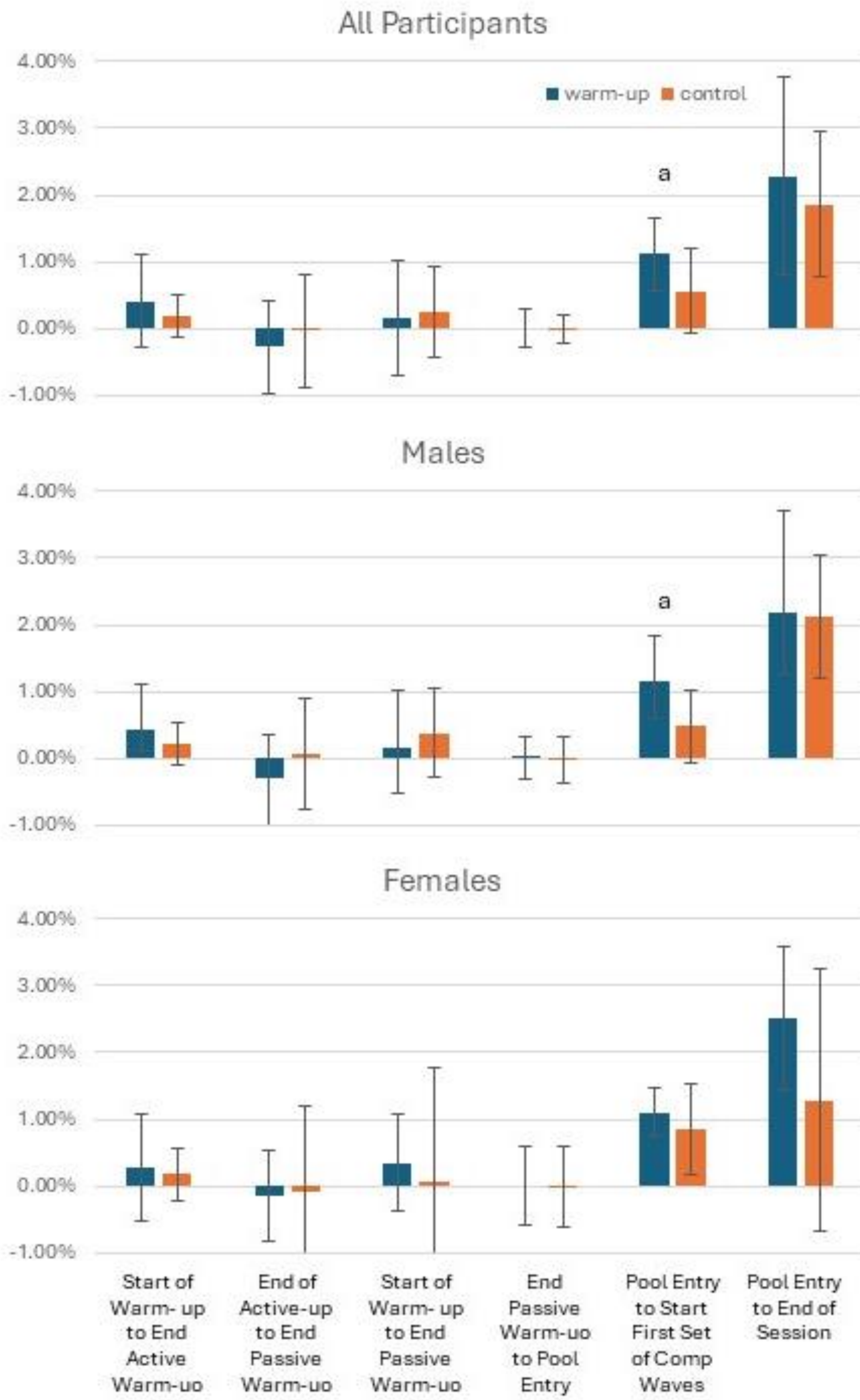

Figure 2. Change in core body temperature as a proportion of baseline (start of warm-up) core body temperature. Values are median ± interquartile range. [a] = magnitude of increase significantly greater for warm-up ($p < 0.05$).

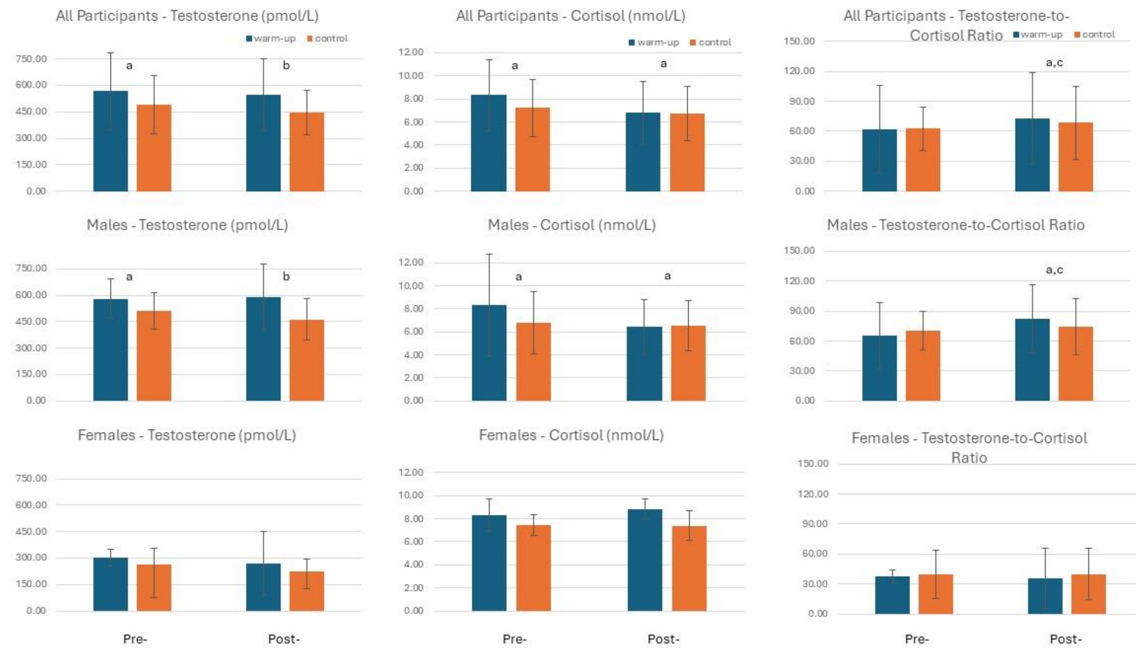

Figure 3. Cortisol, testosterone, and testosterone-to-cortisol ratio before and 15-minutes after active warm-up, or equivalent times under control conditions (i.e., 8:20am and 8:50am respectively). Values are median ± interquartile range. ^{a} = significantly greater under warm-up conditions compared to control conditions ($p < 0.05$). ^{b} = significantly greater post warm-up compared to pre-warm-up ($p < 0.05$). ^{c} = significantly greater post compared to pre under control conditions ($p < 0.05$).

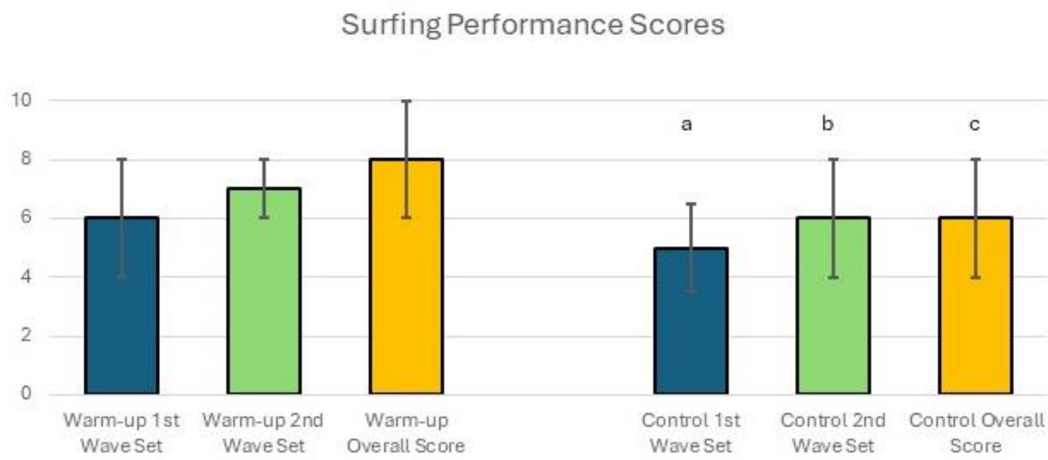

Figure 4. [a] = significantly lower than first wave set under warm-up conditions overall and for male participants ($p < 0.05$). [b] = significantly lower than second wave set under warm-up conditions overall and for male participants ($p < 0.05$). [c] = significantly lower than overall score under warm-up conditions overall and for male participants ($p < 0.05$).