Heat Attainment and Retention in Surfers with and without a Land-Based Warm-Up and Accompanying Passive Heat Retention

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Abstract: Surfing is a growing, high participation recreational and competitive activity. It is relatively unique being performed on, in, and through water with a range of temperatures. In other sports, warm-up and heat retention have proved useful at augmenting performance and ameliorating injury risk. Little work has been done examining this in surfing. The purpose of this work was to measure thermal profiles in surfers with and without warm-up and passive heat retention, and secondarily to assess any potential influence on free surfing. A repeated measures pre- and post- design was adopted whereby participants surfed in an artificial wave pool following an active warm-up combined with passive heat retention (experimental condition), and after no warm-up (control). Core body temperature was measured both occasions. Our results showed a clear advantage to body temperature for the experimental condition versus control. Both groups showed a warm-up effect in the water itself, presumably due to further activity (e.g. paddling) and wetsuit properties. Finally, performance trended to being superior following warm-up. We conclude, body warmth in surfers may be facilitated by an active warm-up and passive heat retention. In free surfing this is associated with a trend towards better performance; it may also reduce injury risk.

Keywords: surfing; warm-up; performance

INTRODUCTION

Surfing is a high participation and growth sport. In Australia, across the 2000's surfing participation had a growth rate of 24% year-on-year [1] and it has been reported that between 2019 to 2021 196,000 new participants registered with formal surfing clubs [2]. Furthermore, from 2016 to 2023 there was a surfing population increase of 46% amongst people aged 18 years or older [3]. Currently, in Australia, it ranks as one of the top five nature-based recreations for popularity and it is believed nearly 730,000 adults engage in surfing, spending nearly $3 billion annually. These numbers are likely to mirror world-wide numbers where it is thought that more than 50 million people engage in surf sports [3], however this likely under-represents actual participation because it is a sport that men and women of all ages can participate in without engaging in organized events [1,3]. Despite the popularity or the sport, relatively little research exists surrounding performance in surfing. This is particularly surprising given surfing's inclusion as an Olympic Sport from the 2020 Tokyo Olympics onwards.   Surfing is one of few sports which requires physical acts both above and below water; with padding through water, surfing on water, and disembarking board and duck diving under water all being required.   As such, data is needed to observe if other sport knowledge translates to surfing.   Given the nature of the sport, aspects of warm-up and maintenance of body temperature presents itself as of interest.

Both water and wind factors affect body temperature, however most research exploring how these elements affect body temperature has been undertaken in swimmers or divers [4–7] and a small amount with water skiers [8]. Heat loss, and heat perception, is individual in nature and it is known that for most humans water can start to markedly cool the body at 20 degrees Celsius and below [9]. Wetsuits, which are often used by surfers, are thought to ameliorate the rate of cooling; and this is supported by a small amount of research conducted with surfers which showed that a 2 mm wetsuit can prevent most heat loss for short periods in water temperature of 15 degrees Celsius or greater [10,11]. However, as wave quality and availability is often better in winter, surfers will often encounter combined chill factors well below 15 degrees Celsius. Therefore, more comprehensive, and ecologically valid data examining heat attainment and retention in surfing would be useful.

From a performance perspective, core, and correspondingly muscle temperature, has an important sport performance related effect - namely increasing potential power generation capacity in muscles [12–14] and potentially reducing injury risk [15]. For sports with relatively high muscular power demands, and in conditions where maintenance of that elevation is challenged by environment, structuring warm-ups to include muscle temperature elevation and combining passive heat retention mechanisms to retain that heat until competition start has proved a highly successful performance strategy [16–20]. Even in sports where hot and humid environments may better be prepared for by pre-cooling, combinations of muscle warmth and core cooling facilitate enhanced overall performance compared to pre-cooling or warming alone [21]. In surfing competition, one of the key judging criteria is demonstration of power on the wave and evidence shows that land based tested strength and power increase with elite performance [22,23]. Surfing is also a timed sport, and common strategy often involves obtaining several early wave scores (best two wave score combination wins). Therefore, having added core and muscle temperature, and potentially better early generation of muscle power, poses as a useful attribute.   In free surfing where no judgement is applied participants want to pop-up cleanly onto waves, catch as many good waves as possible and often spend maximum time on waves performing manoeuvres, all these likely have power contributors. In addition, in free surfing reducing participation injury is a worthy goal and muscle heat may offer some amelioration to risk [15].

The aims of this study were 1) to explore the thermal profile of surfers across the duration of a surfing session, in cold water, which would be similar in length to a competition with and without a structured warm-up combined with passive heat retention, and 2) to explore any relationships to free surfing performance (surfing in which strict competition criteria have not been requested).   We hypothesised that the warm-up and heat retention strategy would elevate core body temperature enabling surfers to enter the water warmer and potentially sustain a higher core body temperature throughout the session.   Furthermore, we hypothesised that performance following the warm-up would be enhanced on waves early in the session when warm-up temperature effects were potentially more marked.

MATERIALS and METHODS

Study Overview

This research adopted a repeated measures pre- and post- design with randomized crossover treatment.   Participants attended an artificial wave pool (UBRN Surf, Victoria, Australia) on several occasions – once for familiarization, once under 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; therefore, 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.   For a subset of participants, performance on their first two waves and their tenth wave was scored under both experimental and control conditions by two Australian State level qualified surfing judges (though they were not told they were being scored and they were free surfing).   Consequently, core body temperature under experimental conditions was compared to core body temperature under control conditions for all

participants; and performance, using scoring criteria, was also compared between conditions but for a subset of participants only.

Participants

Thirty-four participants (n = 20 males; n = 14 females) were recruited to this study.   The mean (± SD) age, height and weight for the male participants was 25.8 ± 10.6 years, 176.8 ± 7.5 cm, and 71.6 ± 10.2 kg respectively, and for females it was 34.9 ± 11.4 years, 167.1 ± 6.1 cm, and 60.7 ± 4.4 kg respectively.   All participants ranged from advanced surfers (i.e., they were capable of executing aerial maneuvers, and competitive at state level in Australia) down to intermediate level recreational surfers (i.e., could execute maneuvers considered one to two 'levels' down from advanced). Fourteen of the surfers were goofy footed (i.e., they stood on a surfboard with right foot forward), and 20 surfed with a natural stance (i.e., they stood on a surfboard with left foot forward).   The subset of participants who were scored by the qualified judges (n = 19) were all advanced level surfers. Of the subset of participants, 15 were male, four were female, nine were goofy footed, and ten were natural.   The mean (± SD) age, height, and weight for the males in subset of the sample was 20.0 ± 6.8 years, 176.1 ± 7.7 cm, and 67.9 ± 9.1 kg respectively, and for the females in this subset of the sample it was 32.4 ± 14.2 years, 164.5 ± 5.3 cm, and 60.0 ± 0.1 kg respectively.

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, at least 24 hours apart, but no more than 72 hours apart, participants attended the wave pool at approximately 7:00 am and swallowed an activated 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.   Survival blankets are low-weight, low bulk blankets made of thin plastic heat-reflective sheeting.   The warm-up was similar to that described elsewhere [24], and thus 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.   The order of days whereby participants undertook a land-based warm-up prior to entering the wave pool vs. preparing as they normally would was randomized per participant.   The wave pool water temperature was 13 degrees Celsius, and participants wore full length arm and leg wetsuits of at least 2 mm neoprene foam thickness. Core body temperature was analyzed from 8:20am to 9:40am on both experimental and control days, and data was compared.   A schematic of the research protocol can be seen in Figure 1.
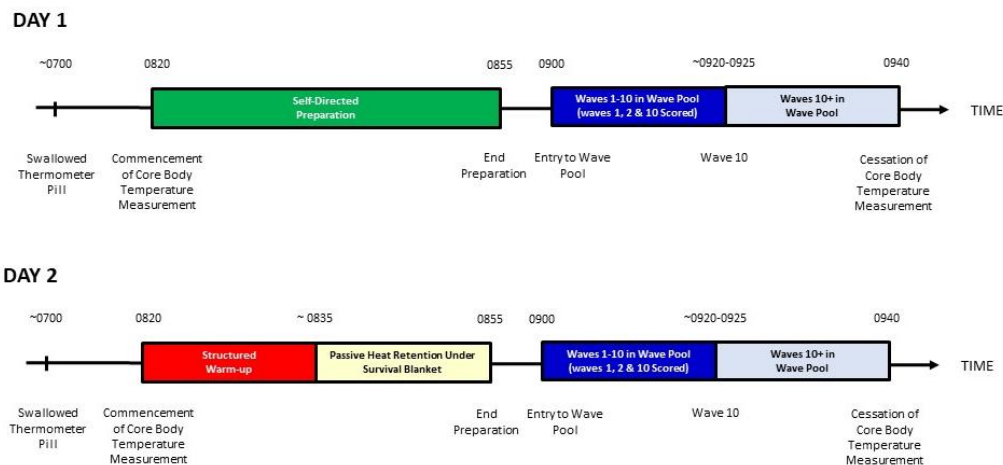
Figure 1. Schematic of research protocol. Note, whether participants completed session 1 or session 2 first was randomized.   Both sessions were completed greater than 24 hours between each other, but no more than 72 hours.

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 eCelcsius Performance Monitor (BMedical, Paris, France) and downloaded to ePerformance Manager (BMedical, Paris, France) and exported to Microsoft Excel for later analysis.

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 with the first being an 'intermediate' level wave, for warm up purposes, and the second and tenth waves being 'advanced turns' level waves.   Furthermore, wave 10 was always completed approximately 20 minutes after wave 2 (i.e., in 20 minutes participants surfed nine waves).   For the intermediate level wave, the wave face height was 1.0 to 1.5 m.   For the advanced turns wave, the wave face height was 1.6 to 2.0 m.   For both wave types, the wave length was 12 to 16-seconds.   For waves one, two and ten participants were scored for if they successfully 'popped-up' on the wave (yes/no).   For waves two and ten only they were also scored for, quality of entry (scale of three to five with increments of 0.5 and a high score being favorable), quality of each maneuver (scale of zero to ten with increments of 0.5 and a high score being favorable), and if they completed one, two or three maneuvers.   Finally, an overall score was established across the entire wave for waves two and ten from 'pop-up' to exit (scale of zero to ten with increments of 0.5 with a high score being favorable).   Overall score was awarded in accordance with standard surfing Australia judging criteria [25], which was judges perceptions of 'flow', 'speed', 'style', 'power' and 'progression' (i.e., innovation and risk of maneuver on wave).   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).   Thus, scoring data was largely categorical in nature.

Statistical Analysis

A linear mixed model with the dependent variable being temperature change from baseline (i.e., start of warm-up), considering time (i.e., end of active warm-up, end of passive warm-up, wave pool entry, approximate time for wave 10, and end of session) and condition (i.e., control, warm-up) as fixed effects, and the participant as a random effect.

For the subset of participants' whose data was analyzed for performance, descriptive data was initially explored. Thereafter, given data was somewhat categorical in nature, non-parametric statistical analysis was performed to establish whether a difference for any scoring variables where present for entry score, maneuver scores, and overall scores using a Friedman's test. Where a significant difference was indicated, separate Wilcoxon's were performed on all possible combinations to establish where the significant differences exist.

RESULTS

The overall performance for the model exploring core body temperature as per R-squared was 0.55. Statistically significant main effects were present for time ($p < 0.001$) and condition ($p = 0.006$), but no statistically significant interaction effects were present for time and condition. Post-hoc analysis revealed a main effect for condition where control had a lower temperature change compared to warm-up as an effect across entire surfing session ($p = 0.006$). For the main effect of time, there were statistically significant temperature changes between the end of the active warm up, end of passive warm-up and wave pool entry to the approximate time of wave 10 and the end of the session (see Figure 2).

For scoring metrics, as can be seen in Table 1, descriptive statistics reveal less people execute maneuvers on later waves, and it appeared that participants were less likely to complete as many maneuvers as possible on later waves. Furthermore, the Friedman test showed a significant difference for 'entry score' (χ [2] (3) = 7.96, $p = 0.04$). Wilcoxon analyses revealed that entry score under warm up conditions for wave two was better than wave10 under warm-up conditions ($Z = 2.11$, $p = 0.03$), although wave 10 was not significantly different across treatments. Interestingly, entry score for wave two under was better under warm-up conditions ($Z = 2.30$, $p = 0.02$). No other statistically significant observations were made, although trends as in Table 1 suggest a slight favorability across all criteria in the warm-up condition.
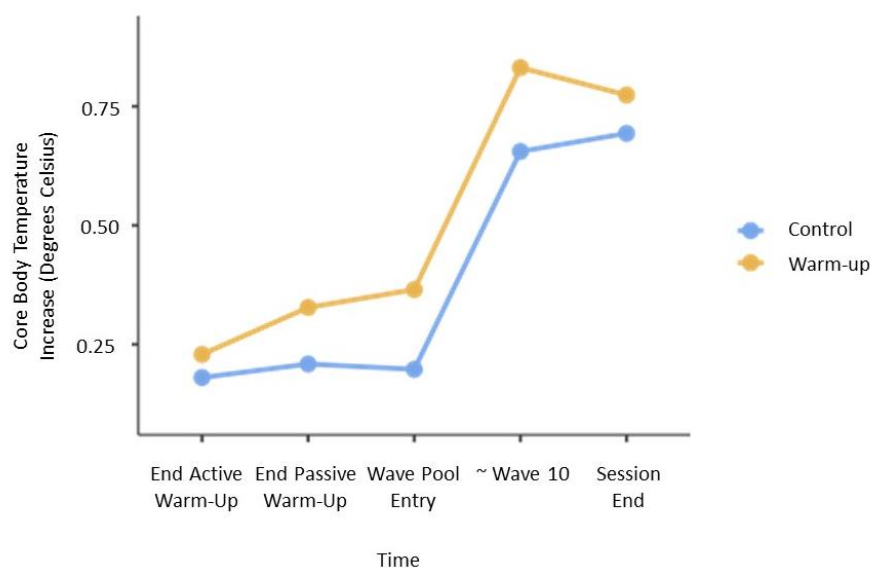
Figure 2. Mean core body temperature over time under control conditions vs. warm up conditions.

Table 1. Summary of surfing performance with or without a structured active warm-up with passive heating. Total number of participants = 19.

	Wave 1 (median ± IQR)*	Wave 2 (median ± IQR)*	Wave 10 (median ± IQR)*
Number of Participants Who Popped-Up Onto the Wave			
Warm-Up	19	19	19
No Warm-Up	18	19	17
Entry Score			
Warm-Up		3.0 ± 0.5	2.0 ± 1.0[†‡]
No Warm-Up		3.0 ± 1.0	2.0 ± 2.0
Number of Participants Who Executed One Manoeuvre on The Wave			
Warm-Up		19	17
No Warm-Up		18	12
Score for First Manoeuvre			
Warm-Up		3.0 ± 1.0	2.0 ± 1.0
No Warm-Up		3.0 ± 2.0	2.0 ± 1.0
Number of Participants Who Executed Two Manoeuvres on The Wave			
Warm-Up		14	9
No Warm-Up		13	7
Score for Second Manoeuvre			
Warm-Up		3.5 ± 2.5	2.0 ± 1.0
No Warm-Up		3.0 ± 3.0	3.0 ± 1.0
Number of Participants Who Executed Three Manoeuvres on the Wave			
Warm-Up		8	6
No Warm-Up		7	0
Score for Third Manoeuvre			
Warm-Up		3.5 ± 2.0	2.5 ± 2.5
No Warm-Up		2.0 ± 2.5	n/a
Overall Score			
Warm-Up		4.0 ± 3.0	3.0 ± 1.0

No Warm-Up	3.0 ± 2.0	3.0 ± 2.0

NB. * = only shown where we are not presenting the count of the variable (e.g., we are not presenting median ± IQR when showing the number/count of people popping up onto the wave). n/a = no participants surfed this wave. † = significantly lower than score on wave 2 under warm-up conditions. ‡ = significantly lower than score on wave 2 when no warm-up was completed.

DISCUSSION

The primary purpose of this work was to explore core body temperature changes in surfers with and without a structured warm-up combined with a passive heat retention strategy (wrapping post active warm-up in a survival blanket). Secondary to this, in a subset of participants who were advanced surfers, we examined whether warm-up influenced performance criteria across free surfing. Our results showed a clear thermal advantage to undertaking an active warm-up combined with passive heat retention strategy prior to surfing. Specifically, we saw that the warm-up protocol resulted in consistently high core body temperature changes compared to baseline versus control conditions. Furthermore, this was maintained across the entire pool session. Across the session both treatments (control and warm-up) showed warming-up further, a product of paddling and surfing likely combined with the effects of a wetsuit. A well-designed wetsuit with combination of 3/2mm thickness (i.e., chest and back panels of wetsuit made of 3 mm neoprene foam, whereas limb panels are made of a 2 mm neoprene foam) will almost certainly facilitate heat retention. Finally, and secondary to the thermal effect, our data suggests performance in free surfing may be slightly enhanced following the warm-up.

Free surfing is characterized by the surfer's freedom to choose maneuvers, length of ride, taking risk, having fun etc., and not be bound to any scoring criteria. However, it is possible to characterize each ride using standard performance criteria with the expectation that lower scores may be observed (participants are less concerned in trying to achieve standardized criteria). Hence, we utilized standard surfing Australia judging criteria applied by two independent blinded judges to observe if any performance data trends emerged. At a descriptive level across all criteria, post-warmup waves scored slightly higher. In particular, pop-ups were more likely and entry score, of the pop-up, on wave two was higher as were the number of maneuvers following warm-up. In addition, variation across performance scores following warm-up was less than in control (i.e., interquartile range was lower under warm-up conditions versus control). Wave ten performance was slightly less than wave two, possibly reflecting some fatigue. Certainly catching nine waves in 20 minutes is likely to have been physically challenging. In "free" surfing, surfers will often go longer on waves past the point where they get best scores so fatigue may have been more than would have been observed in a directed competitive scored situation. Speculation is difficult given the open end of what surfers perceive in free surfing, however the results tantalizing suggest that warm-up did affect aspects of performance early in the surf session. This is consistent with other data around performance effects of warm-up [16,21,26]. The lack of clear effect by wave ten does not negate this potential benefit as the warm-up treatment was not in any-way penalized relative to the control treatment. Is it unknown if injury risk was reduced, however as warmth has been suggested as ameliorating risk in land-based sport [15], this may be an additional potential benefit.

An extension of this work would be the converse research in a very hot and humid environment where surfing can also often occur; in other sports previous work has suggested precooling to be beneficial to performance mainly due to reducing endurance fatigue [27]. However, in sports involving a benefit from early power availability the innovative combination of both warming (legs) and cooling torso may offer benefits that exceed either treatment alone [21], something worthy of further surf performance research. Thus, the results from this study are certainly provocative to suggest further work should be undertaken under surfing competition conditions where surfers are under onus to perform to judged criteria. Moreso the results speculatively suggest even in recreational free surfing there may be advantages to the warm-up protocols in terms of ability to

catch waves, stay on waves and get more manoeuvres (likely equating to more fun, a major goal of free recreational surfers).

Numerous other studies have shown the use of passive heat maintenance, such as survival blankets, can maintain and even add to body heat from active warm-ups [16,28,29]; and data herein supports the same in surfing. Often warm up needs to be time separated from actual competition start and in surfing anecdotally it is popular to sit and analyse waves immediately before water entry. The addition of a passive warming technology from our study appears ideal to assist in heat maintenance under such conditions. However, it is worth noting that thermal comfort and individual perception is another interesting factor which can influence clothing choice; for example, research has showed synthetic garments enhance comfort, thermoregulatory it sense can sometimes trump performance based choices in terms of adoption of a practice [30,31]. As such, factors other than performance gains may influence likelihood of uptake of passive heating strategies. In terms of the outcomes speculated for free surfing and recreational surf markets clothing designs incorporating comfort, fashion and appropriately designed and tested warmth retention may be useful.

While this study produced some interesting findings, the results should not be considered without their limitations. The main being that thermometer pills were swallowed relatively soon to when experimental measurement started. Research suggests that thermometer pills should be swallowed near six hours prior to experimental measurement so they can lodge in the intestines, not stomach, and not be subject to rapid changes of temperature due to consumption of food and drink [32]. However, recent work has shown that, if unaffected by such confounding factors, then thermometer pills can still accurately measure core body temperature [32]. Another limitation was the scoring method adopted for overall score applied to a free surfing format; given overall score considered performance across the whole wave, and not all participants complete three maneuvers on each wave, a person who only complete one maneuver, for example, may have scored disproportionately high or disproportionately low. Whereas a participant who complete three maneuvers on each wave is likely to have been scored more accurately, and achieving more scoreable maneuvers would be something surfer would aim for in a competitive scenario (as opposed to maximum fun in free surfing). Nonetheless, it should be noted that for participants who execute two or more maneuvers on each wave, no statistically significant difference in performance between maneuver one, maneuver two and maneuver three was typically observed; as such, scoring and performance was likely reasonably robust, and it may still be argued that some interesting trends were observed. It should also be noted that, despite them being lower after warm-up versus control, the relatively high interquartile ranges suggest some may have been 'better' responses to the warm-up intervention than others. Across our sample we had both gender and broad BMI differences. We did not attempt to tease these out as our study was focused on a broad sample effect, but obviously doing so in a further study could be insightful. Finally, it should be acknowledged that the frequency of waves was far greater than what would we be expected in real world environment. However, our arguments would largely be unaffected by this.

CONCLUSIONS

A land-based active warm-up combined with passive heat retention (e.g., being wrapped in a survival blanket) has a clear benefit to heat attainment and retention in surfers. Furthermore, our results suggest that surfing performance may be enhanced by this protocol; and, speculatively, injury risk may decline. The outcomes of this study has implications for surfing performance in recreational and competitive settings, as well as product design (i.e., land-worn heat retaining garments, wetsuit etc.).

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data for this study is not publicly available due to guidelines from the approving institutional review board.

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Conflicts of Interest: The authors declare no conflict of interest.

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