Effect of Post-Warm-Up Three Different Duration Self-Selected Active Rests on 100 Meter Swimming Performance: Preliminary Findings

Denizhan Türkmen¹, Erkan Günay², Çağdaş Güdükü³, Adile Öniz⁴, Cem Ş. Bediz⁵

Affiliations: ¹Institute of Health Science, Dokuz Eylül University, Izmir, Turkey, ²Faculty of Sport Sciences, Celal Bayar University, Manisa, Turkey, ³Faculty of Medicine, Department of Biophysics, Dokuz Eylül University, Izmir, Turkey, ⁴Faculty of Health Sciences, Near East University, Nicosia, Cyprus, ⁵Faculty of Medicine, University of Kyrenia, Kyrenia, Cyprus.

Correspondence: E. Günay, Faculty of Sport Sciences, Celal Bayar University, Manisa, Turkey. E-mail: erkanswim@gmail.com

Abstract
The question of when the optimal effect of warm-up is reached after the warm-up phase in swimming competitions is still not fully elucidated. The purpose of this study was to see how self-selected active rest in three different duration periods affected 100-m maximum swimming performance. Eight well-trained elite swimmers (6 males and 2 females, mean age: 17.2 ± 3, mean 616 FINA points) were included in the study. After the participants completed a standard warm-up consisting of dryland-based dynamic warm-up (10-min) and in-water warm-up protocols (1200-m / ~25-min) in 3 different sessions, they observed different transition phase periods (15, 30 and 45-min) with standard clothes in their maximum heart rate of 30% and self-selected movement forms (stretching, walking, etc.) completed by active rest. Subsequently, swimmers carried out the 100-m maximum time-trial swim test using their main stroke. Tympanic temperature (T\text{tympanic}), forehead temperature (T\text{forehead}), heart rate (HR), rating of perceived exertion (RPE), and maximal 100-m-time-trial (TT) were recorded during all sessions. Measurements were evaluated in repeated measures ANOVA. Delta (Δ) calculation was used to score changes and strengthen the analysis. The 100-m time-trial demonstrated a trend of improvement in 30-min active rest (p=0.037). In addition, there was no difference between rest times in T\text{forehead}, T\text{tympanic}, HR, and RPE conditions (p>0.05). The 30-min active rest interval improved 100-m swimming performance by 1.6% and 0.8% compared to 15-min and 45-min active rest. The positive effect of pool warm-up can be maintained for up to 30 minutes with self-paced active rest.

Keywords: Active Rest, Thermoregulation, Sprint Swimming Performance, Thermal Imaging

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Introduction
Warm-up protocol models preceding competitions and training have become a popular topic for researchers and coaches (McGowan et al., 2015; Neiva et al., 2017). Engaging in a warm-up routine before physical activity has many positive physiological and metabolic effects on performance. For instance, it reduces the viscous resistance of muscle, increases nerve conduction velocity (Pearce et al.,
transformation duration for improved swimming performance (Toubekis et al., 2008). For example, McGowan et al. (2016) reported that during the 30-min transition phase, active rest had a better effect on 100-m swimming performance than passive rest. In another study, Dalamitros et al. (2018) demonstrated that a dynamic stretching routine or a power exercise circuit had better performance in 50-m swimming performance than in passive conditions.

However, these active rest strategies cannot be used in real racing conditions due to the regulations of competition preparation (equipment) described in the above paragraph and the need for mental preparation in the last minutes before the race. Practically speaking, in real racing conditions during the transition phase, the swimmers would prepare themselves for the race with their prescribed movements, which could increase their motivation and feelings of physical and psychological well-being. Therefore, non-structured or semi-structured movements (stretching, walking, gymnastics, etc.) can be used easily without any specific equipment as a transition phase strategy in competitions.

To the best of our knowledge, previous studies have focused on the effects of different passive rest times during the transition phase on swimming performance. Moreover, no studies have compared the effects of different self-paced active transition phases after warm-up in swimming performances. Therefore, the purpose of this study was to examine the impact of three different durations of self-paced active rest (15, 30 and 45-min) on 100-m swimming performance in competitive swimmers. Also, it aimed to reveal the possible relationship between the thermal responses during active rest periods and swimming performance. We first hypothesized that the duration of active rest would have an impact on swimming performance. Additionally, it was hypothesized that the different active rest durations could have different thermoregulatory responses and could lead to different swimming performances.

**Material and methods**

**Participants**

Eight national and international level competitive swimmers (6 males, 2 females) volunteered to take part in this study (table 1). All swimmers had at least 6 years of experience in competition and performed 40.000 ± 5.000 m per week during 6-8 training sessions. All swimmers had previously participated in national competitions, and their maximum test performances for their strokes corresponded to 616 FINA (2020) scoring points (table 1). All test procedures were conducted during the taper period. Swimmers and their parents were informed of potential risks associated with the study and about experimental designs before all of the tests; they also signed an informed consent form. For this study, all procedures and experimental design were approved by the local Ethics Committee (approval number and date: 2019/01-48, 18.01.2019), and the study was conducted according to the Helsinki declaration.

**Study Protocol**

Each swimmer completed three testing sessions with different active rest times (15-min, 30-min, and 45-min) on 3 different days; these were separated by at least 48 hours. All test sessions were randomized among the swimmers. Sessions took place at the same time of the day (16.00-
19.00) and under similar environmental conditions (pool water temperature of 26.3 ± 2.2°C, air temperature of 24.6 ± 2.3°C, humidity 67.2 ± 12.8%). Swimmers maintained the same training and diet routine, abstained from caffeine intake during the 12 h before each test. Additionally, it was not allowed to test the thermic effect of food consumption before the last two-hours of testing.

In each session, all swimmers completed a warm-up protocol followed by a 100-m-time-trial test (figure 1). The warm-up protocol consisted of two main sections with a 5-min rest between them. Swimmers performed a land-based dynamic warm-up protocol for 10 minutes. This period included dynamic stretching and mobility exercises. In the 5-minutes between dynamic warm-up and water warm-up, swimmers completed preparations for water warm-up and conferred with their coach for the last reminder. After this preparation phase, they carried out a 1200-m (~25-min) standard pool warm-up in the swimming pool (table 2).

Table 1. Participant characteristics

| Participant | Gender | Age (yr) | Height (cm) | Weight (kg) | Main Stroke | 100-m Time* (s) | FINA Points |
|-------------|--------|----------|-------------|-------------|-------------|----------------|-------------|
| 1           | M      | 17       | 187         | 80          | Freestyle   | 53.66          | 663         |
| 2           | F      | 14       | 169         | 56          | Freestyle   | 69.50          | 513         |
| 3           | M      | 21       | 180         | 76          | Breaststroke| 65.78          | 646         |
| 4           | M      | 17       | 183         | 67          | Butterfly   | 57.21          | 647         |
| 5           | F      | 14       | 163         | 50          | Freestyle   | 61.90          | 635         |
| 6           | M      | 18       | 176         | 70          | Freestyle   | 55.99          | 588         |
| 7           | M      | 15       | 176         | 68          | Ind. Med    | 68.50          | 575         |
| 8           | M      | 22       | 180         | 74          | Freestyle   | 53.67          | 667         |
| Mean        |        | 17.2     | 176.7       | 67.6        |             | 616            |             |

* 100-m Time is the best swimming performance time of swimmers in the last year.

Table 2. Standardized pool-warm-up

| Distance (meters) | Content |
|-------------------|---------|
| 400               | Freestyle, free I.M |
| 200               | Kick     |
| 200               | Pulling  |
| 200               | I.M. drill/sw |
| 2x50              | Race-pace rest: 30 s |
| 100               | Easy sw  |
| Total: 1200 m (~25 min) |         |

I.M: Individual Medley. Sw: Swim. S: Second.

After completing the warm-up protocol, swimmers promptly donned their standard clothes (race swimsuit, t-shirts, trousers, socks, and shoes) and performed active rest periods (figure 1). During this period, participants were not allowed to sit or do any movements that could cause neuromuscular activity. They were completed with 30% of maximum heart rate physical load in all active rest sessions with self-selected movements (stretching, walking, gymnastics, etc.) before completing a 100-m-time-trial using their main stroke. However, during the active rest periods of the swimmers, their heart rate controls were regularly checked at 5-minute intervals.

Measurements

This study included evaluation of tympanic (T\text{tympanus}) and forehead (T\text{fronthead}) temperature, heart rate (HR), rating of perceived exertion (RPE), and a 100-m time-trial (TT). All measurement points were demonstrated in figure 1. The tympanic membrane temperature was measured as core temperature using a Braun thermometer (Braun thermoscan IRT 6520, Germany). A clean lens filter was used for each measurement to achieve correct data collection. A thermal imager was used to evaluate changes in skin temperature. The forehead was marked as a reference point in measurements. The thermal imaging camera (FLIR SC305, USA) was mounted at a distance of 1.5 m from the subject. The device had 320x240 pixels at 7.5-13 μm in bandwidth. Heart rate was recorded using fingertip pulse oximeters (Beurer P030, Germany) during active rest sessions. A fingertip pulse oximeter was placed on the thumb of the right hand. Before each measurement of the heart rate, fingers were dried with a towel.

Measuring points of tympanic (T\text{tympanus}) and forehead (T\text{fronthead}) temperature, and HR were recorded as baseline (Base), immediately post-dynamic-warm-up (Post\text{DWU}), immediately post-pool-warm-up (Post\text{PWU}), and immediately pre-100-m-time-trial (Pre\text{TT}). HR was additionally measured at active rest duration every 5 minutes until pre-TT.

The rate of perceived exertion (RPE) was recorded immediately following the 100m time trial (Figure 1). All 100-m-time-trial swim tests were carried out at maximum effort. They were recorded manually by a level 5 qualified coach (member of the Turkish national team) using two digital chronographs (Casio hs-80tw-1df, Tokyo, Japan) at the point where their contact with the wall is most clearly visible. The average value of the two chronographs was recorded. Swimmers started the time trials with a dive start from the starting blocks to simulate competitive race condi-
tions. For high motivation and best performance, all swimmers completed performance tests in their main strokes. In this context, five swimmers completed the freestyle technique, one swimmer the butterfly technique, one swimmer the breaststroke technique, and one swimmer the medley technique during test sessions. Immediately following each 100-m-time trial, RPE was recorded using a 10-point Borg scale.

Statistical analysis

The results are presented as mean ± SD. All statistical analyses were carried out using SPSS software (version 24; SPSS Inc., Chicago, USA). The distribution of dependent data was checked using the Shapiro–Wilk test. Measurements were evaluated with two factors: ANOVA (4x3, measurement points x rest times) to check the session difference in \( T_{\text{tympanic}}, T_{\text{forehead}}, \) and HR. A Delta (\( \Delta \)) calculation was used to score changes and strengthen the analysis. Delta values were calculated by subtracting the post-pool-warm-up data from the pre-time-trial data. Analysis of variance for repeated measures on one-factor analysis of variance (ANOVA) was used to compare the Delta (\( \Delta \)) parameters. To analyze the effect of the 100-m time-trial and RPE, we used one-way repeated measures ANOVA. The sphericity was conducted by Mauchly's test. If sphericity was not violated, Greenhouse–Geisser correction was employed to determine the significance of F-ratios. A Bonferroni confidence-interval adjustment was applied to the pairwise comparison. Effect sizes were determined by calculating partial eta-squared values using SPSS.

Results

100-m-Time-Trial and Rating of Perceived Exertion

The result of the one-way ANOVA revealed a significant interaction between rest times in the 100-m test time (\( p=0.037, \eta^2=0.375 \); table 3). It showed that 30-min active rest (62.65±7.62 s) improved the time trials 1.6% when compared to the 15-min rest (63.66±8.16 s) and, 0.8% when compared to the 45-min active rest period (63.17±8.44). In RPE values, there were no significant effects in three rest times at all measurement points (\( p=0.916, \eta^2=0.013 \); table 3).

Physiological responses

\( T_{\text{forehead}}, T_{\text{tympanic}}, \) and HR raw data were given in table 3. There were significant effect measurement points in \( T_{\text{forehead}} \) (\( p=0.000, \eta^2=\text{high effect} \)) and in \( T_{\text{tympanic}} \) (\( p=0.000, \eta^2=\text{high effect} \)), but there were no significant rest times and measurement points x rest time interaction effects (\( p>0.05 \)).

Figure 2 illustrates the \( T_{\text{forehead}} \) response in the thermal images. \( T_{\text{forehead}} \) decreased similarly during dynamic land warm-up and water warm-up in rest sessions (figure 3). There was a significant difference between PostDWU and PostPWU in \( T_{\text{forehead}} \) measurement points in all sessions (\( p=0.007 \)), but this was not significant between rest times in these measurement points (\( p>0.05 \); figure 3). During the transition phase, \( T_{\text{forehead}} \) increased in all sessions (\( p = 0.01 \)), but there was no significant difference between rest times (\( p>0.05 \)). According to one-way ANOVA in delta calculations (\( \Delta=T_{\text{forehead}, \text{PostPWU}}-T_{\text{forehead}, \text{PreTT}} \)) for \( T_{\text{forehead}} \) there was a significant change in forehead temperature between the rest times (\( \Delta_{15\text{min}}=-2.17, \Delta_{30\text{min}}=-2.92, \Delta_{45\text{min}}=-3.45 ; p=0.015, \eta^2=\text{high effect} \)). When multiple pairwise comparisons were employed, a significant change was found between the 15-min and 45-min active rests (\( p=0.007 \)), while there was
no significant change between 15-min and 30-min (p=0.216), and 15-min and 45-min (p=0.927). Measurements of tympanic temperature were shown in Figure 3. There was a significant decrease between PostDWU and PostPWU in \( T_{\text{tympanic}} \) measurement in all rest times (p=0.001). \( T_{\text{tympanic}} \) increased during the transition phase (p = 0.04), but there was no significant change between rest times (p>0.05; figure 3) and delta values (\( \Delta_{15\text{min}}=-0.65, \Delta_{30\text{min}}=-1.03, \Delta_{45\text{min}}=-1.15; p=0.116, \eta^2=\text{high effect} \)). In HR, there were no significant effects in three rest times at all measurement points (p=0.148, \( \eta^2=\text{high effect} \)).

Discussion

This study examined the effect of post-warm-up 15, 30, and 45-min active rest times on 100-m-time-trial swimming performance. The results of this study showed that the 30-minute active rest time improved the 100-m time trial. This improvement was between 1.6% and 0.8%. In the study of Pyne et al. (2004), it was considered that the chance of medals could be significantly enhanced if the swimmers improved their performance by 1% in the year leading up to the race and an additional increase of 0.4% in the main competition. Therefore, performance improvements in the current study are a remarkable contribution for swimming competitors. In addition, there was no significant effect between rest times in \( T_{\text{forehead}} \) and \( T_{\text{tympanic}} \). Therefore, the acute changes in \( T_{\text{forehead}} \) and \( T_{\text{tympanic}} \) may not have a direct effect on swimming performance.

Active Rest Versus Passive Rest

It is clear that water warm-up improves swimming performance. In studies based on passive rest after water warm-up, Zochowski et al. (2007) demonstrated 1.4% better swimming performance following the 10-min transition phase, compared to 45-min rest time. Similarly, West et al. (2013) reported a 1.5% improvement in swimming performance.

Table 3. Tympanic temperature (\( T_{\text{tympanic}} \)), forehead temperature (\( T_{\text{forehead}} \)), heart rate (HR) raw data at baseline (base), post-dynamic warm-up (PostDWU), post-pool warm-up (PostPWU), pre-time-trial (PreTT); 100-m Time-Trial (TT) and rating of perceived exertion (RPE) raw data at post-time-trial (PostTT), for 15, 30, 45 min rest times

| Rest Times (min) | \( T_{\text{tympanic}} \) (°C) | \( T_{\text{forehead}} \) (°C) | HR | TT (s) | RPE |
|------------------|-----------------------------|-----------------------------|----|--------|-----|
| Base             | 15 | 37.1 ± 0.3               | 36.4 ± 0.4       | 81.6 ± 12.7 | -   |
|                  | 30 | 37.07 ± 0.7              | 36.5 ± 0.5       | 87.2 ± 14   | -   |
|                  | 45 | 37.1 ± 0.2               | 36.5 ± 1.2       | 94.6 ± 15   | -   |
| PostDWU          | 15 | 37.15 ± 0.2              | 35.03 ± 0.5      | 98.1 ± 14.5 | -   |
|                  | 30 | 37.05 ± 0.2              | 35.25 ± 0.8      | 103.5 ± 12.7 | -   |
|                  | 45 | 37.03 ± 0.3              | 35.1 ± 1.4       | 109.7 ± 10.6 | -   |
| PostPWU          | 15 | 35.09 ± 0.9              | 33.05 ± 0.8      | 119.1 ± 11.1 | -   |
|                  | 30 | 35.8 ± 0.7               | 32.4 ± 0.9       | 117.3 ± 15.5 | -   |
|                  | 45 | 35.9 ± 0.5               | 32.6 ± 1.4       | 122.6 ± 23.1 | -   |
|                  | 15 | 36.6 ± 0.3               | 35.2 ± 0.8       | 99.6 ± 9.2  | -   |
| PreTT            | 30 | 36.7 ± 0.2               | 35.3 ± 0.7       | 95.1 ± 14.3 | -   |
|                  | 45 | 37.06 ± 0.3              | 36.1 ± 0.7       | 103.2 ± 13.1 | -   |
| PostTT           | 15 | -                        | -               | 63.66±8.16  | 8.5±0.5|
|                  | 30 | -                        | -               | 62.65±7.62  | 8.3±1 |
|                  | 45 | -                        | -               | 63.17±8.44  | 8.3±0.9|

All data presented as mean ± SD
following a 20-min passive rest time, compared to the 45-min passive recovery period. Therefore, a short passive rest time between warm-up and competition has been recommended for better performance in swimming. However, since the swimmers must be prepared for the race and must notify the call room 20 minutes before the race, these short passive rest times are not suitable for the competitions. Hence, the benefits of warm-up in the transition phase need to be maintained for a longer time. Mcgowan et al. (2016) investigated the effects of different transition phase strategies, such as conventional tracksuit top and pants (Control), insulated top with integrated heating elements (Passive), 5-min dryland-based exercise circuit (Dryland), and a combination of Passive and Dryland (Combo) during the 30-min transition phase on 100-meter swimming performance. Dryland and Combo strategies caused 0.7% and 1.1% faster time-trial performances, respectively, and less reduction in core temperature. Similarly, Dalamitros et al. (2018) compared two different dryland active rest strategies to 50m swimming performance during the 30-min transition phase, and found an improvement in the 50-m swimming performance. The Dryland protocols consisted of a dynamic stretching routine or a power exercise circuit. In the current study, active rest periods were compared, and unexpectedly, the improving effects of 30-min active rest time were 1.6% and 0.8% higher than the 15-min and 45-min active rest times, respectively. But these performance improvements were in line with the previous studies. Active rest in addition to the post-warm-up may positively affect the benefits of the warm-up.

The Effect of Active Rests on Swimming Performance

The optimal post-warm-up passive rest time is recommended to be between 5 and 20 minutes (Bishop, 2003; West et al., 2013; Zochowski et al., 2007). These passive rest times cannot be performed in a real competition environment, so they are insufficient between warm-up and race. At least 20 min before their race, swimmers must change their swimsuit and enter the call-room. However, if swimmers stay active in this period, the suggested recovery time may be extended to 30-min (Anthesanos A. Dalamitros et al., 2018; McGowan et al., 2016). This current study demonstrated that when comparing active rest durations (15 vs 30 vs 45-min), subsequent swimming performance after 30-minute rest may reach its peak. These results suggest that the positive effects of warm-up may be maximized up to 30 minutes with low-intensity active rest.

The Effect of Water Temperature on Forehead and Tympanic Temperature

Many studies reported that performance may be related to the concomitant reduction in body core temperature after warm-up. We also could not observe any link between body temperature and swimming performance since body temperature was not measured with an invasive method. During pool warm-up, the core temperature of the body increases only slightly (~0.7°C) (Fujishima et al., 2001; McGowan et al., 2016; Neiva et al., 2017; West et al., 2013) whereas the skin temperature decreases significantly (~4°C) (Jimenez-Perez et al., 2021). In the current study, there was observed an increase in T_forehead and T_tympanic when active rest durations are performed (table 3). We used two non-contact infrared devices (infrared thermography and infrared thermometer) to monitor the body. These devices detect the heat emitted from a surface and directly measure the object’s temperature. In the current study, the forehead and tympanic temperature values increased immediately during the post-pool warm-up relatively compared to the baseline (figure 3). This is most likely since, when the nature of the heat transfer is considered, the heat transfer rate of water is higher than air; this means that faster heat exchange occurs in the water (Fujishima et al., 2001). So, the skin temperature will have a sharp decrease when the swimmers dive into the water (Fujishima et al., 2001; Sagawa et al., 1988). The sharp decreases in skin temperature are due to the clamping of skin temperature to water temperature and may not reflect any true shifts in core temperature in the study, which depend on the duration of the rest (Jimenez-Perez et al., 2021). Therefore, in the water, forehead and tympanic temperatures may have acted as skin temperatures.

The Effect of Water on the Body’s Physiological System

In the current study, there was no significant difference between T_forehead and T_tympanic rest periods in immediately pre-measurement points of 100-m swimming performance. It was observed that the swimmers made rapid skin thermoregulatory adjustments up to 15 minutes, but its speed slowed down after 15 minutes. Cold-induced vasoconstriction in cutaneous blood vessels (Giovanni Tanda, 2018). Thus, blood is retained in the core regions to decrease heat loss from the body (Charkoudian, 2003; Giovanni Tanda, 2018). However, body temperature is compensated by the thermoregulation mechanism and muscle activity. By increasing the skin blood flow again, muscle performance is increased. Therefore, the first 15 minutes may have an important role in the thermoregulation system’s adaptation to land conditions after swimming warm-up. Indeed, besides body temperature, oxygen uptake and heart rate changes during warm-up may have direct effects on swimming performance (Neiva et al., 2014). Although the effect of warm-up on performance may be attributed to temperature-related mechanisms, such as rapid metabolic reactions and increased nerve conduction velocity, it can be concluded that water-based warm-up may not be directly related to body skin temperature changes. Therefore, swimmers need to adapt to aquatic environments and stimulate physiological systems related to performance before the race. There might be numerous underlying mechanisms to explain this topic, but the factor addressing physiological mechanisms affecting warm-up on swimming performance would be one of the further research.

One of the limitations of this study is the fact that the age range of the swimmers is wide. Due to the requirement of participation in the study of 500 FINA points and above and the low number of athletes engaged in swimming, the study was conducted with a rather small number of participants. But since the age range of world record-breaking athletes is wide, it is reasonable to suggest that the results of this study are applicable. Finally, the lack of more valid devices, such as ingestible telemetric body core temperature sensors (ingestible thermal pills), for monitoring core temperature was a second limitation. Nevertheless, as the tympanic thermometer and thermal imaging use infrared technology, it is important to note that the ambient conditions are similar.
Therefore, the environmental conditions were controlled and stabilized during all test sessions. However, with an ingestible thermal pill, the core body temperature could have been more precisely captured.

The present study revealed the possible effects of active rest times on swimming performance. The 30-min active rest time applied after warm-up, which can be easily adapted to the race conditions, improves the 100 meter swimming performance. Individual differences (such as age, gender, amount of muscle) may affect those performances. Therefore, we suggest that the coaches and swimmers should observe the best effective rest-time duration by making trials during the training period to determine which time duration can fit the swimmers’ performance after the warm-up.

Conclusions

One of the key findings of this study was that the 100-m swimming performance was improved with a 30-min self-paced active rest time. When the nature of the competitions was considered, swimmers need sufficient time to prepare for the race and have to report to a call room 20-min before the start of their race sessions. This information showed that the transition phase duration with low-intensity active rest can extend up to 30 min after warm-up. In addition, our results demonstrated that $T_{\text{temp_e}}$ and $T_{\text{temp_h}}$ had similar track records and did not have a direct effect on swimming performance.

During international and national swimming competitions, swimmers may need to repeatedly perform maximum effort throughout the same session. Particularly in competitions without a extra warm-up pool, the inability to warm up in the water between races is a problem for second maximal effort. That is why determining the effects of a rest period after a warm-up on a second maximal effort may be regarded as important information for swimmers and coaches.

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References

Athanasiou A, Dalamitos, Athanasios Vagios, Argyris G. Toubekis, Georgios Tsalis, Vicente J. Clemente-Suarez, & Vasiliki Manou. (2018). The effect of two additional dry-land active warm-up protocols on the 50-m front-crawl swimming performance. Human Movement, 19(3), 75–81. https://doi.org/10.5114/hm.2018.76082

Bishop, D. (2003). Warm up I: Potential mechanisms and the effects of passive warm up on exercise performance. Sports Medicine, 33(6), 439–454. https://doi.org/10.2165/00007256-200333060-00005

Burnley, M., Davison, G., & Baker, J. R. (2011). Effects of priming exercise on VO2 kinetics and the power-duration relationship. Medicine and Science in Sports and Exercise, 43(11), 2171–2179. https://doi.org/10.1249/ mss.0b013e31821f26f6

Charkoudian, N. (2003). Skin blood flow in adult human thermoregulation: How it works, when it does not, and why. Mayo Clinic Proceedings, 78(5), 603–612. https://doi.org/10.4065/78.5.603

Cortis, C., Tessitore, A., D’Arbitale, E., Meeusen, R., & Capranica, L. (2010). Effects of post-exercise recovery interventions on physiological, psychological, and performance parameters. International Journal of Sports Medicine, 31(5), 327–335. https://doi.org/10.1055/s-0030-1248242

Faulkner, S. H., Ferguson, R. A., Gerrett, N., Hupperets, M., Hodder, S. G., & Havenith, G. (2013). Reducing muscle temperature drop after warm-up improves sprint cycling performance. Medicine and Science in Sports and Exercise, 45(2), 359–365. https://doi.org/10.1249/ MSS.0b013e31826fba7f

Fujishima, K., Shimizu, T., Ogaki, T., Hotta, N., Kanaya, S., Shono, T., & Ueda, T. (2001). Thermoregulatory responses to low-intensity prolonged swimming in water at various temperatures and treadmill walking on land. Journal of Physiological Anthropology and Applied Human Science, 20(3), 199–206. https://doi.org/10.2114/jpa.20.199

Galbraith, A., & Willmott, A. (2018). Transition phase clothing strategies and their effect on body temperature and 100-m swimming performance. European Journal of Sport Science, 18(2), 182–189. https://doi.org/10.1080/1 7461391.2017.1411528

Giovanni Tanda. (2018). Total body skin temperature of runners during treadmill exercise A pilot study. Journal of Thermal Analysis and Calorimetry, Volume 131(2), 1967–1977. https://doi.org/10.1007/s10973-017-6634-4

Jimenez-Perez, I., Gil-Calvo, M., Vardasca, R., Fernandes, R. J., & Vilas-Boas, J. P. (2021). Pre-exercise skin temperature evolution is not related with 100 m front crawl performance. Journal of Thermal Biology, 98, 102926. https://doi.org/10.1016/j.jtherbio.2021.102926

Kilduff, L. P., West, D. J., Williams, N., & Cook, C. J. (2013). The influence of passive heat maintenance on lower body power output and repeated sprint performance in professional rugby league players. Journal of Science and Medicine in Sport, 16(5), 482–486. https://doi. org/10.1016/j.jsams.2012.11.889

McGowan, C. J., Pyne, D. B., Thompson, K. G., Raglin, J. S., Osborne, M., & Rattray, B. (2017). Elite sprint swimming performance is enhanced by completion of additional warm-up activities. Journal of Sports Sciences, 35(15), 1493–1499. https://doi.org/10.1080/02640414.2 016.1223329

McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. Sports Medicine (Auckland, N.Z.), 45(11), 1523–1546. https://doi. org/10.1007/s40279-015-0376-x

McGowan, C. J., Thompson, K. G., Pyne, D. B., Raglin, J. S., & Rattray, B. (2016). Heated jackets and dryland-based activation exercises used as additional warm-ups during transition enhance sprint swimming performance. Journal of Science and Medicine in Sport, 19(4), 354–358.
Mohr, M., Krustrup, P., Nybo, L., Nielsen, J. J., & Bangsbo, J. (2004). Muscle temperature and sprint performance during soccer matches—Beneficial effect of re-warm-up at half-time. *Scandinavian Journal of Medicine & Science in Sports, 14*(3), 156–162. https://doi.org/10.1111/j.1600-0838.2004.00349.x

Mota, M. R., Dantas, R. A. E., Oliveira-Silva, I., Sales, M. M., Sotero, R. da C., Venâncio, P. E. M., Teixeira Júnior, J., Chaves, S. N., & de Lima, F. D. (2017). Effect of self-paced active recovery and passive recovery on blood lactate removal following a 200 m freestyle swimming trial. *Open Access Journal of Sports Medicine, 8*, 155–160. https://doi.org/10.2147/OAJSM.S127948

Neiva, H. P., Marques, M. C., Barbosa, T. M., Izquierdo, M., & Marinho, D. A. (2014). Warm-up and performance in competitive swimming. *Sports Medicine (Auckland, N.Z.), 44*(3), 319–330. https://doi.org/10.1007/s40279-013-0117-y

Neiva, H. P., Marques, M. C., Barbosa, T. M., Izquierdo, M., Viana, J. L., & Marinho, D. A. (2017). Effects of 10min vs. 20min passive rest after warm-up on 100m freestyle time-trial performance: A randomized crossover study. *Journal of Science and Medicine in Sport, 20*(1), 81–86. https://doi.org/10.1016/j.jsams.2016.04.012

Pearce, A. J., Rowe, G. S., & Whyte, D. G. (2012). Neural conduction and excitability following a simple warm up. *Journal of Science and Medicine in Sport, 15*(2), 164–168. https://doi.org/10.1016/j.jsams.2011.09.001

Pyne, D., Trewin, C., & Hopkins, W. (2004). Progression and variability of competitive performance of Olympic swimmers. *Journal of Sports Sciences, 22*(7), 613–620. https://doi.org/10.1080/02640410310001655822

Sagawa, S., Shiraki, K., Yousef, M. K., & Konda, N. (1988). Water temperature and intensity of exercise in maintenance of thermal equilibrium. *Journal of Applied Physiology (Bethesda, Md.: 1985), 65*(6), 2413–2419. https://doi.org/10.1152/japph.1988.65.6.2413

Sargeant, A. J. (1987). Effect of muscle temperature on leg extension force and short-term power output in humans. *European Journal of Applied Physiology and Occupational Physiology, 56*(6), 693–698. https://doi.org/10.1007/BF00424812

Sarramian, V. G., Turner, A. N., & Greenhalgh, A. K. (2015). Effect of postactivation potentiation on fifty-meter freestyle in national swimmers. *Journal of Strength and Conditioning Research, 29*(4), 1003–1009. https://doi.org/10.1519/JSC.0000000000000708

West, D. J., Dietzig, B. M., Bracken, R. M., Cunningham, D. J., Crewther, B. T., Cook, C. J., & Kilduff, L. P. (2013). Influence of post-warm-up recovery time on swim performance in international swimmers. *Journal of Science and Medicine in Sport, 16*(2), 172–176. https://doi.org/10.1016/j.jsams.2012.06.002

Zochowski, T., Johnson, E., & Sleivert, G. G. (2007). Effects of varying post-warm-up recovery time on 200-m time-trial swim performance. *International Journal of Sports Physiology and Performance, 2*(2), 201–211. https://doi.org/10.1123/ijspp.2.2.201