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

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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 ($T_{tympanic}$), forehead temperature ($T_{forehead}$), 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 $T_{forehead}$, $T_{tympanic}$, 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.,

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2012), accelerates the metabolic reaction, and enhances both the baseline oxygen consumption (Burnley et al., 2011) and post-activation potentiation (McGowan et al., 2015). However, the major contributing factors for these metabolic changes are mostly related to an increase in body temperature (Bishop, 2003). With the beginning of the warm-up (especially for dryland-based sports), core and muscle temperature (Tm) increase and reach a plateau after ~15-min of exercise (Bishop, 2003). After cessation of exercise, muscle and core temperature begin to rapidly decrease (Mohr et al., 2004). But this rapid decrement negatively affects subsequent performance. Sargeant et al. (1987) observed that every 1°C cooling of the muscle temperature resulted in a 3% drop in leg muscle power. Similarly, Faulkner et al. (2013) reported that every 1°C increase in muscle temperature is correlated with a 9% improvement in peak power output. Thus, studies underlined that maintaining body temperature that is raised with a warm-up is important for subsequent performance (Galbraith & Willmott, 2018; Kilduff et al., 2013).

Warm-up protocols in swimming consist of two main parts: dryland and water warm-up. The Dryland session is performed out of the water and includes a general warm-up, dynamic stretching, and may include some resistance (such as theraband) exercises (Neiva et al., 2014). Water warm-up involves low to moderate intensity swimming, kicking and arm pulling, technical and coordination drills, short distance race-pace phase, turning, finish and swimming start combination. There is a cool-down period to conclude the water warm-up; this has several components, such as intensity, duration, and transition phase (Neiva et al., 2014). Out of these factors, the transition phase is defined as the duration of time between warm-up and the start of the competition (McGowan et al., 2015). The researchers reported that during these transitions, the metabolic effects of pool warm-up should be maintained. It has been indicated that shorter passive rest times after post-warm-up increase performance. Such as, when compared to 45-min rest, 10-min (1.5%) (Zochowski et al., 2007) and 20-min (1.4%) (West et al., 2013), passive rest enhanced 200-m freestyle swimming performance. Similarly, Neiva et al. (2014) found that 100-m freestyle swimming performance was 1.12% improved after 10-min compared to a 20-min time gap during passive rest conditions. Based on these findings, increasing the muscle temperature, and starting the race with a higher core temperature were found to be the main mechanisms related to improved performance (Neiva et al., 2014; West et al., 2013). However, these passive rests are not suitable for real competition conditions, because swimmers have to complete tasks such as wearing swimsuits, which keep them active during this period, and spend 20 minutes outside the water in a call room for grouping before the race starts. Therefore, the real-race transition phase may extend up to 30-45 min.

Active rest seems to be more effective on performance due to the change in body temperature (McGowan et al., 2015), faster metabolic recovery (Mota et al., 2017), and an increased feeling of well-being (Cortis et al., 2010). In this context, previous studies reported that active rest strategies, such as dry-land-based exercises (McGowan et al., 2017), dynamic stretching routines (Athanasios A. Dalamitros et al., 2018), and neuromuscular effects (Sarramian et al., 2015), were all used as additional warm-up schemes during transition 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 completed 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-

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Table 1. Participant characteristics

Participant	Gender	Age (yr)	Height (cm)	Weight (kg)	Main Stroke	100-m Time* (s)	FİNA 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.

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 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 ($T_{tympanic}$) and forehead ($T_{forehead}$) 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 ($T_{tympanic}$) and forehead ($T_{forehead}$) temperature, and HR were recorded as baseline (Base), immediately post-dynamic-warm-up ($Post_{DWU}$), immediately post-pool-warm-up ($Post_{PWU}$), and immediately pre-100-m-time-trial (Pre_{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-

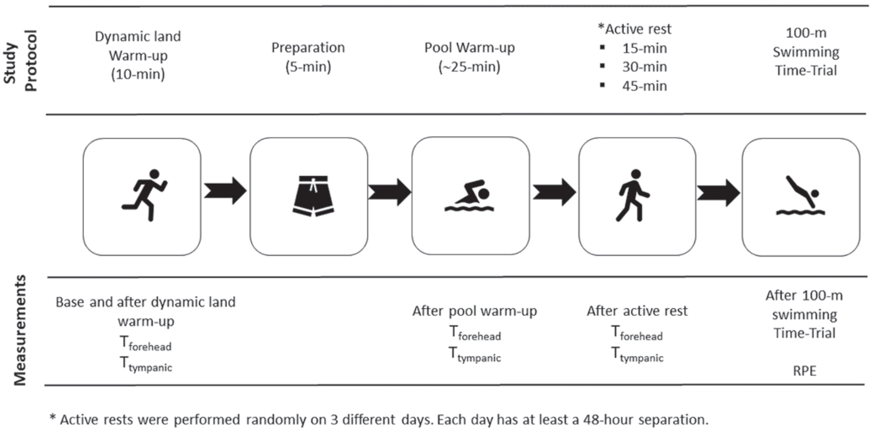

Figure 1. The experimental design and measurement points of the study. $T_{tympanic}$: Tympanic temperature; $T_{forehead}$: Forehead temperature; RPE: Ratings of perceived exertion.

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 $T_{tympanic}$, $T_{forehead}$, and HR. A Delta (Δ) 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 (Δ) 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.

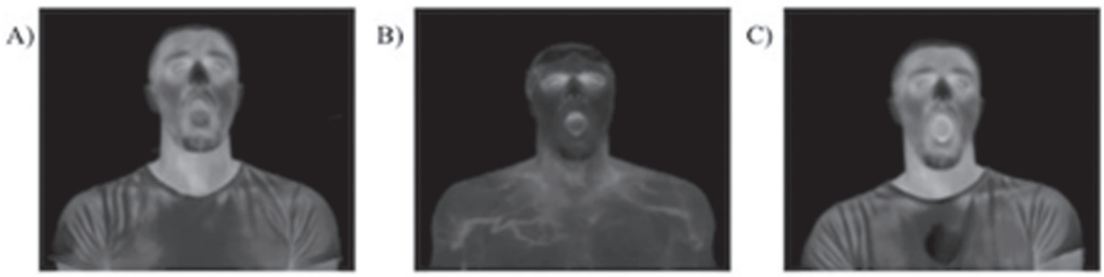

Figure 2. Thermal images of; A) baseline, B) immediately post-pool warm-up, and C) pre-time-trial, during the 30-min rest time. As the color gets lighter, the body temperature increases.

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

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

Figure 2 illustrates the $T_{forehead}$ responses in the thermal images. $T_{forehead}$ decreased similarly during dynamic land warm-up and water warm-up in rest sessions (figure 3). There was a significant difference between $Post_{DWU}$ and $Post_{PWU}$ in $T_{forehead}$ 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, $T_{forehead}$ 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 ($\Delta=Post_{PWU}-Pre_{TT}$) for $T_{forehead}$, there was a significant change in forehead temperature between the rest times ($\Delta_{15min}=-2.17$, $\Delta_{30min}=-2.92$, $\Delta_{45min}=-3.45$; $p=0.015$, η^2=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

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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 $Post_{DWU}$ and $Post_{PWU}$ in $T_{tympanic}$ measurement in all rest times (p=0.001). $T_{tympanic}$ 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 (Δ_{15min}=-0.65, Δ_{30min}= -1.03, Δ_{45min}=-1.15; p=0.116, η^2=high effect). in HR, there were no significant effects in three rest times at all measurement points (p=0.148, η^2=high effect).

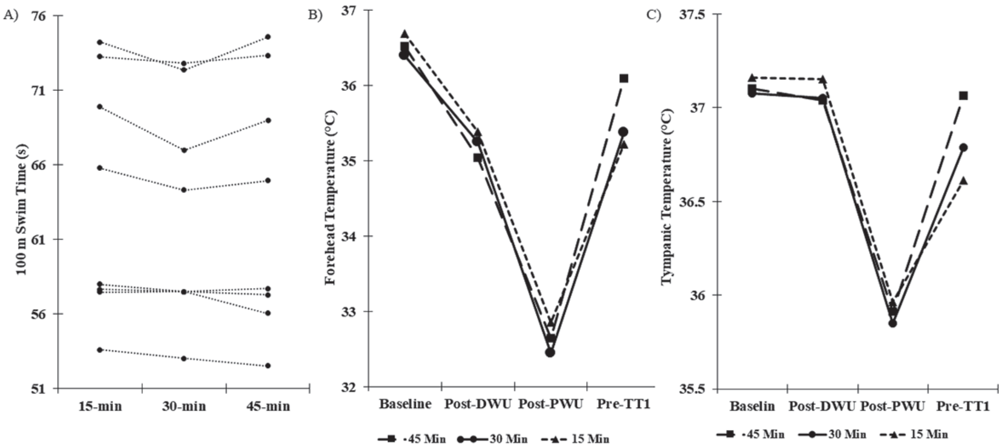

Figure 3. A) Individual 100-m swimming time changes between rest times on time-trial, B) forehead temperature ($T_{forehead}$) and C) tympanic temperature ($T_{tympanic}$) responses throughout to the trials, data presented as mean±SD (n=8).

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 $T_{forehead}$ and $T_{tympanic}$. Therefore, the acute changes in $T_{forehead}$ and $T_{tympanic}$ 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 ($T_{tympanic}$), forehead temperature ($T_{forehead}$), heart rate (HR) raw data at baseline (base), post-dynamic warm-up ($Post_{DWU}$), post-pool warm-up ($Post_{PWU}$), pre-time-trial (Pre_{TT}); 100-m Time-Trial (TT) and rating of perceived exertion (RPE) raw data at post-time-trial ($Post_{TT}$), for 15, 30, 45 min rest times

	Rest Times (min)	$T_{tympanic}$ (C°)	$T_{forehead}$ (C°)	HR	TT (s)	RPE
Base	15	37.1 ± 0.3	36.6 ± 0.4	81.6 ± 12.7	-	-
	30	37.07 ± 0.7	36.4 ± 0.5	87.2 ± 14	-	-
	45	37.1 ± 0.2	36.5 ± 1.2	94.6 ± 15	-	-
$Post_{DWU}$	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 ± 1.4	109.7 ± 10.6	-	-
$Post_{PWU}$	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	-	-
Pre_{TT}	15	36.6 ± 0.3	35.2 ± 0.8	99.6 ± 9.2	-	-
	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	-	-
$Post_{TT}$	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 (Athanasios 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.

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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 $T_{tympanic}$ and $T_{forehead}$ 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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