applied sciences

Article

The Effect of Two Activation Protocols During the Transition Phase: Sprint Swimming Performance

Daniel Paiva [1,2], Luís Rama [3,4], Henrique Neiva [1,2,*], Célia Nunes [5], Jorge E. Morais [6,7] and Daniel A. Marinho [1,2]

1. Department of Sport Sciences, University of Beira Interior, 6201-001 Covilha, Portugal; daniel.paiva@ubi.pt (D.P.); marinho.d@gmail.com (D.A.M.)
2. Research Centre in Sport Sciences, Health Sciences and Human Development (CIDESD), 6201-001 Covilha, Portugal
3. Faculty of Sports Sciences and Physical Education (FCDEFUC), University of Coimbra, Avenida de Conímbriga, Santa Clara, Pavilhão 3, 3040-248 Coimbra, Portugal; luisrama@fcdef.uc.pt
4. Interdisciplinary Center for the Study of Human Performance (CIPER), University of Lisbon, Estrada da Costa, Cruz Quebrada-Dafundo, 1499-002 Lisbon, Portugal
5. Department of Mathematics and Center of Mathematics and Applications, University of Beira Interior, Avenida Marquês D'Ávila e Bolama, 6200, 6201-001 Covilha, Portugal; celian@ubi.pt
6. Department of Sport Sciences, Instituto Politécnico de Bragança, 5300-253 Bragança, Portugal; morais.jorgestrela@ipb.pt
7. Research Centre for Active Living and Wellbeing (LiveWell), Instituto Politécnico de Bragança, 5300-253 Bragança, Portugal

* Correspondence: hpn@ubi.pt

Featured Application

In competition, swimmers may experience prolonged transition phases, which can contribute to a loss of body temperature and reduced readiness before performance. In the present study, a dryland explosive re-warm-up protocol was associated with faster 100 m freestyle performance than the control condition. Because this strategy is easy to implement in different pool settings, it may represent a practical option for sprint swimmers during competition. By contrast, the in-water, race-pace strategy did not significantly improve the main performance outcomes under the present conditions, although it may deserve further investigation in longer-distance events.

Abstract

The transition phase often causes athletes to lose the benefits of warm-up, so this study aimed to assess the effects of two re-warm-up protocols and a control condition without re-warm-up on 100 m freestyle performance and the kinematic variables (stroke length (SL), stroke rate (SR), and stroke index (SI)), subjective perception of effort (RPE), and physiological variables (heart rate (HR), temperature (T), and blood lactate concentration (La^-)). Twenty competitive-level swimmers completed a dryland and water warm-up, followed by a 30 min transition phase and a 100 m freestyle simulation. Over 30 min, each swimmer randomly performed one of three re-warm-up protocols: control (remaining seated), dryland (explosive exercises), and water (race-pace series). The three experimental re-warm-up protocols affected 100 m freestyle performance ($p = 0.019$; $\eta^2 p = 0.189$). Post hoc comparisons showed that dryland was faster than control (−0.68%, $p = 0.009$), whereas no significant difference was observed between water and control (−0.52%, $p = 0.234$). No significant differences were observed between conditions for SR, SL, RPE, or La^-, whereas peak HR was lower in the control. Although water did not significantly improve performance, swimmers reported more favourable sensations during the trial. In conclusion,

Academic Editor: Francesco Cappello

Received: 3 April 2026
Revised: 16 May 2026
Accepted: 18 May 2026
Published: 20 May 2026

the dryland protocol significantly improved 100 m freestyle performance, whereas the water protocol did not produce significant performance benefits under the present conditions.

Keywords: warm-up strategies; sprint performance; swimmers; re-warm-up

1. Introduction

Warm-up is widely accepted within the sporting community for its essential role in preparing the body for intense physical effort and in preventing injury. For this, the warm-up consists of a set of activities performed before training or competition to prepare the athlete for the subsequent physical and psychological demands. In swimming, performance depends on multiple physiological, biomechanical, technical, and psychological factors [1,2], meaning that even slight variations in readiness can significantly influence performance [3,4].

The increase in core body temperature accelerates metabolic reactions, improves nerve conduction and joint lubrication, and reduces muscle viscosity, favouring faster and more efficient muscular contractions and contributing to injury prevention [2,5]. The cold temperature influences athletes' performance; for example, in a drop jump, a 1 °C variation in muscle temperature can result in a 2% to 5% change in performance [6]. These effects are significant in swimming, where thermal dissipation in the aquatic environment can compromise the gains achieved during the initial warm-up [7,8]. Other essential aspects of warm-up include cardiac activation, which improves blood circulation, muscle contraction time, force production, and motor response speed [9]. Muscular efficiency and the force production potential depend directly on adequate neuromuscular preparation [10]. The balance between the intensity and duration of warm-up is critical to avoid under-stimulation or premature fatigue [11]. During competitions, one of the most significant challenges faced by athletes and coaches is the transition phase—the interval between the warm-up and the event, during which muscle temperature and physiological activation can dissipate. To mitigate these negative effects, the concept of re-warm-up arises, whose objective is to maintain the benefits initially gained and to prepare the body for the competitive effort, especially during extended resting periods before competition, namely, between multiple events [10,12].

The psychological dimension of the warm-up and re-warm-up should not be overlooked. These moments allow the athlete to enter the "ideal competitive state", promoting focus, emotional control, and motivation [13]. Even in challenging logistical contexts, engaging in adapted physical activities can help transform anxiety into useful energy for the competition [4].

The warm-up can be carried out through active strategies—such as dynamic exercises, muscle activation, or explosive work—or through passive strategies, such as thermal clothing, saunas, and hot baths. The adopted strategy depends on factors such as available time, intended intensity, environmental conditions, and the athlete's individual characteristics. Strict control of variables such as the rest interval duration, exercise intensity, and event logistics is crucial to ensure effectiveness, avoiding inducing fatigue [10,14,15].

In this sense, understanding the physiological, metabolic, and psychological effects of the warm-up and re-warm-up, as well as the most effective strategies for their implementation, is crucial for optimising swimmers' performance in competitions.

Zochowski et al. [11] studied the effects of two transition phases, 10 and 45 min, on swimmers' performance, showing that a 35 min increase in transition time leads to a loss in performance. Similarly, West et al. [16] also obtained better results in the shorter transition phase when comparing 20 min and 45 min. Although these results may contribute to improving swimmers' performance, most of them do not fit within the typical competitive context, since the transition time between the water warm-up and competition generally ranges from 25 min to 45 min and can exceed 2 h [4,17], leading to the dissipation of the benefits brought by warm-up [11].

There is a need to develop strategies to mitigate the loss of benefits from warm-up or to regain that state of preparedness. In this sense, Cuenca-Fernández et al. [18] created the definition of postactivation performance enhancement (PAPE) as an improvement in the performance of voluntary movements, such as swimming, after a short, intense activity, followed by a brief rest period (7–10 min). This structure fits the actual necessities of the swimmers during the competition, raising doubts about what the best strategies are.

This study aimed to determine if postactivation strategies currently used in competition can cause performance enhancement. Thus, the effects of two re-warm-up strategies and a control condition without re-warm-up were compared in experienced swimmers in a simulated competitive setting. They were developed in collaboration with experienced coaches, based on information from national- and international-level coaches, and replicated as closely as possible the strategies currently used in competition [17]. The dryland re-warm-up seems to be the one that sprinters use more during competitions, which leads us to hypothesise that following the dryland re-warm-up during the transition phase would improve 100 m freestyle performance compared to the other re-warm-ups.

2. Materials and Methods

2.1. Participants

An a priori sample size calculation was performed using G*Power software (version 3.1.9.7; Heinrich Heine University Düsseldorf, Düsseldorf, Germany) for a repeated-measures ANOVA within-factors design. The expected effect size was informed by previous studies in swimmers that used repeated-measures/cross-over designs and reported meaningful performance improvements. Based on this literature, a moderate effect size ($f = 0.30$) was assumed. With an alpha level of 0.05, a statistical power of 0.80, a correlation among repeated measures of 0.50, and a nonsphericity correction of 1.00, the required sample size was estimated at 20 participants. The study involved 20 male volunteer swimmers aged 16–27 years (mean = 18.30 ± 2.77). The participants had an average height of 175.26 ± 6.32 cm and a weight of 66.09 ± 8.899 kg. According to the Participant Classification Framework [19], participants were classified as Tier 3 (Highly Trained/National Level), had 5–17 years of training experience, and competed at national or international levels. The swimmer's level was indicated by 565.1 ± 96.981 points in the World Aquatics 100 m crawl event (long course). To be included in the study, participants had to be men in good health, at least 16 years old, and trained at least 6 times per week. The University of Beira Interior ethics committee approved the study in accordance with the Declaration of Helsinki. Participants were informed about the experimental benefits and risks before signing an informed consent form, and for those under 18, consent was obtained from parents or guardians.

2.2. Experimental Approach to the Problem

In the present study, all participants completed 3 sessions, separated by 24 h each, following a randomised counterbalanced cross-over design. Testing was conducted one week after the main competition of the season, during a recovery period with no intense training loads. The experimental process followed the following structure: "dryland" warm-up, consisting of mobility and dynamic flexibility exercises, individualised, similar to what occurs in competition (10 min); "in water" warm-up of 1200 m, following the proposal by

Neiva et al. [20] (20 to 25 min); transition phase, where athletes were required to change into their competition suits (10 min); re-warm-up (5 min); and call room with tracksuit (15 min), following the recommendations of World Aquatics, and time trial. During the transition phase, all swimmers remained in their competition suits and tracksuits (trunks and T-shirt) and followed the protocol designated for each session.

Sessions 1, 2, and 3 varied by re-warm-up, control, dryland, and water. In the control session, athletes did not perform a warm-up and remained seated for 5 min. In the dryland session, athletes completed 3 sets of 3 repetitions of 2 explosive exercises, with 1 min rest between repetitions, following the adapted protocol proposed by [14] (3× medicine ball (4 kg) throw downs and 3× tuck jumps, with 1 min rest). In the water session, athletes carried out a water warm-up (50 m build-up, 20 m build-up, 20 m race pace, 10 A1, 25 A1, 15 m build-up, 10 m race pace, 50 m A1) every 1.30 min. The overall experimental design is presented in Figure 1.

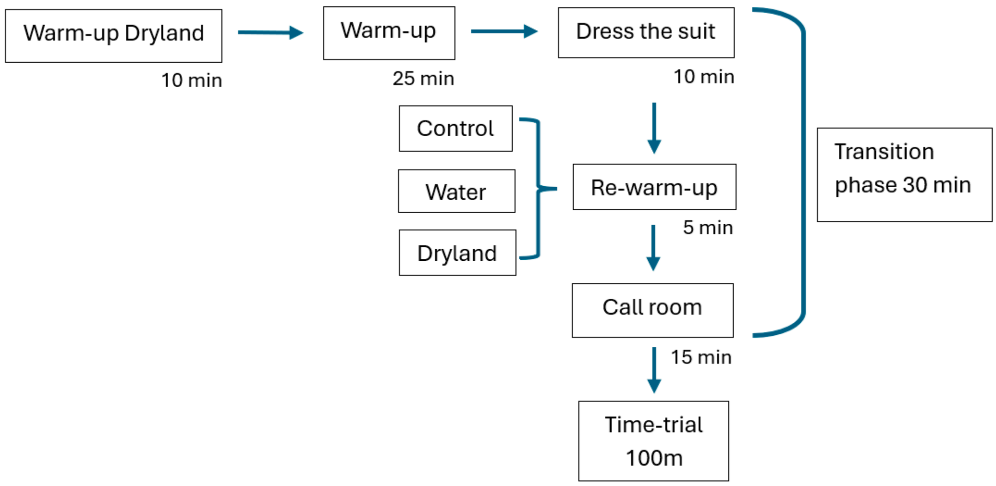

Figure 1. Timeline of project design.

After the 20 min camera call, they performed a time trial of up to 100 m.

The study protocol was carried out in a 25 m pool, with a temperature range of 27 °C to 28.5 °C and an ambient temperature range of 28 °C to 30 °C.

At the end of the experimental protocols, all participants completed an online questionnaire in which they expressed their opinions on the re-warm-up strategies and how they felt during the protocols.

2.3. Trial Test

The times were initially recorded by experienced coaches using a manual stopwatch and were subsequently confirmed through video analysis of the trials. This procedure was adopted to reduce potential timing errors and to improve the consistency of performance assessment. The trials were filmed to obtain start time, turn time, swim time, and kinematic variables (SR, SL, and SI) at 12.5 and 16 m, using 2 Samsung Galaxy S23 Ultra smartphones (Samsung Electronics Co., Ltd., Suwon, Republic of Korea) at 60 fps. Stroke rate (SR) was obtained from video analysis using the stopwatch stroke-rate function by timing 3 complete stroke cycles from the moment the swimmer's hand entered the water. In each lap, the analysis started at the 3rd stroke after the 25 m and 75 m marks. Mean swimming velocity over the analysed section was calculated by dividing the distance covered by the corresponding time. Stroke length (SL) was then calculated as the ratio between swimming velocity and stroke rate, and stroke index (SI) was calculated as the product of swimming velocity and stroke length. Tympanic temperature was measured using a tympanic thermometer (Beurer GmbH, Ulm, Germany), before warm-up, after warm-up, before re-warm-up, after re-warm-up, before the trial, after the trial, and 4 min after the time trial. Capillary blood samples were collected by finger pricking, and blood lactate concentration (La^-) was measured using a Lactate Pro 2 analyser (ARKRAY Inc., Kyoto, Japan), before warm-up, before re-warm-up, after re-warm-up, before the trial, 1 min post-trial, and 4 min post-trial (peak La^- was calculated using the higher of the last two collections). Heart rate was monitored throughout the test using the Polar OH1 (Polar Electro Oy, Kempele, Finland). RPE was assessed using CR10 proposed by Borg [21], which was applied after re-warm-up, before, and after the trial. The timeline of data collection and measurement moments is presented in Figure 2.

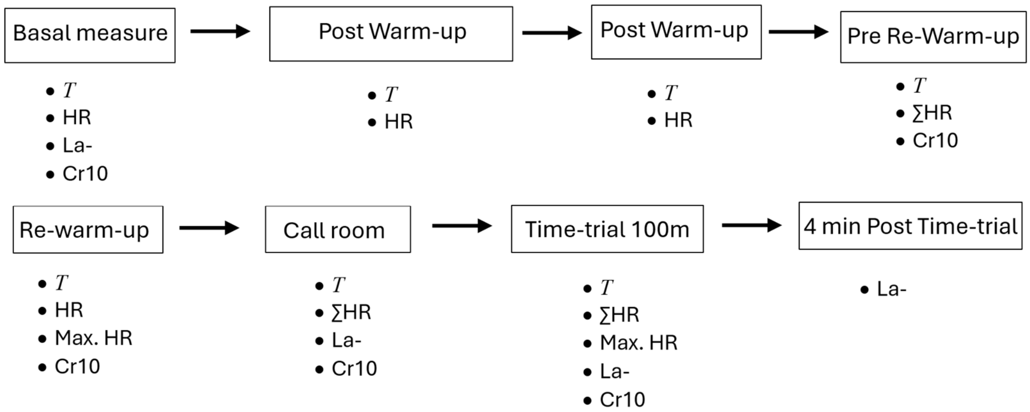

Figure 2. Timeline of data collection.

2.4. Anthropometry

On the day of the first data collection, the anthropometric measurements of the swimmers were taken. Following recommended and standardised protocols [22], the subjects were measured only in underwear, and a single observer collected the data. Height was measured with a stadiometer (Harpenden model 98.603, Holtain Ltd., Crosswell, UK), and body mass was measured with bioimpedance equipment (InBody 770, InBody Co., Ltd., Seoul, Republic of Korea).

2.5. Statistical Analysis

The analyses were conducted using SPSS software (version 29.0.1.0, SPSS Inc., Chicago, IL, USA) with significance set at $p \leq 0.05$. The 100 m freestyle time was considered the primary outcome, whereas the biomechanical, physiological, and perceptual variables were treated as secondary/exploratory outcomes. Bonferroni-adjusted post hoc comparisons were applied within each analysis when appropriate. The Shapiro–Wilk test and Q-Q plots were used to verify the normality of the variables and the residuals. Sphericity was assessed using Mauchly's test for repeated-measures factors with more than two levels. In all cases, the assumption of sphericity was met; therefore, no Greenhouse–Geisser or Huynh–Feldt corrections were required. Whenever the assumptions were met, a two-way repeated-measures ANOVA was conducted between condition (control, water, and dry-land) and moment (50m1 and 50m2; La^-_Pre-trial and La^-_Peak_Post-trial; HR_pre and HR_Max; Temp_Post_Re-warm-up and Temp_pre_trial) as factors. For the 100 m time trial, baseline measures, initial tympanic temperature, initial La^-, and initial heart rate, a one-way repeated-measures ANOVA was used to analyse differences across conditions, as the assumptions were satisfied. Partial $\eta^2 p$ was used as a measure of effect size and interpreted according to the general guidelines [23], although these thresholds were considered only as descriptive references and interpreted with caution, given the repeated-measures cross-over design.

When the required assumptions for a repeated-measures ANOVA were not met (RPE post-re-warm-up, pre-trial, and post-trial), the nonparametric Friedman test was used. Kendall's Coefficient of Concordance (W) was used as a measure of effect size, and the classification criterion adopted was based on previously proposed thresholds [24], (values between 0 and 0.3 indicate a low effect, values between 0.3 and 0.5 indicate a medium effect, and values larger than 0.5 indicate a strong effect).

3. Results

3.1. Baseline Data

Baseline measures were obtained to confirm that participants started each trial under comparable physiological conditions.

There were no significant differences in the baseline values of the variables across the different conditions ($p > 0.05$) (Table 1). Likewise, none of the initial physiological measures differed significantly between conditions, indicating comparable starting conditions across trials: initial temperature ($F = 0.94$, $p = 0.401$, $\eta^2 p = 0.047$), baseline lactate concentration ($F = 0.12$, $p = 0.890$, $\eta^2 p = 0.006$), and initial heart rate ($F = 0.98$, $p = 0.384$, $\eta^2 p = 0.049$). These findings suggest that participants began the trials under similar physiological conditions.

Table 1. Comparisons of baseline data (temperature, La^- and HR) across different conditions.

	Control	**Water**	**Dryland**	**F (p [#1])**	**$\eta^2 p$**
Temperature	36.75 ± 0.39	36.65 ± 0.45	36.69 ± 0.40	0.936 (0.401)	0.047
La^-	2.3 ± 0.68	2.39 ± 0.87	2.28 ± 0.93	0.117 (0.890)	0.006
HR	69.85 ± 14.85	72.45 ± 12.94	69.85 ± 13.25	0.981 (0.384)	0.049

[#1]—One-way repeated measures ANOVA.

3.2. Performance Times

Overall swimming performance outcomes, including total time and split times, are presented below to examine whether the different re-warm-up strategies influenced race performance and pacing.

According to the results presented in Table 2, there was a significant main effect of condition on 100 m performance ($F = 4.44$, $p = 0.019$, $\eta^2 p = 0.189$). Post hoc pairwise comparisons indicated that this effect was attributable to significantly faster 100 m times in the dryland condition compared with the control ($p = 0.009$). No significant differences were observed between control and water or between water and dryland.

Table 2. Comparisons of 100 m time performance across different conditions.

Conditions		**Mean ± SD**	**F (p [#1])**	**η2p**	**Multiple Comparison**	**p [#3]**
100 m	Control	56.36 ± 3.25	4.439 (0.019)	0.189	Control vs. Dryland	0.009 *
	Water	56.07 ± 3.16			Control vs. Water	0.234
	Dryland	55.98 ± 2.96			Dryland vs. Water	1.000

[#1]—One-way repeated measures ANOVA; [#3]—Bonferroni multiple comparison test * $p < 0.05$.

https://doi.org/10.3390/app16105089

According to Table 3, there was a significant main effect of condition on 50 m performance (F = 4.31, p = 0.021, $\eta^2 p$ = 0.185). A significant main effect of trial was also observed, with swimmers performing the second 50 m significantly slower than the first (F = 312.89, mboxemphp < 0.001, $\eta^2 p$ = 0.943). However, the condition × trial interaction was not significant (F = 0.94, p = 0.399, $\eta^2 p$ = 0.047), indicating that the change in performance from the first to the second 50 m was consistent across conditions. Only the control and dryland conditions differed significantly, with the dryland trial producing faster 50 m times (p = 0.011). No significant differences were found between control and water or between water and dryland (p > 0.05).

Table 3. Comparisons of the 1st and 2nd 50 m performance across different conditions.

Conditions	50m1	50m2	Condition		Moment		Condition × Moment		Multiple Comparison p [#3]	
	Mean ± SD	Mean ± SD	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$		
Control	26.99 ± 1.54	29.36 ± 1.80	4.308 (0.021 *)	0.185	312.894 (<0.001 *)	0.943	0.941 (0.399)	0.047	Control vs. Dryland	0.011 *
Water	26.95 ± 1.62	29.12 ± 1.60							Control vs. Water	0.250
Dryland	26.82 ± 1.68	29.16 ± 1.68							Dryland vs. Water	1

[#2]—Two-way repeated measures ANOVA; [#3]—Bonferroni multiple comparison test. * p < 0.05.

3.3. Kinematic Analysis

This section presents the main kinematic variables across conditions and race halves to describe how swimming mechanics and efficiency changed between the first and second 50 m and whether these patterns differed by condition.

3.3.1. Stroke Rate

According to Table 4, no significant interaction between conditions and moments (the first and second 50 m of the race) was found for SR (F = 0.77, p = 0.171, $\eta^2 p$ = 0.089). The SR in the second 50 m was significantly lower than in the first 50 m (F = 10.12, p = 0.005, $\eta^2 p$ = 0.348). No significant differences were found across the conditions (F = 1.85, p = 0.469, $\eta^2 p$ = 0.039).

Table 4. Comparisons of the SR of the 1st and 2nd 50 m across different conditions.

Conditions	50m1_SR	50m2_SR	Condition		Moment		Condition × Moment	
	Mean ± SD	Mean ± SD	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$
Control	49.09 ± 3.25	47.20 ± 4.32	1.85 (0.469)	0.039	10.12 (0.005 *)	0.348	0.77 (0.171)	0.089
Water	48.18 ± 3.47	47.20 ± 3.35						
Dryland	49.02 ± 3.66	47.19 ± 4.32						

[#2]—Two-way repeated measures ANOVA; * p < 0.05; 50m1_SR, stroke rate 1st 50 m; 50m2_SR, stroke rate 2nd.

3.3.2. Stroke Length

As shown in Table 5, no significant interactions were found between the conditions and the moments (first and second 50 m of the race) for SL (F = 1.19, p = 0.316, $\eta^2 p$ = 0.059). The SL in the second 50 m was significantly shorter than in the first 50 m (F = 30.78, p < 0.001, $\eta^2 p$ = 0.618). No statistically significant differences were found across the conditions (F = 1.46, p = 0.246, $\eta^2 p$ = 0.071).

Table 5. Comparisons of SL of 1st and 2nd 50 m across different conditions.

Conditions	50m1_SL	50m2_SL	Condition		Moment		Condition × Moment	
	Mean ± SD	Mean ± SD	F (p #2)	η^2p	F (p #2)	η^2p	F (p #2)	η^2p
Control	2.28 ± 0.20	2.19 ± 0.23	1.457 (0.246)	0.071	30.782 (<0.001 *)	0.618	1.189 (0.316)	0.059
Water	2.33 ± 0.20	2.20 ± 0.19						
Dryland	2.30 ± 0.21	2.20 ± 0.22						

#2—Two-way repeated measures ANOVA; * $p < 0.05$; 50m1_SL, stroke length 1st 50 m; 50m2_SL, stroke length.

3.3.3. Stroke Index

As shown in Table 6, no significant interactions were found between the conditions and the moments (first and second 50 m of the race) regarding SI (F = 0.50, $p = 0.611$, $\eta^2p = 0.026$). The SI in the second 50 m was significantly lower than in the first 50 m (F = 243.81, $p < 0.001$, $\eta^2p = 0.928$). No significant differences were observed between conditions (F = 3.11, $p = 0.056$, $\eta^2p = 0.140$), although the control condition presented the lowest mean SI values.

Table 6. Comparisons of the SI of the 1st and 2nd 50 m across different conditions.

Conditions	50m1_SI	50m2_SI	Condition		Moment		Condition × Moment	
	Mean ± SD	Mean ± SD	F (p #2)	η^2p	F (p #2)	η^2p	F (p #2)	η^2p
Control	4.25 ± 0.57	3.76 ± 0.56	3.105 (0.056 **)	0.140	243.809 (<0.001 *)	0.928	0.500 (0.611)	0.026
Water	4.35 ± 0.59	3.80 ± 0.49						
Dryland	4.31 ± 0.57	3.80 ± 0.52						

#2—Two-way repeated measures ANOVA; * $p < 0.05$; ** $p < 0.1$; 50m1_SI, Stroke index 1st 50 m; 50m2_SI, Stroke index 2nd.

3.4. Physiological Variables

3.4.1. La^-

As observed in Table 7, no significant interaction between conditions and moments (pre-trial and post-trial) was observed for the La^- variation (F = 1.71, $p = 0.195$, $\eta^2p = 0.082$). A significant effect was found in the variation in La^- between moments (F = 374.39, $p < 0.001$, $\eta^2p = 0.952$), with higher values in the post-trial. No significant differences were found across the conditions (F = 1.49, $p = 0.238$, $\eta^2p = 0.073$).

Table 7. Comparisons of La^- pre-trial and La^- peak post-trial across different conditions.

Conditions	La^-_Pre-Trial	La^-_Peak_Post-Trial	Condition		Moment		Condition × Moment	
	Mean ± SD	Mean ± SD	F (p #2)	η^2p	F (p #2)	η^2p	F (p #2)	η^2p
Control	2.77 ± 1.26	14.05 ± 3.47	1.489 (0.238)	0.073	374.386 (<0.001 *)	0.952	1.706 (0.195)	0.082
Water	2.44 ± 0.97	13.78 ± 2.80						
Dryland	2.67 ± 1.35	14.87 ± 2.92						

#2—Two-way repeated measures ANOVA; * $p < 0.05$.

3.4.2. La^- Net

Table 8 indicates that no significant differences were observed between the control, water, and dryland conditions (F = 1.16, $p = 0.323$, $\eta^2p = 0.058$), indicating that the La^- Net response did not differ across the three experimental conditions.

Table 8. Comparisons of La^- Net across different conditions.

	Control	Water	Dryland	F (p [#1])	$\eta^2 p$
La^- Net	10.97 ± 3.74	11.34 ± 2.75	11.90 ± 2.85	1.164 (0.323)	0.058

[#1]—One-way repeated measures ANOVA, La^- Net (La^- peak − La^- pre-trial).

3.5. RPE

The results presented in Table 9 showed that post-re-warm-up RPE did not differ significantly across conditions (p = 0.054), with a small effect size (Kendall's W = 0.146). Similarly, pre-trial RPE showed no significant differences among conditions (p = 0.215), with a small effect size (Kendall's W = 0.077), indicating minimal variation in perceived exertion before the start of the trial.

Table 9. Comparisons of RPE post-re-warm-up, pre-trial, and post-trial across the different conditions.

	Conditions	Mean ± SD	Median	χ^2	p [#4]	Kendall's W
Post-re-warm-up	Control	2.25 ± 1.12	2	5.833	0.054	0.146
	Water	2.90 ± 0.91	3			
	Dryland	2.90 ± 1.21	3			
Pre-trial	Control	1.83 ± 1.37	1	3.073	0.215	0.077
	Water	2.15 ± 1.42	2			
	Dryland	1.75 ± 1.02	1			
Post-Trial	Control	8.05 ± 1.05	8	1.227	0.541	0.031
	Water	8.25 ± 0.97	8			
	Dryland	8.15 ± 1.09	8			

[#4]—Friedman test.

3.6. Heart Rate

The values reported in Table 10 show that the interaction between conditions and the HR collection moments (HR pre and HR max) was not statistically significant (F = 1.50, p = 0.235, $\eta^2 p$ = 0.073). A significant effect was observed in HR variation, with higher values during the trial than at the pre-trial moment (F = 420.56, $p < 0.001$, $\eta^2 p$ = 0.957). The effect of the conditions was significant (F = 5.45, p = 0.008, $\eta^2 p$ = 0.223), indicating differences across at least two conditions. The multiple-comparison analysis showed a difference between the water condition and the control (p = 0.005), with higher HR values in the water condition. Although the difference is not significant, the values tend to be lower in the control than in dryland (p = 0.063 < 0.1).

Table 10. Comparisons of heart pre-trial and heart peak between them and across the different conditions.

Conditions	HR_Pre-Trial	HR_Peak	Condition		Moment		Moment × Trial		Comparison	p [#3]
	Mean ± SD	Mean ± SD	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$		
Control	114.20 ± 19.50	160.95 ± 11.91	5.450 (0.008 *)	0.223	420.563 (<0.001 *)	0.957	1.504 (0.235)	0.073	Control vs. Dryland	0.063
Water	123.65 ± 15.40	163.1 ± 15.80							Control vs. Water	0.005 *
Dryland	125.45 ± 15.90	164.45 ± 15.35							Dryland vs. Water	1

[#2]—Two-way repeated measures ANOVA; [#3]—Bonferroni multiple comparison test; * $p < 0.05$.

In Table 11, no statistically significant interaction between the conditions and the moments (between HR_Baseline and HR_Peak) was found for heart rate (F = 0.65, $p = 0.529$, $\eta^2 p = 0.033$). When analysing the effect of the moments, a significant effect was observed (F = 67.90, $p < 0.001$, $\eta^2 p = 0.972$), with values being significantly higher at the trial peak than at the protocol's initial moment. No significant differences were observed across the conditions (F = 1.00, $p = 0.376$, $\eta^2 p = 0.050$).

Table 11. Comparisons of the heart rate baseline and the heart rate peak across the different conditions.

Conditions	HR_Baseline	HR_Peak	Condition		Moment		Condition × Trial	
	Mean ± SD	Mean ± SD	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$
Control	69.85 ± 14.85	160.95 ± 11.91	1.004 (0.376)	0.050	665.901 (<0.001 *)	0.972	0.647 (0.529)	0.033
Water	72.45 ± 12.94	163.1 ± 15.80						
Dryland	69.85 ± 13.25	164.45 ± 15.35						

[#2]—Two-way repeated measures ANOVA; * $p < 0.05$.

3.7. Tympanic Temperature Data

In Table 12, the results show a significant interaction between condition and moment in the temperature analysis (post-re-warm-up and pre-trial) (F = 53.52, $p < 0.001$, $\eta^2 p = 0.738$). Bonferroni-adjusted multiple comparisons with the moment fixed are presented in Table 13. Significant differences were observed between the control and water conditions ($p < 0.001$) and between the dryland and water conditions ($p < 0.001$). The same pattern was observed at moment 2, with significant differences between control and water ($p = 0.010$) and between dryland and water ($p = 0.003$). In this case, we observe that water presents lower temperatures during both moments.

Table 12. Comparisons of post-re-warm-up and pre-trial temperatures across the different conditions.

Conditions	Temp_Post_Re-Warm-Up	Temp_Pre_Trial	Condition		Moment		Condition × Trial	
	Mean ± SD	Mean ± SD	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$	F (p [#2])	$\eta^2 p$
Control	36.53 ± 0.48	36.68 ± 0.43	146.553 (<0.001 *)	0.885	144.590 (<0.001 *)	0.884	53.523 (<0.001 *)	0.738
Water	34.49 ± 0.51	36.31 ± 0.48						
Dryland	36.41 ± 0.53	36.76 ± 0.42						

[#2]—Two-way repeated measures ANOVA; * $p < 0.05$.

Table 13. Bonferroni multiple comparison fixing the moment.

Moment	Condition	Condition	p [#3]
1	1	2	<0.001 *
		3	1.000
	2	3	<0.001 *
2	1	2	0.010 *
		3	0.970
	2	3	0.003 *

[#3]—Bonferroni multiple comparison test; * $p < 0.05$.

3.8. Psychological Variables

Questionnaire: Self-Reported Preferences and Sensations

Fourteen athletes indicated that warming up in the water was their favourite method, reporting a greater feeling of activation, increased sensitivity in the water, a better swimming sensation, and less fatigue during the final stretch. The same athletes indicated dry warming as the second most effective, often providing the same feeling of activation but without the fatigue. Five athletes said they preferred the warm-up, saying they felt more active and explosive, and that it was more practical and feasible in all race situations, and two athletes said they were already used to this warm-up. In the control area, athletes said it was the least active method, making them feel very relaxed and tired; only one athlete reported preferring not to warm up, but did not justify their opinion.

4. Discussion

Previous studies have demonstrated that additional activation strategies implemented during prolonged transition phases may enhance subsequent swimming performance, particularly when dryland exercises are combined with passive heating interventions. McGowan et al. [14,25] and Knight [26] reported performance improvements ranging from ~0.7 to 2.0% following combined re-warm-up strategies, with the largest effects observed when plyometric or explosive dryland exercises were associated with passive heating. Specifically, Knight [26] observed a 2.0% improvement (~1.15 s), whereas McGowan et al. [25] and McGowan et al. [14] reported improvements of ~0.8% (~0.50 s) and 1.05% (~0.80 s), respectively. Together, these findings suggest that active re-warm-up strategies may be beneficial during prolonged transition phases. In the present study, however, this resulted in a significant improvement in 100 m freestyle performance compared with the control condition (~0.68%). Although the water condition also produced a numerically faster performance (~0.52%), this difference did not reach statistical significance. Therefore, under the conditions of the present study, only the dryland protocol demonstrated a clear positive effect on performance. However, these findings should be interpreted within the methodological context of the study. Although performance times were initially recorded manually, all trials were subsequently verified through video analysis to enhance measurement accuracy. Furthermore, the inclusion of well-trained national-level swimmers provides relevant applied insight, although caution should be exercised when generalising these findings to elite international athletes.

As expected, when analysing the 50 m splits of the trial, we observed that the first part of the race was faster than the second part in all conditions, probably due to factors such as muscular fatigue [27], explosive start from the block, energy management, and technique [28]. In the present study, only the dryland condition was significantly faster than the control in the split analysis. No significant differences were observed between water and control or between water and dryland. Therefore, the split results support dryland as the only protocol associated with a significant improvement in sprint performance under the present conditions.

All stroke metrics (SR, SL, and SI) showed a reduction in the second 50 m compared with the first 50 m, which is consistent with the fatigue-related changes expected during a 100 m effort. No differences were found between conditions; however, the results of our study showed a trend for the values of SI in the water condition to be less variable during the trial, suggesting that this condition may enhance technical patterns and their maintenance during the race. As Morais et al. [29] state, the SI is strongly correlated with performance and technical efficiency, serving as an indirect measure of efficiency.

The La^{-} Net values reflect the metabolic intensity achieved during the trial, reporting the difference between La-peak and La-pre-trial. All conditions achieved comparable metabolic intensities, with no differences observed in this variable. Generally, the greater the anaerobic glycolytic activity required, the greater the accumulation of La^{-} during the test, and a higher glycogen capacity contributes to better results in short-duration events [30]. In the present study, La^- increased by an average of 407% from pre-trial to post-trial in La^-, indicating that the athletes exerted very intense effort across all conditions.

The RPE results also did not show differences between conditions, reinforcing the idea that, despite the effort felt and applied by the athletes being similar across conditions, the trial times differed, probably due to physiological and technical factors arising from the different warm-up protocols.

Neiva H. [3] reported that warm-up in water could improve performance without increasing La^- values or perceived effort, as was the case in our results, in which no differences were found between conditions in La^- values or RPE. However, differences in athletes' performance were observed. Thus, considering that the control condition showed 100 m times worse than those in the dryland condition, we can suggest that the control condition may have caused a sub-warm-up and a lack of metabolic readiness compared to the dryland condition, maintaining the effort level of the other conditions but resulting in worse times in the trial.

The HR values were lower in control than in water in the pre-trial and peak-trial comparison, with a significant condition effect in this analysis. This finding may indicate a lower level of physiological activation in the control condition before the trial. However, given that not all pairwise comparisons were significant, this interpretation should be approached with caution. There was a significant increase in baseline and pre-trial HR leading up to the peak HR during the trial, once again demonstrating that, despite differences between protocols and results, the trials reflected high levels of effort by the athletes [31].

The water condition showed lower temperatures than the other conditions in both the post-re-warm-up and pre-trial phases, likely due to the body's immersion for 5 min during the re-warm-up. Due to the water's high thermal conductivity, which ranged from 27 °C to 28.5 °C, body temperature decreased [32]. However, from the post-re-warm-up to the pre-trial, this temperature increased by an average of 1.82 °C, with the water condition becoming very close to the temperature of the other conditions, likely because even though the temperature drops due to water immersion, during the transition phase, the temperature rises again due to heat accumulation in the body resulting from the physical effort induced by re-warm-up and the use of clothing. The dryland condition also showed an increase in temperature from post-re-warm-up to pre-trial, possibly due to the effort exerted during the re-warm-up activity, as this increase in heat is a universal response to intense muscular activity [33].

Overall, the present results indicate that dryland was the only protocol associated with a significant improvement in 100 m freestyle performance. Although swimmers subjectively preferred the water strategy and reported more favourable sensations during the trial, these perceptions were not accompanied by significant improvements in the main performance outcomes. Therefore, the water protocol should be interpreted cautiously and may be better viewed as a strategy for future investigation rather than as a confirmed performance-enhancing intervention.

A larger sample size could have provided stronger support for the present findings, which should be acknowledged as a limitation of this study. In addition, although all participants were experienced competitive swimmers, not all were specialists in the 100 m freestyle event and stroke. Furthermore, because the sample comprised competitive athletes assessed in a real training context, care was taken to avoid disrupting the normal training process, which necessarily reduced experimental control over the athletes' psychophysiological state at the time of testing. Another limitation was that the primary performance outcome was not measured using an official electronic timing system, as such a system was not available in the testing setting. Performance times were recorded manually by experienced coaches and subsequently confirmed through video analysis, which helped reduce potential timing errors. Nevertheless, the small differences observed between conditions should still be interpreted with caution, and future studies should prioritise the use of official electronic timing systems whenever possible. Although Bonferroni adjustments were applied to post hoc pairwise comparisons within each analysis, the number of secondary and exploratory outcomes analysed may have increased the overall probability of type I error. Therefore, findings related to secondary variables should also be interpreted with caution. Finally, the 24 h interval between sessions was chosen because testing took place one week after the main competition of the season, during a recovery period without intense training loads. Moreover, the participants were well-trained swimmers accustomed to competing in multiple events across several sessions and consecutive competition days. For this reason, 24 h was considered a reasonable recovery interval within the ecological context of the study, although residual fatigue cannot be completely excluded. Future studies should consider larger samples, longer washout periods, and official electronic timing systems.

5. Conclusions

The dryland condition appears to be beneficial for 100 m freestyle performance, producing faster trial times than the other conditions. This effect seems to be mainly related to the first 50 m, where differences between conditions were observed. Therefore, explosive dryland exercises targeting swimming-specific movement patterns may induce physiological and mechanical changes that are advantageous for short-distance events. In contrast, the water condition produced times close to those observed in the dryland condition, but these differences were not statistically significant. Although this condition showed a tendency toward a higher SI, and swimmers reported more favourable sensations during the trial, these findings should be interpreted with caution. Therefore, rather than indicating a confirmed performance benefit, the present results suggest that this strategy may deserve further investigation, particularly in longer-distance events such as the 400 m, 800 m, or 1500 m, where swimming economy may play a more important role.

Author Contributions: Conceptualization, D.P., D.A.M., L.R. and H.N.; methodology, D.P., D.A.M., L.R. and H.N.; formal analysis, D.P., J.E.M. and C.N.; investigation, D.P.; resources, D.A.M., L.R. and H.N.; writing—original draft preparation, D.P.; writing—review and editing, D.P., J.E.M., D.A.M. and L.R.; supervision, D.A.M. and L.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Funds by FCT—Foundation for Science and Technology, grant number 2022. 14676.BD, and under the projects UID/04045/2025 (https://doi.org/10.54499/UID/04045/2025), UID/PRR/04045/2025 (https://doi.org/10.54499/UID/PRR/04045/2025), and UID/PRR2/04045/2025 (https://doi.org/10.54499/UID/PRR2/04045/2025).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of the University of Beira Interior (protocol code: CE-UBI-Pj-2023-049-ID1849, approved on 16 July 2024).

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

Data Availability Statement: The data presented in this study are available on request from the corresponding author (the data are not publicly available due to privacy reasons).

Acknowledgments: The authors would like to thank the athletes who volunteered to participate in the present study and the researchers who helped with data collection.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

SL	Stroke length
SR	Stroke rate
SI	Stroke index
RPE	Subjective perception of effort
T	Temperature
HR	Heart rate
La^-	Blood lactate concentration
PAPE	Postactivation performance enhancement

References

1. Lätt, E.; Jürimäe, J.; Mäestu, J.; Purge, P.; Rämson, R.; Haljaste, K.; Keskinen, K.L.; Rodriguez, F.A.; Jürimäe, T. Physiological, biomechanical and anthropometrical predictors of sprint swimming performance in adolescent swimmers. *J. Sports Sci. Med.* **2010**, *9*, 398–404.
2. Bishop, D. Warm Up I. *Sports Med.* **2003**, *33*, 439–454. [CrossRef]
3. Neiva, H.; Morouço, P.; Silva, A.J.; Marques, M.C.; Marinho, D.A. The effect of warm-up on tethered front crawl swimming forces. *J. Hum. Kinet.* **2011**, *29A*, 113–119. [CrossRef] [PubMed]
4. McGowan, C.J.; Pyne, D.B.; Raglin, J.S.; Thompson, K.G.; Rattray, B. Current warm-up practices and contemporary issues faced by elite swimming coaches. *J. Strength Cond. Res.* **2016**, *30*, 3471–3480. [CrossRef] [PubMed]
5. Woods, K.; Bishop, P.; Jones, E. Warm-Up and Stretching in the Prevention of Muscular Injury. *Sports Med.* **2007**, *37*, 1089–1099. [CrossRef]
6. Racinais, S.; Oksa, J. Temperature and neuromuscular function. *Scand. J. Med. Sci. Sports* **2010**, *20*, 1–18. [CrossRef]
7. Bagshaw, J. The Effects of a Dryland Activation Protocol During the Transition Phase on Elite Swimming Performance. Master's Thesis, University of Victoria, Victoria, BC, Canada, 2019.
8. McGowan, C.J.; Pyne, D.B.; Thompson, K.G.; Rattray, B. Evaluating Warm-Up Strategies for Elite Sprint Breaststroke Swimming Performance. *Int. J. Sports Physiol. Perform.* **2016**, *11*, 975–978. [CrossRef]
9. Cuenca-Fernández, F.; López-Contreras, G.; Arellano, R. Effect on swimming start performance of two types of activation protocols: Lunge and YoYo squat. *J. Strength Cond. Res.* **2015**, *29*, 647–655. [CrossRef]
10. Cuenca-Fernández, F.; Gay, A.; Ruiz-Navarro, J.J.; Morales-Ortiz, E.; López-Contreras, G.; Arellano, R. Protocolización de la post-activación potenciación estimulada (PAPE) en natación y su relación con la fuerza relativa. *Rev. Andal. Med. Deporte* **2020**, *13*, 150–154. [CrossRef]
11. Zochowski, T.; Johnson, E.; Sleivert, G. Effects of Varying Post-Warm-Up Recovery Time on 200-m Time-Trial Swim Performance. *Int. J. Sports Physiol. Perform.* **2007**, *2*, 201–211. [CrossRef] [PubMed]
12. Türkmen, D.; Günay, E.; Güdücü, Ç.; Öniz, A.; Bediz, C.Ş. Effect of Post-Warm-Up Three Different Duration Self-Selected Active Rests on 100 Meter Swimming Performance: Preliminary Findings. *Montenegrin J. Sports Sci. Med.* **2022**, *11*, 57–64. [CrossRef]
13. Van Raalte, J.L.; Brewer, B.W.; Cornelius, A.E.; Keeler, M.; Gudjenov, C. Effects of a Mental Warmup on the Workout Readiness and Stress of College Student Exercisers. *J. Funct. Morphol. Kinesiol.* **2019**, *4*, 42. [CrossRef]
14. McGowan, C.J.; Thompson, K.G.; Pyne, D.B.; Raglin, J.S.; Rattray, B. Heated jackets and dryland-based activation exercises used as additional warm-ups during transition enhance sprint swimming performance. *J. Sci. Med. Sport* **2015**, *19*, 354–358. [CrossRef] [PubMed]
15. Galbraith, A.; Willmott, A. Transition-phase clothing strategies and their effects on body temperature and 100-m swimming performance. *Eur. J. Sport Sci.* **2018**, *18*, 182–189. [CrossRef] [PubMed]
16. West, D.J.; Dietzig, B.M.; Bracken, R.M.; Cunningham, D.J.; Crewther, B.T.; Cook, C.J.; Kilduff, L.P. Influence of post-warm-up recovery time in international swimmers. *J. Sci. Med. Sport* **2013**, *16*, 172–176. [CrossRef]
17. Paiva, D.; Marinho, D.; Neiva, H.; Rama, L. Warm-up in swimming competition: Characterization of the strategies used by Portuguese coaches. *Motricidade* **2024**, *20*. [CrossRef]
18. Cuenca-Fernández, F.; Smith, I.C.; Jordan, M.J.; MacIntosh, B.R.; López-Contreras, G.; Arellano, R.; Herzog, W. Nonlocalized postactivation performance enhancement (PAPE) effects in trained athletes: A pilot study. *Appl. Physiol. Nutr. Metab.* **2017**, *42*, 1122–1125. [CrossRef]
19. McKay, A.K.A.; Stellingwerff, T.; Smith, E.S.; Martin, D.T.; Mujika, I.; Goosey-Tolfrey, V.L.; Sheppard, J.; Burke, L.M. Defining training and performance caliber: A participant classification framework. *Int. J. Sports Physiol. Perform.* **2022**, *17*, 317–331. [CrossRef] [PubMed]

20. Neiva, H.P.; Marques, M.C.; Barbosa, T.M.; Izquierdo, M.; Viana, J.L.; Marinho, D.A. Effects of 10 min vs. 20 min passive rest after warm-up on 100 m freestyle time-trial performance: A randomized crossover study. *J. Sci. Med. Sport* **2017**, *20*, 81–86. [CrossRef]
21. Borg, G. *Borg's Perceived Exertion and Pain Scales*; Human Kinetics: Champaign, IL, USA, 1998.
22. Lohman, T.G.; Roche, A.F.; Martorell, R. *Anthropometric Standardization Reference Manual*; Human Kinetics: Champaign, IL, USA, 1988.
23. Richardson, J.T.E. Eta squared and partial eta squared as measures of effect size in educational research. *Educ. Res. Rev.* **2011**, *6*, 135–147. [CrossRef]
24. Kinnear, P.R.; Gray, C.D. *IBM SPSS Statistics 18 Made Simple*; Psychology Press: New York, NY, USA, 2010.
25. McGowan, C.J.; Pyne, D.B.; Thompson, K.G.; Raglin, J.S.; Osborne, M.; Rattray, B. Elite sprint swimming performance is enhanced by completion of additional warm-up activities. *J. Sports Sci.* **2017**, *35*, 1493–1499. [CrossRef] [PubMed]
26. Knight, J. Pre-Race Strategies to Maintain and Enhance the Physiological Effects of a Warm-Up in 100 m Freestyle Performance. Master's Thesis, St Mary's University, Twickenham, UK, 2017. Available online: https://research.stmarys.ac.uk/1884/ (accessed on 16 October 2025).
27. Costa, M.J.; Santos, C.C.; Ferreira, F.; Arellano, R.; Vilas-Boas, J.P.; Fernandes, R.J. Association between elite swimmers' force production and 100 m front crawl inter-lap pacing and kinematics. *Front. Sports Act. Living* **2023**, *5*, 1205800. [CrossRef] [PubMed]
28. Cuenca-Fernández, F.; Ruiz-Navarro, J.J.; Polach, M.; Arellano, R.; Born, D.-P. Short-course performance variation across all race sections: How 100 and 200 m elite male swimmers progress between rounds. *Front. Sports Act. Living* **2023**, *5*, 1146711. [CrossRef]
29. Morais, J.E.; Jesus, S.; Lopes, V.; Garrido, N.; Silva, A.; Marinho, D.; Barbosa, T.M. Linking Selected Kinematic, Anthropometric and Hydrodynamic Variables to Young Swimmer Performance. *Pediatr. Exerc. Sci.* **2012**, *24*, 649–664. [CrossRef] [PubMed]
30. Sengoku, Y.; Shinno, A.; Kim, J.; Homoto, K.; Nakazono, Y.; Tsunokawa, T.; Hirai, N.; Nobue, A.; Ishikawa, M. The relationship between maximal lactate accumulation rate and sprint performance parameters in male competitive swimmers. *Front. Sports Act. Living* **2024**, *6*, 1483659. [CrossRef]
31. Olstad, B.H.; Bjørlykke, V.; Olstad, D.S. Maximal Heart Rate for Swimmers. *Sports* **2019**, *7*, 235. [CrossRef]
32. Rüst, C.A.; Knechtle, B.; Rosemann, T. Changes in body core and body surface temperatures during prolonged swimming in water of 10 °C—A case report. *Extrem. Physiol. Med.* **2012**, *1*, 8. [CrossRef]
33. Nybo, L.; Rasmussen, P.; Sawka, M.N. Performance in the Heat—Physiological Factors of Importance for Hyperthermia-Induced Fatigue. *Compr. Physiol.* **2014**, *4*, 657–689. [CrossRef]