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Physiological Responses of Male and Female Swimmers in Different Warm-Up Protocols

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Abstract Swimmers undertake in-water warm-ups in the race pool ahead of the competition. The objective of this study is to examine the effects of three warm-up protocols (critical velocity (CV), kick, drill, swim (KDS), critical velocity, kick, drill, swim (CVKDS)) and a no-warm-up (NOWU) condition on heart rate (HR), blood lactate (LA), and rate of perceived exertion (RPE) during a 4x50-meter maximal mixed swimming test. Forty-two national swimmers participated on a voluntary basis (21 female and 21 male). Under their coaches' supervision, the swimmers executed the CV, KDS, CVKDS, and NOWU warm-up routines on separate days. After a period of complete rest, the swimmers completed a maximum of four 50-meter laps, each consisting of a different stroke (butterfly, backstroke, breaststroke, freestyle). End time and heart rate were measured after each lap, and swimmers were asked to rate their perceived exertion immediately after finishing the test. Lactic acid levels in the swimmers were measured during the rest periods at the first (LA1), sixth (LA6), and fifteenth (LA15) minutes. Following preliminary measurements, swimmers were separated into three groups and completed the CV, KDS, and CVKDS warm-up protocol for eight weeks at the beginning of their training. After eight weeks, the tests were repeated. Data analysis was conducted using the IBM SPSS 24.0 program with statistical significance set at $p<0.05$. Paired-samples t-tests, independent t-tests, one-way ANOVA, and repeated measures ANOVA tests were employed. Differences in HRbut, HRback, HRbre, HRfree and LA1, LA6, LA15 between genders were observed ($p<0.05$). There was also a significant difference in HRbut, HRback, HRbre, HRfree and LA1, LA6, LA15 based on warm-up protocols ($p<0.05$); however, no significant difference was found in RPE ($p>0.05$). After pre-race water warm-ups, physiological responses varied by gender among male and female swimmers.

Keywords Swimming, Warm-up, Blood Lactate, Heart Rate, RPE

1. Introduction

Swimming is the act of completing a distance in the shortest time possible. Consequently, swimmers competing in races aim to beat both their rivals and them within seconds [1,2]. The length of swimming competitions depends on the type of event. Typically, in international competitions, preliminary races take place in the morning, while final races occur in the afternoon or evening. The competitions typically last between two and eight days [3]. Prior to the commencement of the selection or final races, swimmers access the race pool and execute warm-up routines in preparation for the event. The objective of this activity is to enhance the athletes' performance as well as to ensure that specific physiological characteristics, such as the acceleration of blood flow and increasing body temperature, reach optimal levels. It is important that swimmers avoid reaching fatigue during their water warm-up [4,5]. As a result, research on the ideal duration and volume of warm-ups is ongoing. While some studies

highlight the need for longer warm-up protocols, others examine the necessity of warm-ups altogether [6,7]. Two recent studies have indicated that extensive warm-ups prior to races have a detrimental effect on performance by increasing fatigue. On the other hand, these studies also found that total distance of 1200m can lessen fatigue [8,9]. Furthermore, carrying out critical velocity exercises during warm-ups was seen to decrease performance time and delay fatigue [10]. It is important to bear in mind that swimmers take part in several races during the selection phase, and fatigue may manifest during the final session due to warm-up, which can have an adverse impact on race performance [8]. A review study investigating the scope of warm-up protocols and their impact on performance indicated methodological issues with the small sample group and the choice of freestyle as the swimming performance criteria [11]. The studies further highlighted variations in the warm-up protocols, indicating differences in the optimal performance achieved by swimmers. Thus, it is recommended that swimmers follow an individual rather than group warm-up protocol. It is critical to assess individual swimmers' responses to various warm-up techniques [12-14]. While several warm-up protocols are currently utilized, it remains unclear what load and intensity constitute an optimal warm-up for swimmers. Therefore, a novel warm-up method that combines critical velocity with exercises involving kicking, drills and swimming was incorporated as previous research has not examined this approach. Physiological measurements were conducted in the pool to provide real-time records for each athlete. It has been reported that swimmers' physiological responses to warm-up protocols vary among different populations [15-17]. We conducted a study to examine the potential differences in response to warm-up protocols based on both gender and protocol type. During the initial stage of this study, we examined the immediate impact of three distinctive warm-up protocols on key physiological parameters (HRbut, HRback, HRbre, HRfree, LA1, LA6, LA15, RPE) in 4x50m maximum mixed swimming events (butterfly, backstroke, breaststroke, and freestyle). In the second stage of the investigation, swimmers were segregated into three groups using the Splash Meet Manager system, based on their personal best times (short lane) in 200 m individual medley swimming. The study analysed the lasting effect of three distinct warm-up methods: a) CV warm-up with critical velocity b) KDS warm-up with kick, drill, and swimming workouts c) newly made CVKDS warm-up with critical velocity and kick, drill, and swimming workouts, on physiological parameters. The objective of this research was to examine the short-term and long-term impacts of three distinct warm-up procedures (CV, KDS and CVKDS) and no warm-up (NOWU) on heart rate, levels of lactate in the blood, and the perceived extent of difficulty during the 4x50 m maximal mixed swimming test.

2. Materials and Methods

2.1. Subjects

To establish the study's participant count, G*Power analysis (G*Power 3.1.9.4, Axel Buchner, Heinrich-Heine-Universität Kiel, Düsseldorf, Germany) was employed. The analysis deduced a minimum sample size of 42, yielding ‰943 power and ‰57 type I error levels. 42 national level swimmers of both genders (n=21 female; n=21 male) then volunteered to participate in this study, ensuring gender parity. Table 1 presents the descriptive attributes of the subject group. The research was granted approval for human experimentation by the Istanbul University Clinical Research Ethics Committee, complying with the guidelines set out in the 2013 Declaration of Helsinki (05.03.2021-06). The research conducted was also in accordance with the principles established by the 2013 Declaration of Helsinki. Moreover, all participating swimmers' families gave their consent by signing the forms. The Halic University Scientific Research Projects Coordinatorship supported this research. Project number: HBAP-III-3.

Table 1. Physical and performance characteristics of swimmers

	Female (n=21)	**Male (n=21)**	**Total (n=42)**
Age (years)	13.62±0.86	13.38±1.07	13.50±0.97
Training age (years)	5.05±0.74	5.19±0.81	5.12±0.77
Height (cm)	162.14±6.89	161.82±11.19	161.98±9.18
Body weight (kg)	50.36±8.87	49.98±11.14	50.17±9.95
Body mass index (kg/m^2)	19.08±2.13	18.93±1.98	19.00±2.03
Arm length (cm)	163.13±8.03	165.52±12.50	164.33±10.44
200m Individual medley (s)	167.62±9.98	166.57±12.98	167.10±11.45

2.2. Data Collection

After establishing the physical characteristics of the swimmers, including height, body weight, and arm length, pool measurements were initiated with support from the third-level coaches of the swimmers and the responsible researchers. All measurements were conducted during training hours in the afternoon. The measurements indicated that the pH level of the pool averaged 7.45, the free chlorine level was 1.30, and the water temperature was 27.5 °, with an accompanying ambient temperature of 25.5 °. Swimmers undertook CV, KDS, CVKDS and NOWU warm-up protocols at 24-hour intervals under the guidance of their respective coaches. The intensity and frequency of the warm-up protocols were informed by a review study conducted by McGowan et al. in 2016 [18]. CV, a warm-up protocol which demonstrated the effect of critical velocity on performance, was employed in the study conducted by Neiva et al. [10]. KDS: The warm-up protocol was developed by incorporating findings from three different studies [19,9,13] and involves kick, drill and swimming exercises. CVKDS: The warm-up protocol comprises critical velocity, kick, drills, and swimming. NOWU: No warm-up protocol was implemented (Table 2).

The critical velocity values for the CV and CVKDS warm-up protocols were determined by calculating the times of swimmers in the 50m and 100m distances during their last race, using four different methods, and expressed in meters per second [20]. The critical velocity values were individually calculated for each swimmer and subsequently utilized by both relevant researchers and coaches during the warm-up protocols. Swimmers rested on dry land for ten minutes following three varied warm-up routines. After the rest period, the swimmers were requested to carry out a mixed maximal swim performance of 4x50 meters, incorporating a butterfly, backstroke, breaststroke and freestyle. The swimmers were permitted to swim up to 105% of their best times in order to control maximal performance. A passive 30-second rest period was allowed between each 50-meter swim. Rest periods and maximum performance were monitored by skilled coaches using an Epsan brand stopwatch. The 50-meter finishing time of each swimmer was recorded using the stopwatch function of the software, which captured performance images with an SJCAM external camera during the test. These images were then transferred to the Kinovea 0.9.5 program. The combined finish times of four different styles were calculated to yield a total time of 200 meters.

Table 2. Different warm-up protocols

No	CV	KDS	CVKDS	NOWU
1	300m (100-m usual breathing, 100-m breathing in the fifth stroke, 100-m usual breathing) (**%70**)	300m normal—breathing in the 5th stroke—normal *(Neiva et al., 2015)* (**%60**)	400 m usual breathing (**70%**)	No Warm-Up
2	4x100m on 1:50 (2x [25m kick + 25m increased stroke length]) (**%70**)	4x50m leg kick *(Toubekis et al., 2008)* (**%60**)	4x50m on 1:15 (25m leg kick + 25m drill) Individual Medley (**70%**)	
3	8x50m on 1:00 (98-102% of critical velocity) (**%98-102**)	3x100m (25 m kick—25 m increased stroke length) *(Neiva et al., 2015)* (**%80**)	8x50m on 1:00 (**98-102%** of critical velocity)	
4	100m (easy swim) (**%40**)	8x25m starting at 1:00 (4x25m: 12.5m 90% of the 50-m race pace followed by 12.5m easy and 4x25m vice versa) *(Dalamitros et al., 2018)* (**%90-60**)	4x25m on 0:45 freestyle swim (**85%-90%-95%-100+%**)	
5		2x50m starting at 2:00 (25m at 100% of the 50-m race pace followed by 25m at an easy pace) *(Dalamitros et al., 2018)* (**%100-60**)	100m flutter kick (**60%**)	
6		100m (easy swim) *(Dalamitros et al., 2018; Toubekis et al., 2008; Neiva et al., 2015)* (**%50**)		
	Total: 1200m	Total: 1200m	Total: 1200m	

CV: Critical Velocity; KDS: Kick, Drill, Swim; CVKDS: Critical Velocity, Kick, Drill, Swim

Physiological characteristics of the swimmers were used to extract heart rate, blood lactate values and perceived difficulty levels in this study. Following every 50-meter performance, the heart rate monitor Polar OH1 (Polar Electro Oy, Kempele, Finland) was utilized to measure the swimmers' heart rate. The heart rates of participants were obtained via the Apple Polar Beat application downloaded on the iPhone 7+ phone [21]. Lactate values were measured in swimmers following their performance by an expert using a Lactate Scout+ (LS, SensLab GmbH, Germany) lactate analyzer, with readings taken at the first (LA1), sixth (LA6), and fifteenth (LA15) minute rest periods [22-24,16]. Immediately following the 4x50 m medley test, swimmers were asked to report the perceived degree of difficulty, and this was recorded. Borg's (1982) Perceived Difficulty Rating was employed to establish the level of difficulty [25].

After initial measurements, the swimmers were divided into three groups using the Splash Meet Manager system based on their personal best times in the 200m individual medley (short course). The groups then followed the desired CV, KDS, and CVKDS warm-up protocols for eight weeks at the start of their training. During the commencement of the 2021-2022 season, every 120-minute unit training session adhered to the general training program in accordance with the basic endurance principle (Table 3). Swimmers undertook their training for 2 hours per day, 6 days a week. The total unit training distance ranged between 4500m and 5500m. After the eight-week period had ended, the preliminary measurements underwent repeat testing. The study design is given in Figure 1.

Table 3. Training program

Warm-up	warm-up protocols applied by three different groups in the study
Main	
Monday (PM)	EN2 +EN3 Drills & Kicking
Tuesday (PM)	EN3 Main Training
Wednesday (PM)	EN1 & Recovery
Thursday (PM)	IM or Best Stroke SP1
Friday (PM)	EN1 and EN2 Drills
Saturday (AM)	EN3 Main Training
Sunday	Off
Cool-down	200m any stroke

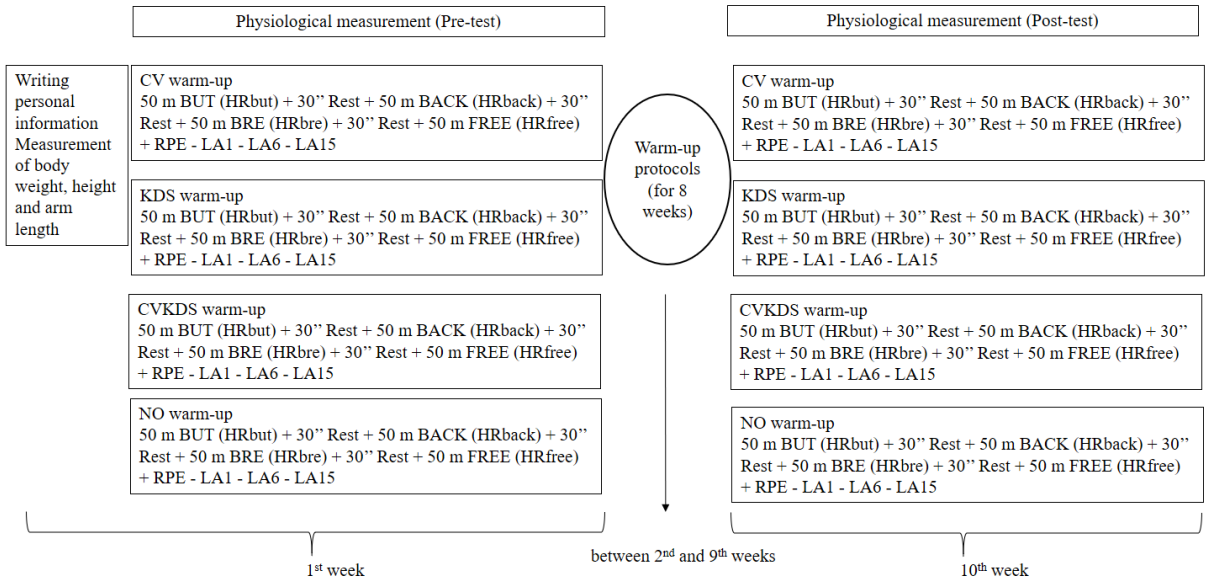

Figure 1. Study design

2.3. Data Analysis

The data analysis was carried out using the IBM SPSS 24.0 program developed by IBM Corp., USA. To determine the normal distribution suitability of the data, Skewness and Kurtosis values were computed. Results showed that the Skewness and Kurtosis values range from "-2.0" to "+2.0", indicating normal distribution of the data [26]. Mean and standard deviation values were calculated for all parameters, categorized according to groups and gender. Paired-samples t-test was employed to establish any distinctions between the measurements within the group. An Independent t-test was conducted to ascertain differences between the pre- and post-measurements and between genders. One-way ANOVA test was conducted to investigate the possible variations among groups according to the warm-up protocol employed. Tukey's test was used to determine the significant differences between paired groups, as there was equality of variance among the Post-Hoc tests. Following four different warm-up protocols, the data from pre- and post-measurements were analyzed using the Repeated Measures ANOVA to determine differences between these protocols according to the warm-up grouping. If the p-value obtained from Mauchly's Test of Sphericity test was greater than 0.05, we used the p-value obtained from the Sphericity Assumed test. However, if the p-value was less than 0.05, we used the p-value obtained from Wilks' Lambda test from Multivariate tests. To identify the different parameters with significant results, we utilized Post-Hoc Bonferroni test statistics and the Pairwise Comparisons table. Effect sizes and confidence intervals are crucial statistics for evaluating the size and accuracy of an effect. They determine whether the difference between the results of the study groups is significant. To calculate effect size, Cohen (d) developed the most frequently used method. The effect sizes were categorized as small (~0.01), medium (~0.06) and large (~0.14) through analysis of the partial eta squared coefficient (η^2p) from the Repeated Measures ANOVA test [27]. The confidence interval was determined to be $p<0.05$.

3. Results

The physiological and performance parameters of the swimmers, categorized by groups and gender, are presented in Table 4 and Table 5, along with their mean and standard deviation values.

Table 6 and Table 7 provides information on the physiological and performance parameters of swimmers. The data indicates variations in HRback and HRbre measurements for CV, KDS, and total male swimmers after NOWU. Moreover, differences were observed in HRbut values among CV group female and male after NOWU, KDS group male and total group after KDS, and CVKDS group female after CV. There was a significant difference in measurements after NOWU in KDS group males and total males in HRfree ($p<0.05$). LA1, LA6, and LA15 values displayed gender-specific variations between measurements after certain warm-up protocols in each group ($p<0.05$). RPE showed dissimilarity in measurements solely in CVKDS group men after KDS and CVKDS warm-ups ($p<0.05$). Differences were found between measurements of the CV, CVKDS and total groups according to gender ($p<0.05$). Upon examining pre- and post-measurement groups, statistical differences were found in HRbut and HRbre after the final NOWU measurement, and in LA6, LA15 and RPE after the final CVKDS measurement ($p<0.05$).

Table 4. Mean and standard deviation values of HR according to groups and gender

			CV (n=14)			KDS (n=14)			CVKDS (n=14)		
			Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
HRbut	**CV**	**Pre**	173.71±17.62	174.71±12.58	174.21±14.72	174.29±26.71	171.86±19.51	173.07±22.51	189.43±5.19	177.00±9.78	183.21±9.91
		Post	181.43±2.30	175.57±12.82	178.50±9.35	184.29±4.35	177.14±9.39	180.71±7.95	185.00±5.10	182.14±5.11	183.57±5.12
	KDS	**Pre**	180.14±4.53	177.00±3.61	178.57±4.26	180.14±10.45	176.86±9.48	178.50±9.73	179.29±12.28	177.29±5.38	178.29±9.17
		Post	181.14±2.34	177.86±3.02	179.50±3.11	184.57±4.04	180.43±8.18	182.50±6.56	184.43±4.08	180.29±4.15	182.36±4.50
	CVKDS	**Pre**	180.00±10.28	179.57±4.58	179.79±7.65	180.29±10.61	177.86±6.74	179.07±8.63	186.43±8.46	183.14±6.23	184.79±7.34
		Post	184.00±5.86	180.71±4.39	182.36±5.26	183.29±3.82	181.86±2.79	182.57±3.30	184.57±5.00	182.00±5.00	183.29±4.98
	NOWU	**Pre**	175.00±2.24	177.14±3.13	176.07±2.84	178.00±6.66	177.43±6.70	177.71±6.43	181.14±4.26	177.71±8.24	179.43±6.55
		Post	179.71±2.50	174.14±3.58	176.93±4.14	179.29±5.79	178.43±2.76	178.86±4.38	180.14±5.01	178.14±3.29	179.14±4.20
HRback	**CV**	**Pre**	184.86±4.41	173.43±19.58	179.14±14.87	187.43±10.21	176.00±24.47	181.71±18.96	193.86±5.05	183.43±12.83	188.64±10.82
		Post	184.43±2.76	175.29±19.67	179.86±14.30	188.43±5.65	182.29±4.99	185.36±6.03	187.43±6.11	184.86±4.63	186.14±5.38
	KDS	**Pre**	185.00±3.51	178.57±6.55	181.79±6.05	187.14±7.03	183.57±6.05	185.36±6.57	182.14±16.16	180.86±6.87	181.50±11.95
		Post	183.57±2.88	181.14±1.46	182.36±2.53	187.71±5.47	185.00±5.10	186.36±5.27	189.14±6.69	180.71±6.05	184.93±7.53
	CVKDS	**Pre**	187.29±5.19	184.29±4.42	185.79±4.89	189.00±5.48	184.29±2.81	186.64±4.85	188.57±9.03	186.29±8.24	187.43±8.39
		Post	185.57±5.03	183.86±2.67	184.71±3.97	188.14±5.05	184.71±3.09	186.43±4.40	187.57±5.91	185.14±6.15	186.36±5.93
	NOWU	**Pre**	181.29±4.99	180.14±4.45	180.71±4.58	181.86±5.73	184.00±5.48	182.93±5.50	187.00±3.70	180.43±5.62	183.71±5.70
		Post	181.14±2.91	176.71±4.99	178.93±4.55	184.57±5.35	180.57±3.15	182.57±4.70	185.14±4.26	180.86±4.81	183.00±4.90
HRbre	**CV**	**Pre**	186.00±4.08	175.14±16.75	180.57±13.00	186.57±10.08	177.71±19.81	182.14±15.78	190.71±5.59	184.71±10.58	187.71±8.70
		Post	185.43±3.21	176.71±16.79	181.07±12.46	188.14±4.88	184.43±3.87	186.29±4.65	187.86±4.98	184.14±4.95	186.00±5.14
	KDS	**Pre**	183.71±3.40	179.71±5.91	181.71±5.08	186.29±6.99	182.71±6.47	184.50±6.73	182.86±13.18	181.71±5.74	182.29±9.79
		Post	183.71±1.38	181.29±2.14	182.50±2.14	186.86±6.15	185.43±4.16	186.14±5.10	188.43±5.32	182.14±5.76	185.29±6.24
	CVKDS	**Pre**	186.57±4.39	183.71±6.85	185.14±5.72	188.86±5.34	186.86±3.58	187.86±4.49	188.71±9.07	187.14±8.34	187.93±8.41
		Post	185.14±3.48	184.29±3.64	184.71±3.45	188.00±6.66	184.71±3.40	186.36±5.36	187.71±4.54	186.14±6.28	186.93±5.33
	NOWU	**Pre**	181.71±4.75	179.29±5.62	180.50±5.16	182.86±5.79	185.71±5.41	184.29±5.58	186.14±5.11	181.43±5.80	183.79±5.79
		Post	181.57±2.88	176.86±5.08	179.21±4.66	186.43±5.06	182.00±3.42	184.21±4.74	184.86±3.93	180.43±5.29	182.64±5.03
HRfree	**CV**	**Pre**	189.29±3.64	175.86±20.90	182.57±16.01	191.00±8.19	181.43±18.99	186.21±14.90	191.71±6.16	187.71±11.18	189.71±8.91
		Post	187.43±4.16	176.86±20.34	182.14±15.13	191.00±4.58	186.00±3.37	188.50±4.65	189.57±5.50	186.86±8.17	188.21±6.84
	KDS	**Pre**	185.71±3.30	182.43±7.81	184.07±6.01	189.29±9.05	186.86±4.22	188.07±6.90	186.86±7.20	183.86±6.67	185.36±6.85
		Post	185.29±2.14	183.00±2.52	184.14±2.54	189.00±6.63	187.86±4.06	188.43±5.32	189.57±4.86	183.57±6.35	186.57±6.26
	CVKDS	**Pre**	187.71±3.82	186.71±5.65	187.21±4.66	190.29±5.22	187.86±3.85	189.07±4.58	190.00±8.08	190.57±4.93	190.29±6.44
		Post	187.00±3.70	186.43±3.31	186.71±3.38	190.14±6.09	187.00±1.63	188.57±4.59	189.43±4.16	188.43±5.16	188.93±4.53
	NOWU	**Pre**	183.71±3.64	181.14±5.76	182.43±4.82	185.14±7.06	187.71±3.86	186.43±5.63	187.14±5.34	183.86±6.09	185.50±5.76
		Post	183.43±2.94	180.00±4.97	181.71±4.30	187.00±4.93	184.71±4.11	185.86±4.52	186.00±4.90	183.14±5.46	184.57±5.20

CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; HRbut: Heart Rate Butterfly (bpm); HRback: Heart Rate Backstroke (bpm); HRbre: Heart Rate Breaststroke (bpm); HRfree: Heart Rate Freestyle (bpm)

Table 5. Mean and standard deviation values of LA, RPE and performance (ET) parameters according to groups and gender

			CV (n=14)			KDS (n=14)			CVKDS (n=14)		
			Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
LA1	**CV**	**Pre**	10.20±2.62	9.29±1.27	9.74±2.04	10.21±3.62	9.57±2.54	9.89±3.03	10.51±2.46	8.66±1.96	9.59±2.34
		Post	8.04±1.81	7.54±1.98	7.79±1.84	8.14±2.66	7.01±1.57	7.58±2.18	9.06±2.58	8.56±2.71	8.81±2.56
	KDS	**Pre**	10.60±1.81	6.41±1.65	8.51±2.74	8.81±2.23	9.03±2.57	8.92±2.31	8.46±2.16	8.94±3.34	8.70±2.72
		Post	8.51±1.59	6.77±2.05	7.64±1.98	6.77±2.92	6.56±1.12	6.66±2.13	8.59±2.65	8.03±2.66	8.31±2.57
	CVKDS	**Pre**	10.54±2.90	8.11±1.68	9.33±2.61	9.10±3.53	7.93±1.72	8.51±2.74	9.77±1.84	10.07±2.64	9.92±2.19
		Post	8.91±2.36	8.09±3.08	8.50±2.67	8.80±2.74	7.64±1.74	8.22±2.28	8.76±2.73	10.91±2.51	9.84±2.76
	NOWU	**Pre**	8.44±0.96	6.80±1.62	7.62±1.54	8.06±3.62	7.74±1.20	7.90±2.60	7.77±2.19	6.97±1.67	7.37±1.92
		Post	8.81±1.58	6.80±1.74	7.81±1.91	8.34±4.00	6.19±2.07	7.26±3.26	7.83±2.69	7.87±2.68	7.85±2.58
LA6	**CV**	**Pre**	9.61±2.70	8.24±1.13	8.93±2.11	9.53±3.04	8.26±2.25	8.89±2.65	8.96±2.38	7.80±1.40	8.38±1.97
		Post	6.57±1.40	6.44±1.49	6.51±1.39	7.19±2.93	6.41±1.62	6.80±2.31	7.60±1.76	6.99±1.90	7.29±1.79
	KDS	**Pre**	9.09±2.02	5.74±1.88	7.41±2.56	8.07±2.95	7.46±2.20	7.76±2.52	7.41±1.78	7.63±2.93	7.52±2.33
		Post	7.20±1.24	5.51±1.96	6.36±1.80	6.31±3.66	6.01±1.91	6.16±2.81	7.44±2.63	6.77±2.76	7.11±2.62
	CVKDS	**Pre**	9.11±3.00	7.47±1.73	8.29±2.50	7.80±3.37	6.93±1.91	7.36±2.67	8.03±2.00	8.20±2.95	8.11±2.42
		Post	7.26±2.13	6.14±2.04	6.70±2.09	7.23±2.55	5.93±1.74	6.58±2.20	7.09±2.46	8.96±2.87	8.02±2.75
	NOWU	**Pre**	7.30±1.67	5.97±1.89	6.64±1.85	6.83±3.34	6.54±1.07	6.69±2.39	6.16±1.30	6.31±1.87	6.24±1.55
		Post	6.87±0.62	5.50±1.22	6.19±1.17	7.19±3.38	5.84±1.77	6.51±2.68	6.29±1.81	5.79±1.64	6.04±1.68
LA15	**CV**	**Pre**	7.61±3.05	6.94±1.28	7.28±2.28	7.80±2.76	7.19±2.07	7.49±2.37	7.36±2.41	6.40±2.12	6.88±2.24
		Post	5.04±1.59	4.83±1.72	4.94±1.59	5.37±2.00	5.06±2.16	5.21±2.00	5.46±2.31	5.54±1.84	5.50±2.01
	KDS	**Pre**	7.61±1.94	4.66±1.17	6.14±2.17	5.77±1.72	6.03±1.53	5.90±1.57	6.14±1.62	7.00±3.59	6.57±2.71
		Post	5.21±1.86	4.39±1.38	4.80±1.63	4.47±2.58	4.69±1.40	4.58±2.00	5.59±2.37	5.04±2.01	5.31±2.13
	CVKDS	**Pre**	7.37±2.70	5.70±1.20	6.54±2.19	6.04±2.22	5.23±1.09	5.64±1.73	6.37±1.21	6.83±2.38	6.60±1.83
		Post	6.04±2.37	4.24±1.60	5.14±2.15	5.79±2.40	4.47±1.36	5.13±1.99	5.10±2.21	6.61±1.71	5.86±2.06
	NOWU	**Pre**	5.09±1.81	4.14±1.38	4.61±1.62	5.41±2.61	5.11±0.99	5.26±1.90	4.51±0.99	4.41±1.81	4.46±1.40
		Post	4.73±0.67	3.79±1.10	4.26±1.00	5.43±3.42	4.50±1.12	4.96±2.49	4.44±1.76	4.50±1.90	4.47±1.76

Table 5. Continued

RPE	**CV**	**Pre**	17.57 ±0.79	16.86 ±1.46	17.21 ±1.19	17.29 ±0.76	17.29 ±1.25	17.29 ±0.99	17.29 ±0.95	17.14 ±1.86	17.21 ±1.42
		Post	17.57 ±0.53	17.43 ±0.79	17.50 ±0.65	17.43 ±0.79	17.29 ±1.11	17.36 ±0.93	17.86 ±0.69	17.43 ±0.98	17.64 ±0.84
	KDS	**Pre**	17.14 ±1.35	17.71 ±0.95	17.43 ±1.16	17.57 ±0.98	17.43 ±1.99	17.50 ±1.51	17.43 ±1.72	17.86 ±1.07	17.64 ±1.39
		Post	17.14 ±1.07	17.43 ±0.98	17.29 ±0.99	17.14 ±0.69	17.14 ±0.69	17.14 ±0.66	17.71 ±0.76	17.14 ±1.46	17.43 ±1.16
	CVKDS	**Pre**	17.43 ±0.53	18.29 ±0.76	17.86 ±0.77	17.43 ±0.79	17.00 ±1.73	17.21 ±1.31	17.43 ±1.40	18.29 ±0.76	17.86 ±1.17
		Post	17.57 ±0.79	18.29 ±0.76	17.93 ±0.83	17.14 ±0.38	17.29 ±0.76	17.21 ±0.58	17.71 ±0.76	17.29 ±0.76	17.50 ±0.76
	NOWU	**Pre**	17.29 ±0.49	17.00 ±1.00	17.14 ±0.77	17.00 ±0.82	17.00 ±0.82	17.00 ±0.78	17.86 ±1.07	17.29 ±1.25	17.57 ±1.16
		Post	17.57 ±0.53	17.57 ±0.98	17.57 ±0.76	17.29 ±0.49	17.00 ±1.00	17.14 ±0.77	17.00 ±0.58	17.00 ±1.15	17.00 ±0.88
ET	**CV**	**Pre**	160.41 ±10.28	162.63 ±6.88	161.52 ±8.48	161.69 ±5.70	161.25 ±10.06	161.47 ±7.86	161.79 ±4.62	164.87 ±13.54	163.33 ±9.85
		Post	160.87 ±7.31	160.36 ±9.01	160.61 ±7.89	161.76 ±4.61	158.65 ±9.82	160.21 ±7.55	161.84 ±6.23	159.94 ±14.68	160.89 ±10.88
	KDS	**Pre**	158.30 ±11.13	163.21 ±5.76	160.75 ±8.89	161.76 ±5.85	159.98 ±13.69	160.87 ±10.15	161.32 ±5.57	163.23 ±14.17	162.28 ±10.39
		Post	161.66 ±8.76	164.04 ±7.16	162.85 ±7.78	165.12 ±5.28	160.56 ±10.61	162.84 ±8.39	163.63 ±7.12	160.84 ±15.69	162.23 ±11.80
	CVKDS	**Pre**	159.37 ±11.54	163.61 ±7.69	161.49 ±9.67	162.39 ±5.24	160.40 ±11.37	161.39 ±8.57	160.65 ±4.88	160.02 ±13.15	160.33 ±9.54
		Post	162.45 ±9.02	159.86 ±8.64	161.15 ±8.59	161.67 ±5.37	159.28 ±11.09	160.48 ±8.46	164.02 ±7.35	157.25 ±13.27	160.64 ±10.89
	NOWU	**Pre**	159.37 ±9.06	164.07 ±8.90	161.72 ±8.97	163.91 ±4.78	159.60 ±11.53	161.76 ±8.77	163.31 ±7.25	163.05 ±13.75	163.18 ±10.56
		Post	162.70 ±7.36	163.45 ±9.24	163.08 ±8.04	162.38 ±4.08	160.39 ±9.83	161.39 ±7.30	164.63 ±6.35	161.89 ±14.04	163.26 ±10.57

CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; RPE: Rate of Perceived Exertion; ET: End Time (s)

Table 6. Differences between intra- and inter-group measurements of HR (p values)

			CV (n=14)			KDS (n=14)			CVKDS (n=14)			TOTAL (n=42)			Differences (inter) between groups		
			Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total
HRbut	CV	Pre	0.276	0.555	0.217	0.347	0.237	0.160	0.035*	0.218	0.882	0.282	0.055	0.067	0.232	0.805	0.219
		Post													0.251	0.429	0.228
	KDS	Pre	0.442	0.510	0.283	0.227	0.017*	0.032*	0.307	0.224	0.124	0.075	0.013*	0.006*	0.982	0.992	0.995
		Post													0.157	0.633	0.205
	CVKDS	Pre	0.151	0.268	0.072	0.428	0.234	0.142	0.656	0.581	0.493	0.386	0.305	0.190	0.403	0.260	0.127
		Post													0.889	0.820	0.855
	NOWU	Pre	0.011*	0.012*	0.523	0.510	0.718	0.473	0.177	0.890	0.849	0.082	0.701	0.489	0.079	0.986	0.289
		Post													0.943	0.040*†	0.334
HRback	CV	Pre	0.830	0.519	0.668	0.706	0.438	0.368	0.011*	0.758	0.342	0.165	0.291	0.709	0.074	0.618	0.246
		Post													0.329	0.327	0.175
	KDS	Pre	0.316	0.304	0.686	0.643	0.434	0.336	0.307	0.942	0.318	0.365	0.261	0.181	0.670	0.374	0.426
		Post													0.149	0.193	0.163
	CVKDS	Pre	0.172	0.675	0.166	0.559	0.819	0.849	0.831	0.688	0.677	0.444	0.729	0.401	0.887	0.749	0.787
		Post													0.647	0.849	0.575
	NOWU	Pre	0.911	0.023*	0.075	0.086	0.030*	0.773	0.191	0.689	0.411	0.773	0.009*	0.104	0.080	0.327	0.308
		Post													0.197	0.173	0.054
HRbre	CV	Pre	0.664	0.448	0.670	0.565	0.338	0.246	0.106	0.879	0.384	0.580	0.318	0.482	0.413	0.531	0.312
		Post													0.468	0.310	0.183
	KDS	Pre	1.000	0.416	0.480	0.749	0.364	0.320	0.293	0.702	0.248	0.258	0.174	0.086	0.755	0.647	0.584
		Post													0.197	0.190	0.125
	CVKDS	Pre	0.229	0.736	0.666	0.658	0.178	0.206	0.825	0.757	0.702	0.482	0.488	0.317	0.770	0.566	0.432
		Post													0.522	0.738	0.455
	NOWU	Pre	0.881	0.047*	0.095	0.073	0.028*	0.961	0.263	0.334	0.116	0.396	0.001*	0.151	0.284	0.121	0.156
		Post													0.101	0.136	0.027*†
HRfree	CV	Pre	0.109	0.707	0.759	1.000	0.494	0.492	0.316	0.817	0.456	0.181	0.532	0.929	0.761	0.464	0.392
		Post													0.391	0.294	0.175
	KDS	Pre	0.727	0.823	0.957	0.851	0.663	0.784	0.394	0.840	0.466	0.570	0.708	0.496	0.625	0.436	0.273
		Post													0.234	0.124	0.085
	CVKDS	Pre	0.618	0.827	0.583	0.915	0.559	0.593	0.885	0.178	0.498	0.725	0.164	0.307	0.683	0.336	0.314
		Post													0.449	0.584	0.337
	NOWU	Pre	0.766	0.121	0.216	0.390	0.031*	0.663	0.436	0.509	0.279	0.871	0.008*	0.169	0.519	0.095	0.137
		Post													0.310	0.212	0.069

*p<0.05; †: CV vs KDS; ‡: CVKDS vs KDS; §: CVKDS vs CV; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; HRbut: Heart Rate Butterfly (bpm); HRback: Heart Rate Backstroke (bpm); HRbre, Heart Rate Breaststroke (bpm); HRfree: Heart Rate Freestyle (bpm)

Table 7. Differences between intra- and inter-group measurements of LA, RPE and performance (ET) parameters (p values)

			CV (n=14)			KDS (n=14)			CVKDS (n=14)			TOTAL (n=42)			Differences (inter) between groups		
			Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total
LA1	CV	Pre	0.019*	0.029*	0.001*	0.027*	0.045*	0.002*	0.183	0.930	0.301	0.001*	0.016*	0.001*	0.975	0.685	0.949
		Post													0.686	0.409	0.303
	KDS	Pre	0.024*	0.420	0.117	0.061	0.030*	0.002*	0.895	0.237	0.508	0.018*	0.039*	0.001*	0.146	0.133	0.915
		Post													0.317	0.368	0.162
	CVKDS	Pre	0.161	0.975	0.247	0.794	0.803	0.701	0.345	0.416	0.906	0.107	0.752	0.326	0.644	0.127	0.343
		Post													0.993	0.051	0.221
	NOWU	Pre	0.623	1.000	0.666	0.464	0.117	0.237	0.951	0.411	0.482	0.539	0.667	0.976	0.882	0.476	0.796
		Post													0.822	0.512	0.808
LA6	CV	Pre	0.003*	0.010*	0.001*	0.006*	0.050	0.001*	0.175	0.316	0.074	0.001*	0.001*	0.001*	0.887	0.844	0.773
		Post													0.669	0.777	0.537
	KDS	Pre	0.023*	0.724	0.046*	0.074	0.213	0.025*	0.977	0.240	0.474	0.021*	0.075	0.003*	0.411	0.285	0.929
		Post													0.717	0.584	0.565
	CVKDS	Pre	0.044*	0.095	0.006*	0.584	0.073	0.160	0.238	0.424	0.879	0.026*	0.239	0.013*	0.660	0.582	0.593
		Post													0.990	0.039*‡	0.214
	NOWU	Pre	0.614	0.457	0.367	0.316	0.280	0.638	0.839	0.388	0.634	0.956	0.092	0.254	0.649	0.812	0.802
		Post													0.751	0.369	0.803
LA15	CV	Pre	0.020*	0.014*	0.001*	0.006*	0.069	0.001*	0.078	0.422	0.057	0.001*	0.003*	0.001*	0.956	0.726	0.774
		Post													0.919	0.778	0.731
	KDS	Pre	0.006*	0.422	0.008*	0.132	0.127	0.023*	0.464	0.059	0.044*	0.002*	0.008*	0.001*	0.148	0.201	0.717
		Post													0.657	0.753	0.590
	CVKDS	Pre	0.068	0.037*	0.003*	0.744	0.313	0.324	0.056	0.808	0.164	0.017*	0.058	0.002*	0.493	0.209	0.344
		Post													0.740	0.020*‡	0.572
	NOWU	Pre	0.647	0.326	0.377	0.987	0.185	0.533	0.870	0.850	0.981	0.724	0.205	0.333	0.680	0.441	0.405
		Post													0.706	0.908	0.589

Table 7. Continued

RPE	**CV**	**Pre**	1.000	0.231	0.336	0.604	1.000	0.671	0.103	0.604	0.165	0.204	0.229	0.078	0.764	0.871	0.984
		Post													0.498	0.951	0.654
	KDS	**Pre**	1.000	0.457	0.583	0.289	0.673	0.336	0.604	0.047*	0.512	0.847	0.107	0.185	0.841	0.848	0.914
		Post													0.373	0.853	0.736
	CVKDS	**Pre**	0.604	1.000	0.583	0.457	0.522	1.000	0.689	0.018*	0.389	0.858	0.261	0.570	1.000	0.088	0.220
		Post													0.274	0.034*† §	0.044*†
	NOWU	**Pre**	0.356	0.231	0.111	0.522	1.000	0.686	0.111	0.522	0.088	0.705	0.733	1.000	0.171	0.840	0.245
		Post													0.164	0.565	0.160
ET	**CV**	**Pre**	0.811	0.114	0.436	0.967	0.234	0.342	0.980	0.016*	0.081	0.843	0.002*	0.035*	0.925	0.812	0.816
		Post													0.948	0.959	0.979
	KDS	**Pre**	0.098	0.543	0.077	0.273	0.827	0.306	0.094	0.391	0.979	0.013*	0.797	0.129	0.680	0.842	0.902
		Post													0.673	0.827	0.981
	CVKDS	**Pre**	0.293	0.033*	0.847	0.722	0.396	0.417	0.122	0.198	0.846	0.147	0.008*	0.706	0.773	0.799	0.935
		Post													0.834	0.901	0.980
	NOWU	**Pre**	0.010*	0.686	0.190	0.184	0.643	0.712	0.466	0.618	0.953	0.218	0.746	0.583	0.461	0.755	0.898
		Post													0.759	0.879	0.824

*p<0.05; †: CV vs KDS; ‡: CVKDS vs KDS; §: CVKDS vs CV; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; RPE: Rate of Perceived Exertion; ET: End Time (s)

Table 8 and Table 9 present the variations in physiological and performance parameters between genders amongst the swimmers. Statistical disparities were found between genders in the HRbut, HRback, HRbre, LA1, LA6, LA15 and RPE values of the CV group after some warm-up protocols ($p<0.05$). The KDS group alone exhibited differences in HRfree between genders, while the CVKDS group displayed disparities in HRbut and HRback ($p<0.05$) after some warm-up protocols. Differences between genders were observed in HRbut, HRback, HRbre, and HRfree values after certain warm-up protocols ($p<0.05$) within the entire cohort.

Table 8. Differences in HR parameters between gender (p values)

			CV (n=14)	KDS (n=14)	CVKDS (n=14)	TOTAL (n=42)
HRbut	**CV**	**Pre**	0.905	0.849	0.012*	0.379
		Post	0.257	0.093	0.316	0.026*
	KDS	**Pre**	0.176	0.549	0.700	0.254
		Post	0.042*	0.253	0.084	0.011*
	CVKDS	**Pre**	0.921	0.619	0.424	0.421
		Post	0.258	0.440	0.355	0.080
	NOWU	**Pre**	0.166	0.876	0.347	0.724
		Post	0.005*	0.732	0.395	0.031*
HRback	**CV**	**Pre**	0.158	0.276	0.081	0.020*
		Post	0.247	0.052	0.392	0.045*
	KDS	**Pre**	0.041*	0.329	0.850	0.158
		Post	0.070	0.356	0.029*	0.007*
	CVKDS	**Pre**	0.267	0.074	0.630	0.079
		Post	0.441	0.151	0.466	0.088
	NOWU	**Pre**	0.659	0.488	0.024*	0.262
		Post	0.065	0.114	0.103	0.004*
HRbre	**CV**	**Pre**	0.141	0.312	0.217	0.029*
		Post	0.202	0.140	0.187	0.036*
	KDS	**Pre**	0.147	0.341	0.837	0.206
		Post	0.027*	0.620	0.055	0.025*
	CVKDS	**Pre**	0.371	0.426	0.742	0.283
		Post	0.661	0.268	0.601	0.200
	NOWU	**Pre**	0.400	0.359	0.133	0.419
		Post	0.054	0.079	0.101	0.003*
HRfree	**CV**	**Pre**	0.142	0.244	0.423	0.034*
		Post	0.203	0.038*	0.480	0.051
	KDS	**Pre**	0.325	0.537	0.434	0.160
		Post	0.092	0.704	0.070	0.047*
	CVKDS	**Pre**	0.705	0.341	0.876	0.568
		Post	0.766	0.230	0.697	0.232
	NOWU	**Pre**	0.338	0.414	0.304	0.530
		Post	0.142	0.365	0.323	0.058

*p<0.05; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; HRbut: Heart Rate Butterfly (bpm); HRback: Heart Rate Backstroke (bpm); HRbre, Heart Rate Breaststroke (bpm); HRfree: Heart Rate Freestyle (bpm)

Table 9. Differences in LA, RPE and performance (ET) parameters between gender (p values)

			CV (n=14)	KDS (n=14)	CVKDS (n=14)	TOTAL (n=42)
LA1	CV	Pre	0.423	0.708	0.144	0.133
		Post	0.631	0.353	0.730	0.307
	KDS	Pre	0.001*	0.870	0.752	0.140
		Post	0.101	0.861	0.702	0.240
	CVKDS	Pre	0.080	0.446	0.809	0.161
		Post	0.583	0.364	0.149	0.945
	NOWU	Pre	0.040*	0.834	0.457	0.144
		Post	0.043*	0.229	0.977	0.085
LA6	CV	Pre	0.238	0.392	0.289	0.065
		Post	0.871	0.554	0.543	0.384
	KDS	Pre	0.008*	0.666	0.871	0.094
		Post	0.079	0.851	0.650	0.241
	CVKDS	Pre	0.233	0.563	0.901	0.318
		Post	0.337	0.287	0.215	0.810
	NOWU	Pre	0.189	0.835	0.858	0.420
		Post	0.021*	0.370	0.598	0.069
LA15	CV	Pre	0.606	0.646	0.446	0.288
		Post	0.813	0.782	0.940	0.799
	KDS	Pre	0.005*	0.773	0.580	0.365
		Post	0.362	0.850	0.652	0.520
	CVKDS	Pre	0.160	0.401	0.659	0.262
		Post	0.121	0.231	0.178	0.405
	NOWU	Pre	0.294	0.783	0.900	0.386
		Post	0.077	0.507	0.954	0.290
RPE	CV	Pre	0.278	1.000	0.860	0.442
		Post	0.698	0.786	0.361	0.343
	KDS	Pre	0.377	0.867	0.586	0.493
		Post	0.611	1.000	0.377	0.748
	CVKDS	Pre	0.031*	0.567	0.179	0.220
		Post	0.109	0.663	0.310	0.555
	NOWU	Pre	0.515	1.000	0.377	0.327
		Post	1.000	0.515	1.000	0.712
ET	CV	Pre	0.644	0.921	0.586	0.549
		Post	0.909	0.462	0.760	0.499
	KDS	Pre	0.320	0.757	0.748	0.578
		Post	0.589	0.329	0.679	0.569
	CVKDS	Pre	0.434	0.682	0.908	0.849
		Post	0.593	0.618	0.261	0.170
	NOWU	Pre	0.348	0.380	0.966	0.988
		Post	0.869	0.630	0.647	0.624

*p<0.05; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; RPE: Rate of Perceived Exertion; ET: End Time (s)

Table 10. Differences in physiological and performance parameters according to warm-up protocols by groups

		CV (n=14)		KDS (n=14)		CVKDS (n=14)		TOTAL (n=42)	
		p	**η^2p**	**p**	**η^2p**	**p**	**η^2p**	**p**	**η^2p**
HRbut	**Pre**	0.149	0.372	0.150	0.371	0.031*^{d}	0.201	0.002*^{f}	0.315
	Post	0.027*^{f}	0.551	0.064	0.470	0.007*^{c}	0.262	0.001*^{ef}	0.396
HRback	**Pre**	0.013*^{df}	0.613	0.024*^{f}	0.561	0.021*^{df}	0.573	0.001*^{df}	0.411
	Post	0.001*^{ef}	0.757	0.019*^{ef}	0.222	0.071	0.163	0.001*^{ef}	0.489
HRbre	**Pre**	0.005*^{df}	0.675	0.021*^{f}	0.572	0.004*^{d}	0.688	0.001*^{df}	0.522
	Post	0.001*^{ef}	0.795	0.281	0.092	0.006*^{cf}	0.267	0.001*^{ef}	0.492
HRfree	**Pre**	0.003*^{df}	0.712	0.250	0.301	0.001*^{df}	0.790	0.001*^{df}	0.496
	Post	0.005*^{df}	0.679	0.037*^{cf}	0.193	0.008*^{cf}	0.259	0.001*^{ef}	0.516
LA1	**Pre**	0.001*^{c}	0.331	0.002*^{bc}	0.306	0.001*^{cf}	0.345	0.001*^{acef}	0.282
	Post	0.152	0.369	0.004*^{d}	0.693	0.034*^{f}	0.197	0.001*^{df}	0.146
LA6	**Pre**	0.001*^{c}	0.379	0.001*^{bc}	0.388	0.002*^{cf}	0.316	0.001*^{abcef}	0.326
	Post	0.516	0.056	0.525	0.055	0.031*^{c}	0.202	0.020*^{c}	0.077
LA15	**Pre**	0.001*^{c}	0.395	0.001*^{abc}	0.445	0.001*^{cef}	0.402	0.001*^{abcef}	0.357
	Post	0.106	0.144	0.529	0.055	0.055	0.176	0.010*^{f}	0.088
RPE	**Pre**	0.185	0.115	0.236	0.102	0.476	0.061	0.198	0.112
	Post	0.069	0.461	0.813	0.024	0.171	0.119	0.164	0.040
ET	**Pre**	0.767	0.029	0.895	0.015	0.008*^{bf}	0.258	0.138	0.044
	Post	0.069	0.164	0.020*^{a}	0.221	0.182	0.116	0.001*^{acd}	0.369

*p<0.05; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; HRbut: Heart Rate Butterfly (bpm); HRback: Heart Rate Backstroke (bpm); HRbre. Heart Rate Breaststroke (bpm); HRfree: Heart Rate Freestyle (bpm); RPE: Rate of Perceived Exertion; ET: End Time (s); [a]:CV vs KDS; [b]:CV vs CVKDS; [c]:CV vs NOWU; [d]:KDS vs CVKDS; [e]:KDS vs NOWU; [f]:CVKDS vs NOWU

Table 10 presents the variation in physiological and performance measures amongst swimmer groups following warm-up protocols. Results demonstrate significant differences in pre- and post-pulse rate, lactate values and finish time across all three groups and the total research cohort that arose due to the warm-up protocols ($p<0.05$). Furthermore, the effect size of this variation is primarily characterized at a high level. In contrast, there was no discernable variance in RPE according to the groups with respect to warm-up protocols ($p>0.05$).

Table 11 displays the physiological and performance parameter disparities among swimmers based on their gender-specific warm-up protocols. Results indicate that the pre- and post-pulse rates, lactate values, as well as finish times of all groups, were significantly different following the respective warm-up protocols. The effect size of this variance was classified as high ($p<0.05$). A difference was detected in the RPE study solely in men from the CV group and the entire male cohort, based on pre-post pulse, lactate values, and end time warm-up protocols according to both group and gender ($p<0.05$).

Table 11. Differences in physiological and performance parameters according to warm-up protocols by groups

		CV (n=14)				KDS (n=14)				CVKDS (n=14)				TOTAL (n=42)			
		Female		Male		Female		Male		Female		Male		Female		Male	
		p	η^2p	p	η^2p	p	η^2p	p	η^2p	p	η^2p	p	η^2p	p	η^2p	p	η^2p
HRbut	**Pre**	0.157	0.694	0.282	0.579	0.123	0.731	0.375	0.505	0.037*[c]	0.368	0.155	0.247	0.113	0.276	0.038*[b]	0.365
	Post	0.148	0.251	0.003*[c]	0.958	0.006*[c]	0.494	0.479	0.126	0.298	0.565	0.194	0.225	0.007*[cef]	0.479	0.007*[f]	0.484
HRback	**Pre**	0.033*[f]	0.377	0.035*[d]	0.860	0.013*[f]	0.915	0.550	0.378	0.005*[c]	0.947	0.482	0.125	0.001*[cdf]	0.677	0.058	0.333
	Post	0.033*[f]	0.378	0.001*[f]	0.988	0.095	0.292	0.167	0.240	0.068	0.320	0.099	0.288	0.001*[cef]	0.281	0.002*[f]	0.548
HRbre	**Pre**	0.013*[cf]	0.442	0.069	0.801	0.144	0.254	0.279	0.581	0.005*[ad]	0.947	0.350	0.163	0.001*[cdf]	0.703	0.013*[df]	0.444
	Post	0.004*[cf]	0.509	0.001*[f]	0.980	0.748	0.064	0.274	0.190	0.042*[e]	0.359	0.056	0.335	0.003*[c]	0.210	0.001*[ef]	0.682
HRfree	**Pre**	0.012*[cf]	0.448	0.021*[d]	0.893	0.010*[c]	0.459	0.917	0.108	0.087	0.299	0.087	0.299	0.001*[acf]	0.355	0.002*[df]	0.559
	Post	0.052	0.342	0.008*[df]	0.933	0.052	0.342	0.261	0.195	0.036*[cef]	0.370	0.069	0.319	0.001*[cef]	0.329	0.001*[f]	0.652
LA1	**Pre**	0.057	0.820	0.001*[ac]	0.659	0.067	0.321	0.037*[c]	0.368	0.014*[cf]	0.439	0.021*[f]	0.409	0.001*[cf]	0.311	0.001*[cf]	0.256
	Post	0.561	0.105	0.160	0.244	0.040*[d]	0.362	0.284	0.186	0.126	0.267	0.073	0.314	0.156	0.083	0.001*[df]	0.226
LA6	**Pre**	0.018*[c]	0.419	0.005*[cf]	0.506	0.002*[bc]	0.561	0.148	0.251	0.010*[cf]	0.459	0.165	0.241	0.001*[abcef]	0.447	0.001*[cf]	0.236
	Post	0.029*[a]	0.874	0.147	0.252	0.398	0.148	0.797	0.054	0.062	0.327	0.073	0.314	0.602	0.030	0.024*[c]	0.400
LA15	**Pre**	0.025*[c]	0.396	0.001*[c]	0.598	0.007*[c]	0.481	0.010*[c]	0.458	0.003*[c]	0.523	0.025*[f]	0.398	0.001*[cef]	0.387	0.001*[cef]	0.327
	Post	0.181	0.232	0.096	0.291	0.253	0.198	0.791	0.055	0.168	0.240	0.102	0.285	0.166	0.081	0.078	0.107
RPE	**Pre**	0.851	0.042	0.012*[f]	0.446	0.248	0.200	0.647	0.086	0.854	0.041	0.064	0.325	0.997	0.003	0.004*[f]	0.194
	Post	0.565	0.104	0.290	0.184	0.775	0.058	0.883	0.035	0.073	0.314	0.851	0.042	0.331	0.055	0.384	0.049
ET	**Pre**	0.373	0.156	0.826	0.047	0.744	0.243	0.757	0.062	0.199	0.223	0.011*[f]	0.453	0.148	0.085	0.377	0.050
	Post	0.613	0.093	0.020*[d]	0.413	0.062	0.328	0.310	0.176	0.164	0.242	0.253	0.198	0.071	0.110	0.007*[ad]	0.485

*p<0.05; CV: Critical Velocity; KDS: Kick Drill Swimming; CVKDS; Critical Velocity Kick Drill Swimming; HRbut: Heart Rate Butterfly (bpm); HRback: Heart Rate Backstroke (bpm); HRbre: Heart Rate Breaststroke (bpm); HRfree: Heart Rate Freestyle (bpm); RPE: Rate of Perceived Exertion; ET: End Time (s); [a]:CV vs KDS; [b]:CV vs CVKDS; [c]:CV vs NOWU; [d]:KDS vs CVKDS; [e]:KDS vs NOWU; [f]:CVKDS vs NOWU

4. Discussion

The study investigated the physiological responses of swimmers to varying warm-up protocols to determine potential gender differences. Physiological parameters monitored included blood lactate and heart rate, at various times, and perceived difficulty levels self-reported by the swimmers subsequent to the tests. In literature exploring the impact of warm-up exercises on physiological responses following swimming performance, assessments were made of blood lactate levels at varying time intervals, perceived exertion and heart rate. While certain studies indicate that the quantity of warm-up exercises yields physiological effects [15,9], others have reached contrasting conclusions [28]. For instance, a study carried out on male swimmers (n=10) has depicted that there were significant differences ($p<0.05$) in lactate values among high-intensity warm-up (13.66±2.66 mmol/L), low-intensity warm-up (9.53±2.22 mmol/L) and no warm-up (10.04±2.15 mmol/L) [15]. Another study revealed that LA 5.52±1.29 mmol/L after standard warm-up (1200 m), LA 5.01±0.95 mmol/L after short warm-up (600 m) and LA 4.01±0.74 mmol/L after long warm-up (1800 m) were identified. While standard warm-up and short warm-up did not yield any distinguishable differences ($p=0.19$), research indicates a significant disparity between long warm-up and both standard warm-up ($p=0.01$) and short warm-up ($p<0.01$). There was a significant disparity detected between the levels of LA (12.25±2.28 mmol/L) recorded following standard warm-up and swimming performance compared to the levels of LA (10.36±2.32 mmol/L) recorded following an extended warm-up and swimming performance ($p=0.04$) [9]. Upon examination of the literature indicating no disparity in post-performance blood lactate levels related to warm-up procedures, female swimmers recorded a mean value of 7.93±1.92 mmol/L without warm-up and 8.63±1.49 mmol/L ($p=0.71$) after complete warm-up (1000 m) during 50 m sprint swimming trials [28]. In a study of 13 male swimmers, LA1 was measured immediately after warm-up protocols with and without critical velocity. The results showed that LA1 levels were 3.96±2.23 mmol/L and 3.87±1.01 mmol/L, respectively. The authors found no significant difference in LA values between the two protocols ($p=0.88$). The study by Neiva et al. [10] found a lower peak LA value after reaching critical velocity, although the difference was not statistically significant ($p=0.07$). Czelusniak et al. [5] recently published a study on the effect of warm-up on lactate concentration, which predominantly showed a small to moderate impact. This study found inter-gender differences in LA1, LA6, and LA15 in the CV group ($p<0.05$), whereas the other groups did not show this result ($p>0.05$). Although there was no statistically significant difference, the blood lactate levels of female swimmers were generally higher than those of male swimmers. When analyzing the physiologic responses of male and female swimmers according to the warm-up protocols, similar results were obtained. Blood lactate levels were found to be higher after the CV and CVKDS protocols compared to the NOWU.

Studies investigating the heart rate of swimmers in relation to warm-up protocols did not examine gender differences, despite the inclusion of male and female swimmers in the research group [12,13]. In the study conducted by Al-Nawaiseh et al. (n=13; 4 females), it was observed that women had the lowest heart rate (26.25±0.96 beats/10 s and 26.44±1.51 beats/10 s) after performing a 50 m freestyle swimming event following a standard swim warm-up, compared to men. The heart rate of women was 27.50±1.00 beats/10 s after a short warm-up and 26.75±2.63 beats/10 s after a standard swimming warm-up [12]. Contrarily, a previous report stated that there was no disparity detected in the post-performance heart rate among male and female swimmers with the implementation of three distinct warm-up protocols: power, strength, and control. Males registered a heart rate of 159.9±11.0 beats/min after power warm-up and 161.0±9.6 beats/min after strength warm-up, whereas females accounted for 163.7±6.3 beats/min and 165.8±6.9 beats/min, correspondingly [13]. In a study of elite breaststroke swimmers (n=10; 4 female), the average heart rate following a 1350 m in-water warm-up and performance was 160±22 beats/min [29]. This investigation discovered gender variances in heart rate ($p<0.05$). Additionally, a review of warm-up procedures detected a discrepancy in heartbeats according to the protocols utilized in the studies. Ten male swimmers were studied to compare the effects of low and high intensity warm-ups with no warm-up on heart rate. A statistically significant difference was observed between the heart rate obtained during high intensity warm-up (177.0±7.4 beats/min) and no warm-up (170.4±8.7 beats/min) ($p<0.05$) [15]. In a recent study by Balilionis et al. [8], swimmers' heart rates were measured after completing 50 meters of freestyle swimming. The study found that without any warm-up, the average heart rate was 150±19 beats/min. After a short warm-up, the average heart rate decreased to 142±16 beats/min. However, after a standard warm-up, the average heart rate increased to 156±23 beats/min. A significant difference was observed between the three conditions ($p=0.03$). In another study, the performance of 14-16-year-old swimmers (n=10) was evaluated after completing 1100-1200 meters of in-water warm-up before a 100-meter freestyle swim. Following the performance, the recorded average heart rate was 145.2 beats/min. Ismail's [30] findings underscored that employing an in-water warm-ups consecutively led to a significant increase in heart rate. When comparing in-water warm-up with various static and dynamic land-based warm-ups, Kafkas et al. [17] found that swimmers' heart rate was 178.9±16 beats/min after performing freestyle and 174.9±17 beats/min while performing breaststroke. The warm-up protocols displayed differences that favored in-water warm-up in these two parameters ($p=0.020$; $p=0.010$, respectively). In addition to previous research, Kaya et al.

[31] conducted a study investigating the heart rate of 10 male swimmers aged 10-12 years during a 50 m freestyle without warm-up (134.80 ±8.83 beats/min) and after an in-water warm-up (133.60 ±7.30 beats/min) (p=0.50). Neiva et al. [9] assessed the impact of varied distance warm-ups on sprint swimming performance, with swimmers completing either a short warm-up (600 m), standard warm-up (1200 m), or long warm-up (1800 m). The average heart rate was 128 ±13 beats/min following the standard warm-up, 118 ±21 beats/min following the short warm-up, and 122 ±11 beats/min following the long warm-up. There was no significant discrepancy between the values (p>0.05). In the identical study, Neiva et al. [9] reported that the mean heart rate following warm-up and performance was 169 ±9 beats/min, 165 ±12 beats/min, and 172 ±10 beats/min for three different approaches, respectively. However, there was no significant difference in heart rate between warm-up protocols (p>0.05). A study investigated the impact of passive rest periods of 10 and 45 minutes after a 1500 m in-water warm-up on swimming performance in ten athletes (5 females). The results indicated that heart rate increased following both rest periods, with heart rates of 175 ±8 beats/min and 179 ±8 beats/min recorded after performance [32]. A study investigated the impact of critical velocity aquatic warm-up on sprint performance in male swimmers (n=13). The results showed that the mean heart rate increased by Δ15.7% following critical velocity warm-up (107 ±12 beats/min) compared to 1200 m standard warm-up (93 ±13 beats/min) (p<0.01). However, no significant difference was found in mean heart rate after performance between critical velocity warm-up (163 ±12 beats/min) and standard warm-up (160 ±15 beats/min) (p=0.21) [10]. During the study, variations were observed in the heart rate as per the warm-up protocols. Four distinct heart rate patterns were found to be higher after implementing CV and CVKDS protocols as compared to NOWU.

Upon reviewing the literature, it becomes apparent that the impact of warm-up on perceived difficulty lacks statistical significance in numerous studies [8, 28]. For instance, Neiva et al. [28] examined the ramifications of in-water warm-up on sprint freestyle swimming performance amongst female swimmers (n=7). Results indicated that the RPE was 15.14 ±1.22 after performance without warm-up, and 15.86 ±1.07 following a 1000 m in-water warm-up (p=0.24). A study examined the impact of passive rest time after a 1500-meter in-water warm-up on performance in swimmers (n=10; 5 males). Results indicate that RPE was 12.1 ±1.0 and 11.8 ±0.6 after 10 min and 45 min rest, respectively, whereas RPE was 17 ±1.0 and 16.7 ±0.9 after performance [32]. Dalamitros et al. [13] conducted a study with n=19 and 10 males which supports these results and found no difference between the three warm-up protocols in both women and men. Two studies investigated the impact of in-water warm-up on 50 m freestyle swimming performance for male and female swimmers respectively. Balilionis et al. [8] revealed that RPE was 15.3 ±2.2 after sprint performance without warm-up, 15.2 ±1.7 after short warm-up (50 y), and 16.1 ±1.4 after standard warm-up (~1300 m) for a group of 8 women and 8 men. The difference between RPE before and after warm-up was statistically insignificant (p=0.11). The study results show a mean difference of Δ7.5% (p<0.01) between RPE critical velocity warm-up (13.92 ±1.75) and standard warm-up (12.92 ±1.55). Following warm-up, the RPE critical velocity in the former was reported at 18.54 ±1.20 and 18.00 ±1.29 in the latter, with a significant difference recorded between them (p=0.01) [10]. Another study carried out on a sample of male swimmers (n=14) discovered an RPE of 8.07 ±1.07 [16]. In a study of 10 male swimmers, ages 10-12, the mean RPE was 14.90 ±0.35 after performing without warm-up, and 13.90 ±0.31 after performing with in-water warm-up (~15 min) (p=0.03) [31]. In a separate study, RPE after warm-up varied; it was 7.91 ±1.51 after a standard warm-up consisting of 1200m, 6.73 ±1.01 after a short warm-up consisting of 600m, and 7.36 ±1.69 after a long warm-up consisting of 1800m. There was a significant correlation observed between the standard warm-up and the short warm-up (p=0.02). However, no significant relationships were found between the long warm-up with the standard warm-up (p=0.51) and short warm-up (p=0.17). Neiva et al. [9] found no significant difference between the various warm-up protocols (standard warm-up 18.36 ±1.21; short warm-up 18.45 ±0.93 and long warm-up 18.63 ±0.81) following RPE sprint swimming performance (p>0.05). However, Czelusniak et al. [5] observed that warm-up had a moderate to large effect on RPE. There was no discernible variation in RPE between warm-up protocols, and this pattern persisted when taking gender into account, supporting the studies in the extant literature.

While there have been studies investigating the impact of various warm-up approaches or no warm-up on acute sprint swimming performance, the long-term effects of warm-up techniques that enhance acute performance have yet to be explored in young swimmers. This research established three distinct warm-up protocols (CV, KDS, CVKDS) to analyze the physiological implications of long-term warm-up techniques. When examining the physiological responses to long-term warm-up protocols in the study, differences in blood lactate, heart rate and RPE were found among the in-group measurements. However, although there was a difference between genders in four different heart rate styles in the last measurement, no such difference was detected in blood lactate and RPE. In the CV and CVKDS groups, NOWU was found to be favorable compared to warm-up protocols including critical velocity training in terms of the difference in blood lactate and heart rate. The preliminary and final measurements found no significant difference between the RPE warm-up protocols. The study's limitations are that it only involved young athletes aged 12-15 who had achieved success and that the warm-up protocols were not randomized. Through this research, it was found that swimmers require distinct warm-up protocols in water to attain optimal performance

in competitions, and these differ based on gender. As a valuable outcome of the study, we suggest that coaches identify the most effective warm-up protocol for each swimmer in advance of the competition. Considering the findings from the research, coaches who work with this age group are recommended to incorporate critical speed exercises during their in-water warm-ups.

5. Conclusions

In conclusion, this study demonstrates that gender influences the acute effects of various in-water warm-up protocols on the physiological parameters of swimmers preparing for competition. Interestingly, it was found that no warm-up had a detrimental effect on performance compared to in-water warm-up protocols. These results suggest that the acute performance of warm-up protocols, which included prolonged critical velocity training, was confirmed by the final measurements. It is reported that males and females did not show similar responses in certain parameters during the same warm-up protocol.

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