EFFECTS OF DIFFERENT TYPES OF WARM-UP ON SWIMMING PERFORMANCE, REACTION TIME, AND DIVE DISTANCE

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ABSTRACT

Balilionis, G, Nepocatych, S, Ellis, CM, Richardson, MT, Neggers, YH, and Bishop, PA. Effects of different types of warm-up on swimming performance, reaction time, and dive distance. *J Strength Cond Res* 26(12): 3297–3303, 2012—The purpose of this study was to evaluate the effects of 3 types of warm-up (WU) on swimming performance, reaction time, and dive distance. In repeated-measures counterbalanced design, National Collegiate Athletic Association Division I swimmers (n = 16) used 3 WUs before performing 50-yd (45.7-m) freestyle swim trials. The WU consisted of (a) no WU, (b) short WU (50-yd at 40% of swimmers' maximal effort and 50-yd at 90%), and (c) regular WU (usual precompetition WU). The mean 50-yd time was significantly faster ($p = 0.01$) after the regular WU (24.95 ± 1.53 seconds) when compared with that of the short WU (25.26 ± 1.61 seconds). However, individual data indicated that 19% of the participants performed their best in the 50-yd category after short, 37% after no, and 44% after regular WU. Heart rate was significantly higher ($p = 0.01$) after regular WU (100 ± 13 b·min^{-1}) when compared with that of the no WU category (88 ± 18 b·min^{-1}). However, no significant differences among WUs were found for reaction time ($p = 0.96$), rating of perceived exertion post 50-yd time trial ($p = 0.11$), dive distance ($p = 0.67$), or stroke count ($p = 0.23$). In conclusion, the average regular WU was better than short or noWU to achieve the fastest mean time in the 50-yd freestyle; however, some individual performances were faster after WUs different from their regular approach.

KEY WORDS 50-yd freestyle, stroke count, collegiate swimmers, no warm-up

INTRODUCTION

Swimming is a very demanding sport that requires extreme muscle strength and endurance. Only fractions of a second may separate the first place from the second (4).

A good swimming performance can be influenced not only by training, genetics, and opportunity, but also by a "warm-up" (WU), recognized as a key factor in athletic performance (4). Warm-up in swimming is defined as engaging in physical activity before the main event for the purpose of improving swimming performance (4). The WU intends to raise the body's temperature, increase blood flow, respiration rate, heart rate (HR), and flexibility of the involved muscles; however, it should not cause fatigue (9). In addition, WU in the competition swimming pool allows participants to become familiar with diving blocks, lanes, turning flags, and surface of the walls (for turns) (9). All of these WU aspects are believed to prepare an athlete for optimal performance during competition.

It is customary in a swimming competition to use a long WU, even for very short races. A long WU is, in general, believed to provide a "feel for the water" and to increase blood flow, HR, and flexibility of the involved muscles. However, long WUs require higher energy consumption and may contribute to overall muscle fatigue. For swimmers, swimming heats and finals in multiple events, fatigue from WU may contribute to fatigue accruing from swimming events. During a competitive swim season, when athletes often do not taper before competition, a long WU may detract from swimming training and consequently from performance.

Previous research has found conflicting evidence regarding the impact on performance of WU vs. no-WU (4). Romney and Nethery (11) found that mean 100-yd swimming performance was significantly better after a WU when compared with that after no-WU. Conversely, Mitchell and Huston (10) found no significant differences in mean 200-yd swimming performance after no, short, and regular warm-ups. In addition, unpublished data collected at The University of Alabama (6) and King's study (9) found

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no significant differences in the mean 50-yd swimming performance after no, short, and regular warm-ups. Although a variety of WU protocols are used currently, the precise load and intensity of an optimal WU an athlete requires are not known.

It is important to note that swimmers compete individually and not as a "group mean." Therefore, for swimming, it is important competitively to determine how each individual swimmer responds to different WUs. These individual results have seldom been published for any sport research.

Therefore, considering the inconclusive findings from previous research and the lack of individual data evaluation, the primary purpose of this study was to evaluate the effects of 3 different types of WU (no WU, short WU, and regular WU) on 50-yd swimming performance in collegiate swimmers. We hypothesized that a short WU or no WU would be better or would provide an increase or elicit the same benefits as a regular WU on 50-yd swim performance, reaction time, dive distance, stroke count, HR, and rating of perceived exertion (RPE). If shorter WUs allow equal swim performance, shorter or minimal WU may provide training advantages for some athletes.

Furthermore, individual swimmer's responses to differing WUs are also important. If some swimmers respond negatively to a given WU, their response may obscure the positive response of others. It is practical to match different WU approaches to different swimmers with no penalty (e.g., no loss of team cohesion). Therefore, the secondary purpose of this study was to evaluate individual responses to different types of WUs on 50-yd swimming performance.

Methods

Experimental Approach to the Problem

The purpose of this study was to evaluate the effects of no WU, short WU, and regular WU on 50-yd swimming performance, reaction time, stroke count, and dive distance in collegiate swimmers. A repeated-measures counterbalanced design was used in which National Collegiate Athletic Association (NCAA) Division I swimmers performed no, short or regular WUs before performing 50-yd (45.7-m) freestyle swim trial. The 50-yd swim performance trial was chosen because it is the shortest event in a swimming competition and requires just one flip turn. The impact of the WU would be diluted during a longer swimming event because of multiple turns that swimmers need to complete during the race and the expected reduced impact for longer times and longer swims. The impact of the different WUs on 50-yd swim performance was evaluated. In addition to the 50-yd swim performance, the effect of WUs on other variables such as reaction time, dive distance, and stroke count were evaluated.

Subjects

The number of participants chosen is based on power estimation with an alpha level set at 0.05 and a power of >0.8. The power calculator (DSS Research) estimated our sample size to be 16 to detect an effect size of 0.1 second difference in 50-yd swimming performance between WUs, where alpha level (p) would be 0.05 and power would be >0.8.

Eight male and 8 female NCAA Division I swimmers, between 19 and 25 years of age volunteered to participate in the study. The participants' physical characteristics, such as age, weight, height, and percent body fat, are presented in Table 1. All the participants provided written informed consent in accordance with the local Institutional Review Board.

All the participants had been involved in competitive swimming for at least 5 years. The participants' swimming experience ranged from 6 to 15 years. The average swimming experience is presented in Table 1. During the study, the participants had been in postseason training for the previous 3 weeks and trained 5 times a week during the duration of the study. Volume and intensity were identical for all the swimmers during postseason training. The volume varied between 3 and 4 km per practice session. Before post-training, all the participants were engaged in season practices for 7 months.

Before the study, each participant completed a Health Status Questionnaire (American College of Sports Medicine Risk Stratification) and a Physical Activity Readiness Questionnaire (PAR-Q) to determine any health risks before the study. A positive answer to the PAR-Q eliminated the participant from the study. In addition, a training

Table 1. Participants' mean (± *SD*) age, weight, height, percent body fat, swimming experience, best 50-yd time, and regular warm-up distance during competition ($n = 16$).

Characteristics	Male participants ($N = 8$)	Female participants ($N = 8$)
Age (y)	19.9 ± 0.6	19.8 ± 0.7
Weight (kg)	76.6 ± 5.1	66.3 ± 8.8
Height (cm)	182.4 ± 6.9	172.9 ± 4.6
% Body fat	9.6 ± 2.2	22.5 ± 2.7
Swimming experience (y)	10.9 ± 2.5	12.3 ± 3.1
Best 50-yd time (s)	21.96 ± 0.82	24.35 ± 0.70
Regular warm-up (m)	1257 ± 160	1314 ± 109

status questionnaire was given to the participants to obtain information about years of experience, preferred stroke, distance, and best swimming times. Furthermore, the participants were asked to avoid alcohol, caffeine, and physical activities (that were not related to swimming practice) at least 24 hours before every session. Also, the participants were asked to avoid heavy food consumption and energy drinks at least 3–4 hours before each test session.

The participants were excluded from the study if any of the following was true: (a) the participant was younger than 19 years (age of majority locally); (b) in the past 6 months if the participant had a shoulder injury; (c) screening forms indicated any previous cardiovascular or respiratory problems or other major chronic diseases that may have limitations for exercise in the participant; (iv) the participant had any type of surgery or injury that may have resulted in an increased risk of exercise participation.

Before the testing sessions, study design and procedures were explained; informed consent was obtained, screening procedures were completed; and height, weight, and percent body fat were recorded. The use of skinfold calipers (Lange, Beta Technology Incorporated, Cambridge, MD, USA) measured the following 3 sites (chest, abdomen, and thigh for men and triceps, suprailiac, and thigh for women). Percent body fat was estimated from the sum of skinfold sites and age (7,8). The participants wearing swimwear were weighed using a calibrated scale (Beam Balance, DETECTO, Web City, MO, USA). Height was self-reported and recorded. Also, years of experience, preferred swimming stroke, and best 50-yd freestyle time were recorded through the training status questionnaire (Table 1). The training status questionnaire indicated that 69% of the participants (11 participants) were sprinters and 31% (5 participants) were middistance or long-distance swimmers.

Procedures

Warm-Up Types. Three different types of WU protocols were used in this study. Warm-up order was counterbalanced and separated by 48 hours of rest between each performance trial. After the participants completed each WU, they were afforded 3 minutes of rest before the 50-yd (45.72-m) maximal performance trial. All the participants swam freestyle.

No WU–no physical activity was performed during this time. The participants rested for 3 minutes.

Short WU–The participants completed a 50-yd freestyle swim at 40% of their maximal effort and another 50-yd swim at 90% of their maximal effort (total: 100 yds [91.44 m]).

Regular WU–the participants completed their own precompetition swim WU. The WU lengths were recorded and are given in Table 1.

Measurements

The 45.7-m (50-yd) Maximal Performance Trial. The maximal performance trial measured how fast each participant completed a 47.2-m (50-yd) maximal-effort time trial. A timing system (Colorado Time Systems, Loveland, CO, USA) was used to time the trials. The system was attached to the swimming pool wall. The participants climbed on the diving block and were given a verbal command "take your mark" and a beep sound ("start" signal) of the timing system was used to start the time trial. With the "start" signal, the system started the time as participants dove off the block. As each participant completed the trial by touching the swimming wall, the system stopped and recorded the 50-yd time to the nearest hundredth of a second and, subsequently, each score was recorded. In addition, there were 2 manual stop watches used as a back-up if the main system did not record the time. The mean times of the 2 stop watches were recorded. The 50-yd freestyle was chosen, because it is the shortest swimming event during the competition, and most swimmers are adept at freestyle swimming. Only one flip turn was required to complete the race, whereas longer swimming events would require multiple laps and flip turns which would have diluted the impact of the WU.

Diving Distance

A video camera and software (Dartfish software, Alpharetta, GA, USA) was used to record and measure the diving distance. Dive distance was measured as the distance from the diving block to the first touch of the water. Participants' dive distance was analyzed and reported in centimeters.

Reaction Time

Reaction time was measured as the time between the "start" signal and the first movement of the participant using a reaction pad attached to the block (Daktronics, Brookings, SD, USA). Each participant's reaction time was measured to the nearest hundredth of a second, and reported in seconds.

Rating of Perceived Exertion

The participants were asked to rate the WU and 50-yd maximal performance trial session using Borg's 15-point scale (5). The scale was explained in detail and was supported by a visual aid. The RPE was determined post-WU and post 50-yd-maximal performance swim trial.

Heart Rate

Heart rate was measured by manual palpation method at the wrist or neck. The manual palpation method was explained in detail to the participants before testing. All the participants were familiar with this procedure because they used this method in regular swimming training. The heart rate was measured 30 seconds before the swim trial and immediately after the 50-yd maximal performance trial. The participants counted their own HR for 15 seconds. Heart rate was reported as beats per minute.

Stroke Count

During the 50-yd-maximal performance trial, strokes were counted. However, to minimize error, stroke count was counted in cycles. One cycle was equal to 2 strokes. The cycle started when the first arm of the participant entered the water and it ended when it recovered.

Statistical Analyses

All statistical analyses were performed on a commercially available statistical platform (SSPS Version.16, Chicago, IL, USA). A series of 1-way repeated-measures analysis of variance (ANOVA) was used to analyze the difference in 50-yd time trial performance, dive distance, stroke count, reaction time, RPE, and HR between the 3 WU protocols. Significance was accepted at an $\alpha < 0.05$ level. Differences between WU protocols for any variable that demonstrated significance were examined by a least significant difference post hoc multiple comparison test. In addition, the number of individuals recording their fastest time for a given WU was reported as a percentage of the total group. Data were reported as mean ± *SD*.

Results

Descriptive data of the participants and regular WU distance are shown in Table 1. The timing system did not record 50-yd time for 2 participants in one 50-yd time trial. Two manual stop watches were used as a back-up for time to completion, and the mean time of the 2 was recorded.

Results for the 1-way repeated measures ANOVA revealed a significant main effect ($p = 0.03$) among WU protocols on 50-yd time trial (Table 2). Post hoc measures revealed that the group mean 50-yd time trial was significantly ($p = 0.01$) faster after regular WU (24.95 ± 1.53 seconds) compared with the short WU (25.26 ± 1.61 seconds) and approached significance ($p = 0.06$) between regular and no (25.19 ± 1.54 seconds) WUs. No significant difference was found between no and short WUs ($p = 0.59$) on 50-yd time. Further, individual data indicated that 19% of the participants swam their best 50-yd time after a short WU, 37% after no WU, and 44% after regular WU (Figure 1).

A significant main effect between WUs ($p = 0.02$) was found for HR before the 50-yd swim trial (Table 2). Post hoc measures found HR was significantly ($p = 0.01$) higher after regular WU (100 ± 13 $b \cdot min^{-1}$) compared with no WU (88 ± 18 $b \cdot min^{-1}$) and approached significance between short (92 ± 19 $b \cdot min^{-1}$) and regular WUs ($p = 0.07$). No significant difference was observed between no and short WUs ($p = 0.32$) in HR response.

Similarly, there was a significant main effect ($p = 0.03$) for the HR post 50-yd swim trial among WUs (Table 2). Heart rate was significantly ($p = 0.01$) higher after regular WU (156 ± 23 $b \cdot min^{-1}$) compared with that after short WU (142 ± 16 $b \cdot min^{-1}$). No significant differences were found between no (150 ± 19 $b \cdot min^{-1}$) and short WUs ($p = 0.14$), and no and regular WUs ($p = 0.24$).

A significant main effect ($p < 0.01$) for RPE after WU was found among WU types (Table 2). The RPE was significantly ($p < 0.01$) lower after no WU (6.3 ± 0.5) compared with that after short WU (10.1 ± 1.7) and regular WU (12.1 ± 1.0). Also, the RPE was significantly ($p = 0.001$) lower after short WU compared with that after regular WU.

The reaction pad did not record reaction time for 1 participant in two 50-yd time trials and for 2 participants in one 50-yd time trial. All the 3 participants were removed from the reaction time statistical analysis. No significant differences were found in reaction time ($p = 0.96$), RPE post 50-yd time trial ($p = 0.11$), dive distance ($p = 0.67$), and stroke count ($p = 0.23$) among the WUs. Results from the 50-yd time trial results, HR pre and post 50-yd performance

Table 2. The main effect of no, short, regular WUs on 50-yd swim time, pre and post HRs, warm-up RPE, 50-yd swim RPE, dive distance, reaction time, and stroke count (nr) ($n = 16$).*†

	No WU	Short WU	Regular WU	Sig (p)
50-yd time (s)	25.19 ±1.54	25.26 ± 1.61	24.95 ± 1.53‡§	0.03
HR pre 50 ($b \cdot min^{-1}$)	88 ± 18	92 ± 19	100 ± 13‖	0.02
HR post 50 ($b \cdot min^{-1}$)	150 ± 19	142 ± 16	156 ± 23‡	0.03
WU RPE	6.3 ± 0.5	10.1 ± 1.7	12.1 ± 1.0¶	0.01
50-yd RPE	15.3 ± 2.2	15.2 ± 1.7	16.1 ± 1.4	0.11
Dive distance (cm)	319.9 ± 31.8	317.4 ± 25.8	316.9 ± 31.6	0.67
Reaction time (s)#	0.77 ± 0.10	0.77 ± 0.09	0.77 ± 0.06	0.96
Stroke count	28.7 ± 5.0	29.3 ± 4.9	29.3 ± 4.9	0.23

*WU = warm-up; HR = heart rate; RPE = rating of perceived exertion.
†Values are given as mean ± *SD*.
‡Approached significant difference ($p = 0.06$) between no WU and regular WU.
§Significant difference ($p < 0.05$) between short WU and regular WU.
‖Significant difference ($p < 0.05$) between no WU and regular WU.
¶Significant difference ($p < 0.05$) between short WU and regular WU and between no WU and regular WU.
#Thirteen participants in the statistical analysis.

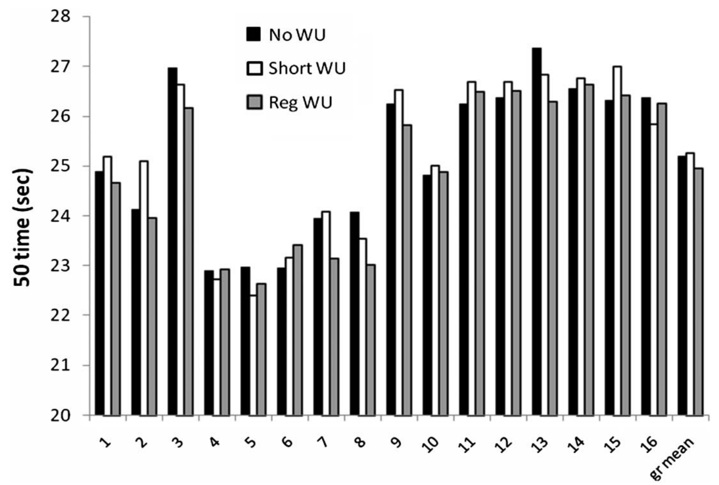

Figure 1. Individual 50-yd times after no, short, and regular warm-ups ($n = 16$).

trial, RPE post WU and post 50-yd performance trial, dive distance, reaction time, and stroke count after each WU are presented in Table 2.

Discussion

The purpose of this study was to evaluate the effect of 3 different types of WU (no WU, short WU, and regular WU) on 50-yd freestyle swimming performance, reaction time, and dive distance in collegiate swimmers. The choice of 50-yd freestyle swimming was made because measuring any longer swimming protocol would dilute the effect of the WU. In addition, it is the shortest event in swimming competition, and all swimmers are adept at freestyle swimming. The hypothesis that short WU or no WU would be better or would have the same benefits as regular WU on 50-yd swim performance was rejected. The results of this study indicated that 50-yd swimming time was significantly faster ($p = 0.01$) after regular WU (24.95 ± 1.53 seconds) compared with that after short WU (25.26 ± 1.61 seconds). In addition, 50-yd swimming time approached a significantly faster time ($p = 0.06$) after regular WU compared with that after no WU (25.19 ±1.54 seconds). However, no significant difference was found between no and short WUs ($p = 0.59$).

Swimming WU serves to raise the body's core temperature, increase blood flow, respiration rate, HR, and flexibility of the involved muscles, which may prepare a swimmer for optimal performance (2,9). In this study, HR was significantly different after 3 WUs. The HR was higher after the regular WU (100 ± 13 b·min^{-1}) compared with that after the short (92 ± 19 b·min^{-1}) and no (88 ± 18 b·min^{-1}) WUs. These results serve to confirm earlier findings by Mitchell and Huston(10) and Zochowski et al. (12). Previously reported improvements in swimming performance after WU have been attributed to an increase in the HR causing elevated baseline $\dot{V}O_2$, increased muscle and core temperature (3). In this study, the HR after regular WU was significantly higher compared with other WUs, which could have had an effect on the time in the 50-yd performance because of an elevated cardiac output at the start. In addition, higher HR and elevated $\dot{V}O_2$ were reported after low- and high-intensity swimming WU protocols compared with low-intensity WU and no WU (10).

Active WU at moderate intensity and for no less than 5 minutes was reported to increase muscle and core temperatures (1–3,12). In this study, the regular WU lasted at least 10 minutes. As would be expected, the reported RPE values indicated that the regular WU (12.1 ± 1.0) was perceived as significantly harder compared with the no (6.3 ± 0.5) and short (10.1 ± 1.7) WU trials. The regular WU was perceived as "somewhat hard" indicating moderate intensity. Therefore, improvements in 50-yd swim time after regular WU may be attributed to increased muscle and core temperatures.

Additionally, psychological changes may contribute to improved performance in athletes (2). Previous research has shown that WU increases preparedness and provides time to concentrate before the race (2). This might contribute to the fastest mean 50-yd times after regular WU. Parallelly, some participants might be discouraged and have lack of motivation to race with no WU or a short WU which may explain the tendency toward slower mean 50-yd times after no (25.19 ±1.54 seconds) and short (25.26 ± 1.61 seconds) WUs in this study.

To date, there are a limited number of studies available that have examined swimming performance using different types of WU protocols. The results from previous reports have been equivocal with conflicting evidence of WU vs. no WU benefits. The results of this study support study of Romney and Nethery (11), who found a significantly faster 100-yd swim time after 15 minutes of swimming WU compared with no WU. However, King (9) found no significant difference in 50-m swim time between a 400-m swim WU and no WU. This might be because of a smaller sample size ($N = 13$) and large age variability (age range 9–24 years) in his study. In addition, a 400-m WU might not be sufficient enough to raise muscle and core temperatures; thus, no difference between 400-m WU and no WU was found. Moreover, Bobo (4) found no significant differences in 100-yd swim time between 800-yd swim WU and no WU. Also, Mitchell and Huston

(10) found no significant difference in 183-m (200-yd) swim time between no-, low-intensity (365 m), and high-intensity (365 m) WUs. Low-intensity, 365-m (400-yd) WU may not be sufficient to raise muscle and core temperatures, thus resulting in no significant difference between no- and 365-m WU protocols. Furthermore, the high-intensity WU was completed at 110% of $\dot{V}O_2$max and thus could have caused fatigue. No difference between WUs in 183-m swim time could be explained by insufficient low-intensity WU and fatigue caused by high-intensity WU. In addition, WU effect might be diluted because of a relatively long swimming event (183 m). There is a possibility that the longer the performance swim the lower the ability to detect a possible difference because of the WU.

The RPE after the 50-yd swim trial was not significantly different among WU protocols. This indicates that participants felt the same after each 50-yd swim trial regardless of WU type and despite variable levels of RPE before the 50-yd swim trial. This study supports the findings of Romney and Nethery (11), who found that RPE was not significantly different after 100-yd trial between WUs. Similarly, there was no significant difference found in stroke count between WUs. These findings confirm the results of a previous work by Zochowski et al. (12), who found no difference in stroke count in a 200-m swim performance. In addition, in this study, WU had no effect on dive distance or reaction time. The specific protocols used in this study may not have prepared specific-skills required for diving and reaction time. No practice dives off the blocks or jumps on the deck were performed during no-, short-, or regular WUs.

Although the regular WU produced, on average, faster mean time, there was a need to look at the individual results to detect individual variability. Swimmers swim as individuals and not as a "group." Indeed, not every individual necessarily responds to the treatments in the same manner. If an individual performs consistently better after a specific WU such as no-, short-, or regular-WU, coaches should recognize that individuality and employ that specific WU to maximize that athlete's performance. For some individuals, no- or short WU might be better than regular WU.

Individual data of this study indicated that 19% of the participants swam the best 50-yd time after short WU, 37% after no WU, and 44% after regular WU (Figure 1). Noteworthy is that in our trials, over half the swimmers swam their best time using a WU different from their usual WUs. These results are similar to the unpublished data previously collected at our university (6). Those data indicated that 15% of participants achieved best time with regular WU (1,100 yd), 54% with mixed WU (200 + 10 vertical push from the bottom of the pool), and 31% with short WU (100 yd).

In individual data, there was no difference observed between sprinters and mid–long distance swimmers. Two mid–long distance swimmers achieved their best 50-yd time after regular WU, 2 after no WU, and 1 after short WU. Also, there was no different pattern observed between genders on 50-yd time with different types of WUs. Four men and 3 women performed their best 50-yd time with regular WU, 2 men and 4 women with no WU, and 2 men and 1 woman with short WU. Individual data indicated that there is a need to recognize the best WU for each individual to achieve the best 50-yd swim time.

In conclusion, the best group-mean 50-yd freestyle mean times were performed after regular WUs. However, regular WU was perceived as more intense compared with the other WUs. In addition, HR was higher before the 50-yd trial after the regular WU than for the other 2 WU conditions. The faster group mean in 50-yd swim time after regular WU may be attributed to an elevated baseline $\dot{V}O_2$, increased muscle and core temperatures, and psychological effects. However, there was large individual variability, and just 44% of the swimmers achieved their fastest time after regular WU. We recommend that swimmers and coaches experiment to determine each individual's optimal WU to maximize the 50-yd swim performance.

This is the first study that has looked at individual results on 50-yd swimming performance after different types of WUs. Our results are limited to the 50-yd swimming event. Because every swim event begins with a 50-yard swim, improvements in the first 50 yds will likely show up in overall swim time, though for longer events, the effect will be diluted. However, there is a need for future research to determine the stability of results of alternative WUs for a 50-yd race. Also, there is a need to investigate the impact of a WU effect on longer swimming event times.

Practical Applications

The results of this study indicated that the fastest mean 50-yd swim time was after regular WU. However, coaches work with individual swimmers rather than group means to maximize training and performance. Individual analyses are necessary to determine the best WU for the individual swimmer. In this study, less than half of our swimmers swam their best time after their regular WU, with the remaining swimming better after short WU or no WU. Coaches should take into consideration that no- or short- WUs may be better for some individuals compared with regular WU. Because, in race, often only one-hundredth of a second separates swimmers in a competition, and coaches should invest time and effort during the off-season to determine the individual WU needed for the athlete to perform at their best. This study indicates that although regular WU does, on average, give the best performance, individuals do not always swim their best 50-yd freestyle time with their traditional WUs.

References

1. Arnett, MG. Effects of prolonged and reduced warm-ups on diurnal variation in body temperature and swim performance. *J Strength Cond Res* 16: 256–261, 2002.

2. Bishop, D. Warm-up I. Potential mechanisms and the effects of passive warm-up on exercise performance. *Sports Med* 33: 439–454, 2003.
3. Bishop, D. Warm-up II. Performance changes following active warm-up and how to structure the warm up. *Sports Med* 33: 483–498, 2003.
4. Bobo, M. The effect of selected types of warm-up on swimming performance. *Int Sports J* 3: 37–43, 1999.
5. Borg, G. Perceived exertion: A note bon "history" and methods. *Med Sci Sports* 5: 90–93, 1972.
6. Individual Study. Warm-up procedures and their impact on a 50-yard sprint swim. Master's Thesis, University of Alabama, Tuscaloosa, 2002.
7. Jackson, AS and Pollock, ML. Generalized equations for predicting body density of men. *Br J Nutr* 40: 497–504, 1978.
8. Jackson, AS, Pollock, ML, and Ward, A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc* 12: 175–182, 1980.
9. King, A. The relative effects of various warm-up procedures on 50 meter times of trained, competitive swimmers. *J Phys Educ* 7: 22–24, 1979.
10. Mitchell, JB and Huston, JS. The effect of high- and low-intensity warm-up on the physiological responses to a standardized swim and tethered swimming performance. *J Sports Sci* 11: 159–165, 1993.
11. Romney, RC and Nethery, VM. The effects of swimming and dryland warm-ups on 100-yard freestyle performance in collegiate swimmers. *J Swim Res* 9: 5–9, 1993.
12. Zochowski, T, Johnson, E, and Sleivert, GG. Effects of varying post-warm-up recovery time on 200-m time-trial swim performance. *Int J Sports Physiol Perform* 2: 201–211, 2007.