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Research article

Diving into Recovery. The Effects of Different Post-Competition Protocols for Enhancing Physio-Psychological Parameters in National Level Youth Swimmers

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Abstract

The purpose of this study was to elucidate whether a specific approach regarding active swimming recovery could better promote psycho-physiological recovery right after competing in a high-level swimming race. To achieve this, we recruited 50 national level youth swimmers, randomly and equally assigning them to two groups, named “experimental” and “coach prescribed”. Each group performed a specific post-competition recovery protocol, consisting of different swimming paces, rest times, self-management of the exercises. We gathered data about blood lactate (BL), heart rate (HR), and rate of perceived exertion (RPE) at two different moments, the first moment right after the swimming competition (named post-competition phase), the second moment right after swimming the respective recovery protocol assigned (named post-recovery phase). A mixed MANOVA with Tukey HSD post-hoc analysis revealed no significant differences between the experimental and coach-prescribed groups in BL, HR, and RPE at the post-competition phase. At the post-recovery phase, however, the experimental group presented lower BL levels than the coach-prescribed group (2.40 ± 1.18 vs. 4.29 ± 2.07 mmol/L, $p < 0.05$). Finally, we found no interaction of swimming race ranking on recovery capacities. We conclude that for immediate improvement of BL in a wide range of high-level swimmers, an efficient recovery protocol should consist of several paces, high volumes, fixed and short rest times, whereas the widely popular self-managed, lower intensity approach does not seem as equally effective. Our study advances the development of novel recommendations for optimizing immediate fatigue management in competitive swimming.

Key words: Cooling-down; performance; fatigue; swimming; sports; exercise.

Introduction

Swimming races involve maximum physio-psychological efforts from its participants, which can result in massive accumulation of metabolic waste products, dehydration, extreme rate of perceived exertion, and almost complete depletion of energy stores (Gonjo and Olstad, 2020). Consequently, the challenging demands of competitive clashes lead the athletes to experience peak levels of fatigue, as well as decreased performances for highly variable periods, which can last from minutes to even days (Kellmann et al., 2018). To mitigate these unavoidable issues, it is crucial to start the recovery process as soon as possible, particularly after competitive/highly intense endeavors (Poppendieck et al., 2013). In this regard, the aquatic medium has been revealed to be decisively influential in improving critical physiological parameters right after intense bouts of swimming. For instance, research has shown that after high-intensity sessions of swimming, recovery protocols performed in-water displayed higher rates of blood lactate removal than either passive recovery or land-based recovery (Ali Rasooli et al., 2012; Mota et al., 2017; Kostoulas et al., 2018). The higher efficiency of water-based protocols has been attributed to several factors. From a fluid-dynamic standpoint, the hydrostatic pressure of water provides external support to the body, which can enhance venous return and reduce pooling of blood in the lower extremities, ultimately allowing for better inter-exchange for H+ removal and faster metabolic recovery (Buchheit et al., 2010). Bearing this evidence in mind, swimmers have then been considerably advised to undertake active, swimming-based recovery protocols, rather than passive or land-based ones.

Nevertheless, when it comes to establish the optimal framework for designing efficient swimming recovery formats, several issues still need to be adequately addressed within the scientific literature. One critical element concerns the lack of standardized protocols. That is, recovery protocols post-intense swimming are largely uncontrolled, being arbitrarily selected by athletes, coaches and/or governing bodies (Mota et al., 2017; Pollock et al., 2019; Faghy et al., 2019). Although this approach may be respectful of the principle of training specificity and has shown to effectively reduce muscular fatigue to some extent, it relies heavily on the personal experience and present sensations of the single swimmer/swimming coach, thus exposing experimental and coaching designs to inter-variability fallacies and limitations. Furthermore, reported inconsistencies about the apt paces to sustain while swimming for post-race recovery purposes (Toubekis et al., 2006; Kostoulas et al., 2018; Pratama and Yimlamai, 2020) further suggest the need to develop more general recommendations for optimal parameters of intensity, volume, duration, and means to use, without basing entirely on the swimmers’ self-perception.

To our knowledge, there are no studies in swimming that examine the effect of a specific recovery protocol after the competition on national youth swimmers. Bearing to this in mind, in the present study we investigated the effectiveness of two different active, water-based, post-competition recovery protocols for enhancing both physiologi-

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cal, i.e., capillary blood lactate (BL) and heart rate (HR), as well as psychological, i.e., rate of perceived exertion (RPE) indicators of fatigue, recruiting youth swimmers competing at the national level from 50m (sprinting) to 400m (middle-distance) races. One protocol, named “experimental”, was designed by an experienced coach and the investigators from this research group, whereas the other protocol, defined as “coach-prescribed”, sought to reflect coaches' habits and common practices in recovery-protocols prescriptions (Lomax, 2012; Pollock et al., 2019; Faghy et al., 2019). We hypothesize that the experimental approach would better enhance BL, HR, and RPE after the swimming race, compared to the coach-prescribed strategy. This was based on the following proposition. If in-water immersion causes increased cardiac output, increased blood flow, and subsequent nutrient and waste transportation through the system without increasing energy expenditure all while decreasing fatigue (Wilcock et al., 2006), and if in-water active recoveries are more effective than passive in-water recovery in removing metabolic waste after intense swimming bouts (Toubekis et al., 2005; Toubekis et al., 2006; Mota et al., 2017), then the key towards optimizing recovery protocols has to be achieved by manipulation of the exercise variables, such as intensity, swimming paces, volume, rest between sets, etc. Considering this, it would then be sub-optimal to maintain a sole “steady” or “self-managing” swimming pace throughout the recovery session, because this strategy would likely miss on maximizing the beneficial physiological processes that elicits during swimming recovery. In the context of defining cardiac output, it is referred to as the volume of blood ejected by the heart per minute (measured in L/min). This process is essential for distributing blood throughout the body (Wilcock et al., 2006). High-intensity physical endeavors can significantly affect the body's demand for oxygen, subsequently leading to alterations in cardiac output. Cardiac output is regulated by two key factors: HR and stroke volume (SV). In fact, it is precisely calculated by multiplying HR and SV. The amount of blood ejected by the heart, where HR plays a central role, closely aligns with the body's overall metabolic requirements. Any deviations from the baseline cardiac output are directly proportional to changes in the body's oxygen needs, particularly during activities such as intense swimming. In situations of intense physiological stress, the cardiac output increases to ensure adequate blood supply to the body's tissues. This physiological response leads to an elevated HR (Wilcock et al., 2006), which we have utilized as a measure of physiological fatigue resulting from the strenuous demands of competitive swimming.

Furthermore, by leveraging on the fact that the experiment was conducted during an official, national swimming competition, we further investigated whether the swimmers with the best rankings also presented the highest recovery rates. This hypothesis was based on research already indicating that top ranked swimmers delivering the best race-times are stronger (Sorgente et al., 2023), faster (Lopes et al., 2021), more powerful (Born et al., 2020), and in general, more prepared in physical and physiological instances than their lower-ranked opponents. Ultimately, this investigation would contribute to the existing body of knowledge by providing novel insights into the generalizability of immediate post-competition recovery protocols, with potential implications for upgrading the processes of fatigue management and consequent performance in competitive swimming.

Methods

A group of 50 young swimmers (25 females, 25 males) competing at the national level took part in the study (15 ± 1.1 years of age; height of 1.76 ± 0.02 m for males, 1.74 ± 0.02 m for females; weight of 67 ± 2.6 kg for males, 65 ± 2.8 kg for females; 8.5 ± 1.3 years of experience; 677 ± 22 Fédération Internationale De Natation points of best performance). All the swimmers competed in one swimming race, ranging from 50 and 100m (sprinters) to 200 and 400m (middle-distance) in one of the four strokes. The total sample was randomly and equally divided in two groups, one named “experimental” (13F, of which 6 sprinters and 7 middle-distance; 12M, 6 sprinters and 6 middle-distance), the other named “coach-prescribed” (12F, 6 sprinters and 6 middle-distance; 13M, of which 7 sprinters and 6 middle-distance). The athletes provided assent and their parents/guardians provided written informed consent after a detailed description of the study. The study was approved by the local Ethics Committee of the university (FGM02102019) and was conducted in accordance with the Declaration of Helsinki.

BL (mmol/L), HR (bpm) and RPE (0 - 10) levels were measured at two different moments. The first assessment occurred immediately after the completion of the swimming race post-swimming competition, called the post-competition phase. The second assessment occurred immediately after the completion of the assigned recovery protocol, called the post-recovery phase. On both occasions, the data was obtained right after the athlete came out of the swimming pool, i.e., +1 minute after maximal effort.

BL was withdrawn employing the finger-stick method and was measured using the Lactate Scout analyzer (SensLab GmbH, Germany) (Tanner et al., 2010). HR was determined using the validated Polar Verity Sense optical heart rate sensor (Polar Electro Oy, Finland) (Schubert et al., 2018). This sensor employs a time-based method to calculate averaged HRs over a predefined interval of 5 seconds. This “5 seconds interval” starts as soon as the sensor makes full contact with the subject’s skin. The obtained average HR is then displayed on a smartphone or tablet application, aptly paired with the sensor via Bluetooth. To clarify, if the sensor was attached for approximately 50 seconds, the sensor would calculate and display ten averaged HR values in temporal succession, one for each 5 second interval. Concerning our study, in order to measure the HR closest to the experimental phases, we considered the average HR during the first 5 seconds after placing the sensor on the swimmer's skin. In other words, after the swimmer wore the HR sensor, we waited 5 seconds to then register the first number that was displayed on the tablet, representing the averaged HR during those initial 5 seconds. Since we conducted our experiment within an ecological and time-constrained context (i.e., during an official, national level swimming competition), this kind of functioning of the Polar Verity Sense sensor presented great advantages. That is, the 5-seconds time frame measurement allowed us to average out small fluctuations of the swimmers' HR, providing a more accurate representation of HR within the critical post-exertion time-window. On the contrary, a single value or a wider mean of HR could not capture these subtle yet significant fluctuations (Schubert et al., 2018), especially after extremely intense cardiovascular efforts like swimming in a national level competition. Finally, the RPE was obtained by administering the Category-Ratio (0-10) RPE scale (BORGCR10) developed by Borg (Borg, 1954).

The official swimming races were held inside a regular, long-course (50 m) competitive swimming pool, whereas the experiments involving the recovery protocols took part inside another adjacent, short-course (25 m) swimming pool, which was in the same facility.

When the swimmer finished the race, i.e., at the post-competition phase, the first evaluation of BL, HR, and RPE occurred. The athlete then moved to the short-course swimming pool, where the assigned recovery protocol was performed. Recovery protocols were swum entirely front crawl. After the athlete performed the designated recovery protocol, i.e., at the post-recovery phase, we measured again the BL, HR, and RPE, employing the same procedures as for the post-competition phase.

During congested periods of the competitive season, swimmers can take part in several races in a single event, e.g., competing in multiple individual races, relays, and/or medleys. In order to efficiently maximize psychophysiological recovery, coach are advised and encouraged to employ active swimming recovery protocols between races (Ali Rasooli et al., 2012; Mota et al., 2017; Kostoulas et al., 2018). Nevertheless, there are some discrepancies between the scientific and swimming communities regarding what type of swimming protocol would be fit for a better recovery and consequent preparation of the swimmers for their next races. Thus, the main difference between the two protocols here utilized reside mainly in the scientific support that the experimental protocol benefits of (Toubekis et al., 2006; Peinado et al., 2014; Hotfiel et al., 2019). Conversely, the coach-prescribed protocol was based on beliefs, habits, routines, and previous experience of swimming coaches. In fact, the coach-prescribed protocol was designed starting from previous works of other colleagues with swimming coaches (Mota et al., 2017; Pollock et al., 2019; Faghy et al., 2019), and then finalized in collaboration with the swimmers' coaches from our sample. This process was entirely supervised by the technical director of the swimming federation, which is also authoring this study. Both recovery protocols are described in Table 1.

Confirming the gap between sport-science and swimming-coaching in this topic, the two protocols turned out rather diverse from each other. In particular, the experimental protocol presented a heterogeneous spectrum of exercises performed and materials utilized, e.g., the kickboard, other than a high variability of swimming intensities, both between and within exercises. Also, the experimental protocol presented a slightly higher volume and duration than the coach-prescribed protocol. Moreover, the rest times were carefully set in the experimental protocol, whereas in the coach-prescribed protocol, the rest times between swimming activities were left as "arbitrary". In general, the coach-prescribed protocol presented a much more "self-managing" approach to recovery, allowing swimmers a narrower and steadier intensity of swimming pace.

Regarding both protocols, we opted to provide the swimmers with qualitative information about stroke pacing (e.g., calling for "easy", "moderate", "hard" pacing). This would accommodate the personal tendencies of each swimmer, according to the principles of training adaptability. For this reason, each protocol duration fluctuated about 5 to 10 minutes.

We would expect the experimental protocol to be more efficient in accelerating physiological recovery than a more "unfluctuating" and self-managing approach to active swimming recovery, i.e., the coach-prescribed protocol. That is because a more heterogeneous, high-variability, intensity-alternating, and carefully designed protocol (i.e., the experimental protocol) could better stimulate and support the body response to the hydrostatic pressure of the aquatic medium, hence providing faster metabolic recovery and ultimately making the swimmers readier to perform at their highest form in back-to-back competition settings. Contrarywise, limiting the ranges of swimming intensities and exercises, as well as not providing specific rest times between working sets, would reduce -or worse, subjectivize- the possibility of maximizing the aforementioned physiological processes that occur when swimming for recovery purposes., e.g., increased cardiac output and blood flow without increasing energy expenditure, subsequent nutrient and waste transportation through the system, etc.

Statistical analysis employed the Prism® 9.0.2 software (GraphPad Software, Inc., USA, 2021). Parametric analyses were conducted, as the Shapiro-Wilk test revealed a normal distribution of data ($p > 0.05$).

Table 1. **Description of the experimental and coach-prescribed swimming recovery protocols.**

	Experimental	Coach-prescribed *
Activity	1 X 300-m: easy 2 X 50-m kick: first 10-m hard, last 15-m easy 6 X 50-m moderate, 20 sec rest between sets 4 X 25-m kick: moderate, 15 sec rest between sets 1 X 200-m: easy	1 X 200-m: steady 8 X 50-m: self-paced 2 X 100-m: easy
Total volume	1000 meters	800 meters
Total duration	20-25 min	15-25 min

* = Rest times were arbitrary. The terms "easy", "moderate", "hard", "steady" and "self-paced" all refer to the swimming pace that the performers had to maintain. The apt execution of each pace was supervised by the swimmers' federal technical director. This meant that when needed, swimmers were verbally encouraged to further adapt their pace according to the specific activity.

Table 2. Between subject effects of the MANOVA followed by the Tukey HSD post-hoc test.

Between subject effects (experimental vs. coach-prescribed)						
Time	**Effect**	**Wilk's Λ**	**F**	**Hypothesis df**	**Error df**	**p**
Post-competition	**Ranking**	0.88	2.48	4	46	0.91
	Recovery protocol	0.75	3.91	4	46	0.12
	Ranking * recovery protocol	0.81	2.71	4	46	0.66
Post-recovery	**Ranking**	0.85	3.01	4	46	0.72
	Recovery protocol †	0.66	13.36	4	46	0.03
	Ranking * recovery protocol	0.69	8.11	4	46	0.09

Multiple comparisons							
		M ± SD				**95% CI**	
Time	**Variables**	**Experimental**	**Coach-prescribed**	**SE**	**p**	**Lower**	**Upper**
Post-recovery	**BL †**	2.40 ± 1.18	4.29 ± 2.07	0.48	0.02	0.96	2.82
	HR	104.16 ± 16.25	105.72 ± 14.06	4.3	0.48	- 6.86	9.98
	RPE	2.16 ± 1.11	2.08 ± 1.19	0.33	0.92	- 0.72	0.56

df = degrees of freedom; † = significant effect at the 0.05 level; M ± SD = mean ± standard deviation; SE = standard error; BL = blood lactate (mmol/L); HR = heart rate (bpm); RPE = rate of perceived exertion; CI = confidence interval.
There was no significant interaction effect of ranking obtained on recovery protocol. However, we found significant differences between recovery protocols in enhancing BL recovery. In particular, the Tukey HSD post-hoc indicated that the experimental protocol was significantly better at reducing BL levels compared to the coach-prescribed intervention.

First, in order to observe whether recovery parameters would differ based on sex, we conducted an independent sample t-test comparing males' and females' BL, HR, and RPE, both post-competition and post-recovery phases.

A MANOVA employing 2 fixed factors (ranking, recovery protocol) and 1 repeated factor (from post-competition to post-recovery phase) was conducted to determine whether there were differences between the experimental and coach-prescribed protocols in BL, HR, and RPE, either at the post-competition or post-recovery phases, as well as interactions with the ranking obtained in the respective swimming races. In the case of statistically significant results, post-hoc comparisons were conducted using the Tukey HSD test.

Results

No significant differences were found in BL, HR, and RPE levels between males and females for the two groups and across the two phases. This allowed us to consider the whole sample of subjects regardless of gender.

As it could be expected, the within subjects MANOVA indicated that there were significant effects of recovery protocols from the post-competition to the post-recovery phases, both within the experimental (Wilks' Lambda = 0.22; F (3, 48) = 128, $p < 0.05$) as well as the coach-prescribed protocols (Wilks' Lambda = 0.49; F (3, 48) = 91, $p < 0.05$). Post-hoc comparisons using the Tukey HSD test indicated that in both recovery protocols, the mean levels for BL (13.74 ± 2.30 vs. 2.40 ± 1.18 mmol/L for experimental; 14.00 ± 3.21 vs. 4.29 ± 2.07 mmol/L for coach-prescribed), HR (191.48 ± 15.50 vs. 104.16 ± 16.25 bpm for experimental; 191.32 ± 16.90 vs. 105.72 ± 14.06 bpm for coach-prescribed) and RPE (8.80 ± 0.82 vs. 2.16 ± 1.11 for experimental; 8.28 ± 0.54 vs. 2.08 ± 1.19 for coach prescribed) were significantly lower post-recovery phase than post-competition phase. This suggested that both protocols were indeed useful in decreasing levels of fatigue both from a physiological and a psychological standpoint.

Regarding the between-subjects' effects, the 2 fixed factors MANOVA for the post-competition phase revealed that there were no significant differences nor interaction of ranking and recovery protocol on the BL, HR, and RPE variables (Table 2). These results confirmed the homogeneity of the two groups and that the various competitions elicited similar levels of fatigue among all the swimmers, regardless if they were sprinters or middle-distance competitors.

The mean swimming race ranking was 13.4 ± 10.57 for the experimental group, 13.48 ± 10.85 for the coach-prescribed group. There were 13 top-ten placements within the experimental group, collecting a total of 4 podiums (1 first place, 1 second place, 2 third places), whereas the coach-prescribed group had 15 top-ten placements with 4 podiums collected (1 first place, 3 second places, zero third places). The bottom-ranked places were at number 52 for the experimental group and number 69 for the coach-prescribed group. However, the between-subjects MANOVA detected no significant interaction of ranking obtained based on the recovery protocol performed.

Despite the non-significant interaction effects, interesting results came from the between-groups analysis regarding the post-recovery phase. Specifically, we found significant differences between recovery protocols on indicators of fatigue (Wilks' Lambda = 0.66; F (4, 46) = 13.36, $p < 0.05$). Tukey HSD post-hoc indicated that the swimmers which performed the experimental protocol had significantly lower levels of BL (2.40 ± 1.18) compared to the swimmers performing the coach-prescribed protocol (4.29 ± 2.07 mmol/L), whereas the mean levels for HR (104 ± 16 vs. 106 ± 14 bpm) and RPE (2.16 ± 1.11 vs. 2.08 ± 1.19) did again present non-significant differences between groups (Figure 1).

Discussion

In this study, we sought to identify the optimal approach to enhance psycho-physiological recovery after a swimming race in national level youth swimmers. To achieve this, we compared the effects of two after-competition protocols on BL, HR, and RPE levels. Secondly, we also investigated whether higher-ranked swimmers would also present higher rates of recovery than the rest of their competitors.

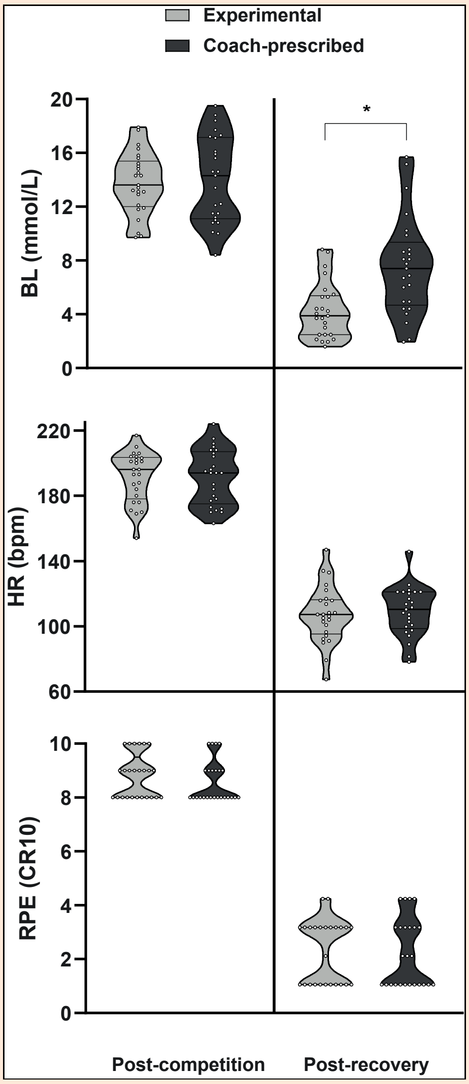

Figure 1. Violin plots comparing the experimental and coach-prescribed groups for BL, HR, and RPE, both post-competition (left side) and post-recovery phases (right side). As it shows, the only significant difference between the experimental and coach-prescribed group was found in BL levels after having performed the relative recovery protocol. This outcome plainly displays that the experimental protocol employed in this study could be more effective than the coach-prescribed protocol in improving a precise parameter of the body's response to intense exercise, that is, BL.
* = statistically significant difference ($p < 0.05$) between the experimental and coach-prescribed groups.

We found that the experimental recovery protocol appears more efficient than the coach-prescribed one in improving BL. However, there were no differences between groups regarding HR and RPE levels measured post-recovery. Moreover, we observed no influence of attained ranking position in BL, HR or RPE rates of recovery.

Predictably, we found significant differences between post-competition and post-recovery BL, HR, and RPE values, both within the experimental and coach-prescribed groups. Moreover, the between groups analysis casted further doubts upon the employment of HR and RPE as reliable means to quantify the best recovery protocol after a swimming race. That is, no differences were found in HR and RPE between the experimental and coach-prescribed groups at the post-recovery phase.

In fact, although post exercise HR can adequately represent cardiovascular fatigue for a single group, the individual variation is too wide for this to be a useful measurement while being subject to external stimuli and comparing for different interventions (Bassey, 1996). Furthermore, despite the RPE being indicated as an ecological and valid tool to assess and quantify loads in swimming (Wallace et al., 2009), some issues when comparing interventions could reside in the fact that it remains a subjective scale, and that asking to quantify fatigue from 0 to 10 could "flatten out" the outcomes of an inquiry conducted with high level athletes competing at the same level, as it happened in the present study.

Nonetheless, BL was the only parameter which returned significant differences between the experimental and coach-prescribed group at the post-recovery phase. In particular, the experimental group presented significant lower levels of BL compared to the coach-prescribed group. Hence, we do not recommend employing exclusively HR and RPE when comparing short-term interventions to enhance recovery in high level swimmers, since the possible difference between groups appears to be excessively subtle for these two kinds of measures. Instead, in line with previous investigations, we suggest using HR (Koenig et al., 2014; Ganzevles et al., 2017) and RPE (Wallace et al., 2009; Czelusniak et al., 2021) as tools to repeatedly test the single group/swimmer over a longer time span, being useful to assess cardiovascular as well as psychological progresses across the whole competitive season.

As noted earlier, interesting results came from the BL levels analysis, i.e., the experimental protocol made the swimmers recover more quickly than the coach-prescribed protocol. In consideration of our outcomes, we then suggest scholars and coaches interested in enhancing swimmers' anaerobic recovery to follow the conceptual foundation of the experimental protocol, i.e., designing in-water, active recovery protocols which range from an easy to a moderate pace, vary rest times, exercises, and materials used, all while not shying away from requesting the swimmers to go at their hardest pace, perhaps for short distances. Our recommendation, however, is in contrast with Lomax (Lomax, 2012), which found that after intense swimming, a recovery protocol consisting of self-paced, continuous steady rate swimming is equally effective in lowering BL levels than a swimming recovery consisting of various strokes, intensities, and rest intervals. The protocols used by these investigators was similar to the coach-prescribed protocol employed in this study. However, it is worth noting that the colleagues recruited regional level swimmers (whereas we recruited national level youth swimmers), also employing the 200m race-paced front crawl in a controlled environment to elicit fatigue. Moreover, there is a compelling element of diversity (i.e., swimming race vs. controlled environment) that well highlights the particularity of our experiment compared to other investigations in the topic (Toubekis et al., 2008; Ali Rasooli et al., 2012; Pratama and Yimlamai, 2020). Mainly, we based on previous works which suggested that swimming performance measurements could have important implications within a competition setting (Faghy et al., 2019; Shell et al., 2020).

Reasonably, the competitive environment already stimulated and motivated the swimmers to perform at their highest level, thus producing “actual” maximum levels of overall fatigue. It would be of interest to test whether our results could be replicated in a more controlled and less stressful environment, or if the competition setting is instead necessary for specific protocols to significantly arouse enhanced recovery from exercise-related fatigue.

Some parameters of physical conditioning were shown to be able to predict swimming performance among youth swimmers, i.e., maximum force-velocity exertion (Sorgente et al., 2023) and mechanics (Pérez-Olea et al., 2018) in the pull-up motion, as well as overall upper (Lopes et al., 2021) and lower limb (Crowley et al., 2018) maximum strength capacities. Considering the closed-skill nature swimming, it is thus widely recognized that the most performing swimmers normally correspond to the most physically accomplished (Bravi et al., 2022). However, recovery capacities do not appear to follow the same trend. Specifically, the MANOVA we implemented resulted in no significant interactions of recovery protocols on indicators of fatigue when controlling for race ranking obtained. Thus, we cannot consider BL, HR, RPE, as valuable indicators nor predictors for swimming performance when comparing different recovery protocols. Notwithstanding, this could also mean that the recovery protocols here employed equally contributed to enhance recovery parameters regardless of the differences in achieved ranking by each swimmer. However, more focused, carefully designed studies should be conducted to confirm this assertion, e.g., by assessing multiple, heterogeneous groups of swimmers competing at different levels.

Surely, some elements from our experimental design could be ameliorated. For instance, we gathered the data at a specific time of the competitive season, which should supposedly be at the peak form of each athlete. However, we did not control any aspect of training in preparation to the competition. Therefore, dedicated research should focus on collecting the fluctuations and changes of physiological indicators of fatigue, especially BL, before and after swimming race/recovery protocols throughout the season.

Furthermore, it is worth noting that we opted for a higher (and unexplored) ecological value for this study, i.e., measuring BL, HR, and RPE during a national-level swimming event. This also meant operating at high temporal efficiencies due to the tight schedule of the competitions. For these reasons, we chose to only collect one BL measurement, and a 5-seconds average of the HR, per subject (for each phase). These kind of procedures for BL and HR assessment have been already used and standardized by other scholars (Tanner et al., 2010; Schubert et al., 2018); hence, they can be indeed telling of the physiological amount of fatigue elicited in swimmers after maxing out their performance. On the other hand, seeing that the lactate peak could subjectively occur at different times after maximal/supramaximal efforts, taking only one measurement may not be as accurate as considering, for instance, the lactate kinetic, which in turn would be more time-consuming. Consequently, the same could be stated concerning the employment of various HR measurements, where maximal HR during a specific time period, the R-R interval, or the HR kinetic could be used or combined in lieu of our approach. However, further research is required to test whether different kinds of BL and HR detection could bring significantly different result from one to another, in the ecological context of high-level swimming races. In other words, the present experimental approach regarding the strategies of BL and HR data collection holds some limitations. One is that, by standardizing the timing of our data collection, we ruled out paramount inter-subjective differences. The other one is that, by offering only a “snapshot” about the swimmers’ physiological levels of stress after competition and their respective recovery after the protocols here proposed, more accurate (thus more time-consuming) assessments of these parameters could bring different results than the ones we found with this experimental design. Because of these factors, it is important to state that there is an inherent (although systemic) limitation in our study, and that the interpretation of our results should be approached with caution.

Nevertheless, a recent work conducted by Mavroudi et al., (2023) found the lactate peak after different all-out swimming sprints (25m, 35m, and 50m) occurring after 2 minutes from the trial. This is rather compelling, given that the lactate peak is usually thought to occur between 4 and 10 minutes after a maximal physical effort. While only partially confirming our approach, this suggests that systematizing and standardizing the timing of BL collection could be practical in detecting common trends in BL behavior after intense bout of swimming, as well as the BL response to a certain type of recovery protocol from these exertions, in spite of the individual differences between athletes.

Another critical element could pertain to the duration of the recovery protocols here employed, i.e., 20 minutes circa, which was fixed regardless of the distance specialization. Surely, it would be expected to design dedicated recovery protocols for sprinters and for middle-distance swimmers, given that the shorter the event is, the longer a swimmer should cool down (Riewald, 2015). This is because the intensity of the swimming bout determines how high blood lactate concentration will rise (Neric et al., 2009). For these reasons, sprinters can produce higher lactate concentrations than endurance athletes do, needing more time to clear lactate from their bodies (Issurin, 2010). However, we argue that there is an antecedent pitfall in swimming performance science. That is, usual recovery times employed for high-level swimmers do not continuously last more than 5-10 minutes (Toubekis et al., 2008). Other scholars pointed out that more time would be advisable. For instance, Riewald suggested that a general proper recovery protocol should consist of at least 15 minutes of active swimming, based on the fact that the lactate concentration rises over the first several minutes after the race, then, over the next 20 to 30 minutes, this concentration declines to near baseline or pre-race levels (Riewald, 2015). The decrement in fatigue between these 20 to 30 minutes happens for any kind of swimmer, regardless if they are sprinters or middle-distance specialists. Hence, leveraging on the latter notion, we opted for a generalized, systematic, and “no-rush” approach for all the swimmers involved, regardless of the distance specialization. Furthermore, despite the differences about lactate characteristics in distance and gender documented in Holfelder et al. (2013), our results highlighted the importance of a recovery protocol employing a relatively large volume (around 1000 meters) and different intensities for a suitable and generally feasible fatigue dissipation, without considering the event or gender in which the swimmer has competed. In such wise, given that BF, HR and RPE levels did not differ within our two respective groups, this study revealed no differences in recovery capacities between sprinters and middle-distance swimmers, as well as among the four strokes. This would be beneficial for the generalizability aspect of these recovery protocols, which could lead to an even more efficient degree of control and comparison of the swimmers' specialization profiles, regarding both the specific stroke and distance expertise. It remains to be seen, however, whether our recommended experimental protocol could be time-optimized for endurance swimmers as well, such as open water swimmers or long-distance ones (i.e., swimmers specialized in 800m and 1500m races).

Specific age-category or gender differences should be taken into account when discussing the implementation of optimal after-competition recovery protocols.

Regarding age, it is worth stressing that for the present study we only recruited national level swimmers competing at the junior level, i.e., the mean age was of 15 ± 1.1 years. Research in the topic of swimming recovery has focused on either elite (Vescovi et al., 2011; Ali Rasooli et al., 2012; Faghy et al., 2019), master (Reaburn and Mackinnon, 1990), collegiate (Pratama and Yimlamai, 2020) or regional level swimmers (Lomax, 2012; Sorgente et al., 2023), with many others referring to competitive/well-trained swimmers without further specifications (Wakayoshi et al., 1992; Buchheit et al., 2010; Kabasakalis et al., 2020). From a competitive standpoint, however, national level youth swimmers represent the most promising category for leveling up at the elite of the sport (Mitchell et al., 2021), making this specific age-level population worth of dedicated investigation. Nevertheless, we did not make any comparison between age-categories, e.g., senior vs. junior, as it was not the purpose of our investigation. Thus, the results from this study should be read under a specific filter of age and competitive level. It remains to be seen whether and how the approach used in this study would be effective for elder categories of swimmers, also considering the different training demands that comes with further progression in the sporting career.

Concerning the gender comparison, possible differences between males and females swimming performances have been explained due to physiological, psychological, anthropometrical and biomechanical aspects (Knechtle et al., 2020). In contrast with this review, however, we did not find differences in BL nor HR or RPE between male and female competitors. To this regard, it is worth noting that Rascon et al. reported that RPE and BL did not differ between genders in determining exercise intensity response, while females had higher HR than males (Rascon et al., 2020). Thus, our results are partially in line with previous research which stated that BL and RPE are gender-independent markers of physical exertion (Korhonen et al., 2005). Thus, the approach here used towards immediate recovery post-competition appears to function regardless of the gender. However, the extent and robustness of this finding should be better investigated with dedicated research about differences in recovery rates between male and female swimmers.

Conclusion

In conclusion, we suggest that for improving BL levels, an optimal after-competition swimming recovery protocol should dictate precise iterations of the exercise variables, such as diversity of paces (even a hard one, but only for short distances), relatively high volumes, fixed and short rest times, a wide use of different exercises.

It is also worth noting that this investigation was conducted employing reliable, quick, simple, quasi non-invasive, and portable validated instrument, in a scalable and laboratory-free approach. Therefore, we encourage any swimming coach to take advantage of the present experimental design when fine-tuning strategies to enhance fatigue-disposal mechanisms in their athletes. Such knowledge would grant a better understanding to swimmers, their teams and interested scholars about which kind of conceptual framework to adopt when designing after-competition recovery protocols, with the ultimate purpose of optimizing and accelerating paramount physiological recovery pathways.

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Key points

- Heart rate and rate of perceived exertion measurements do not seem the right choice when seeking to compare the effectiveness of different post-competition recovery protocols in high-level swimmers. Indeed, they remain paramount parameters in detecting trends, patterns, and response to competition for a single group/swimmer.
- Blood lactate clearance is enhanced by precise iterations of a recovery protocol design in swimmers, such as diversity of paces (even the hard one), relatively high volumes, fixed and short rest times, a wide use of different exercises. It is thus discouraged to employ uniquely “steady” or “self-paced” approaches.
- The enhanced blood lactate clearance was present regardless of ranking position, distance, or stroke specialization among swimmers. Hence, the use of specific recovery protocols may be generally beneficial in improving physiological indicators of fatigue across a wide spectrum of high-level youth swimmers.

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