Lower fatigue and faster recovery of ultra-short race pace swimming training sessions

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ABSTRACT:

Ultra-short race-pace training (USRPT) is a high-intensity training modality used in swimming for the development of the specific race-technique. However, there is little information about the fatigue associated to this modality. In a crossover design, acute responses of two volume-equated sessions (1000-m) were compared on 14 national swimmers: i) USRPT: 20×50-m; ii) RPT: 10×100-m. Both protocols followed an equivalent work recovery ratio (1:1) based on individual 200-m race-pace. The swimming times and the arm-strokes count were monitored on each set and compared by mixed-models. Blood lactate [La$^-$] and countermovement jump-height (CMJ) were compared within and between conditions 2 and 5 min after the protocols. The last bouts in RPT were 1.5–3% slower than the target pace, entailing an arm-strokes increase value of ~0.22 for every second increase in swimming time. USRPT produced lower [La$^-$] ([Mean ± standard deviation], 2 min: 8.2±2.4 [p = 0.021]; 5 min: 6.9±2.8 mM/L [p = 0.008]), than RPT (2 min: 10.9±2.3; 5 min: 9.9±2.4 mM/L). CMJ was lowered at min 2 after RPT (-11.09%) and USRPT (-5.89%), but returned to the baseline in USRPT at min 5 of recovery (4.07%). In conclusion, lower fatigue and better recovery were achieved during USRPT compared to traditional high-volume set.

Keywords: high-intensity interval training (HIIT); Physical conditioning; Athletic performance; Endurance training; Short-term potentiation; Physiology.

INTRODUCTION

Competitive swimming requires large amounts of training volume to develop the physiological parameters needed to succeed[1, 2]. For this reason, coaches prescribe long-lasting exercises in which glycogen depletion and lactate accumulation $[La^-]$ are generated[3, 4]. This is reflected in the typical preparation of elite middle-distance swimmers (200-400m) who often follow the model of high-volume, low-intensity training (55-70% below $[La^-]$ 2 mM/L, and 30-45% between $[La^-]$ 2 and 4 mM/L) aiming to develop a high aerobic capacity (maximal oxygen uptake – VO_2max) and the ability to maintain it for longer periods[5, 6]. However, since the energy required to swim at a certain speed is derived from that specific speed[7, 8], a training stimulus should also include exercises at race-specific velocity with the aim to stimulate different energetic pathways and aerobic power [9], including intensities above $[La^-]$ ~4 mM/L and ~75-80% of VO_{2max} capable to stimulate the glycolytic system[2, 10-12].

One of the problems of maintaining high-intensity exercises during training sessions of high-volume is the severe depletion of ATP and phosphocreatine stores (PCr) which results in excessive fatigue levels[11, 13]. One appealing option to increase race-specific velocity training while obtaining the endurance performance gains, is the polarized training model[14], which is characterized by training most of the time (75-80%) at low intensities (< 2 mM/L $[La^-]$), and the remaining time (25-20%) at high-intensities (> 4 mM/L $[La^-]$), with very little or no training (0-5%) in between ($2 \text{ mM/L} \geq [La^-] \leq 4$ mM/L)[5]. For this purpose, coaches often include a derivative of high-intensity training (HIT) known as Ultra-short race-pace training (USRPT)[9]. With this procedure, the aerobic and glycolytic systems are stressed through brief bursts of vigorous activity (e.g., 20 to 50 swimming intervals completed over short distances 15 to 100-m), interspersed with work-recovery ratios of 1:1, 1:2 or 2:1, according to the individual best competitive performance (i.e. competitive race-pace)[2, 12]. The application of this method may be supported by expected adaptations such as an increase in VO_{2max}[11], an improved ability of working muscle to produce and utilize ATP from the glycolytic system[12], higher velocity at [La^-] threshold[2], and a decrease in the energy cost of swimming (-20%)[8].

While USRPT protocols are frequently included on swimming programs, it is surprising that there is scarce scientific information about this HIT modality in swimming. For example, sprint interval training (SIT) through short sprint cycling bouts (e.g., <10-s) has demonstrated to elicit greater cardiorespiratory and power performances with less fatigue than longer HIT bouts equated by volume [15]. Therefore, it is expected that short-lasting efforts as in USRPT would generate lower [La^-] than training modalities of higher volume[16, 17]. This would entail a lower related acidosis which, in turn, would favour oxidative metabolism and prolonged race-pace training at the desired intensity[1, 3]. However, this needs to be experimentally confirmed. On the other hand, it is uncertain whether USRPT may reach or maintain the intensity requirements ([La^-] $\geq$ 4 mM/L) needed to improve the aerobic capacity[2, 10-12], as the long-term adaptations after HIT programs are related to the accumulated training load at higher intensities[18]. A previous research investigated the demands of a 20 × 25-m USRPT session (100-m race-pace; 35-s recovery period)[19], showing [La^-] of 11.4 ± 3.7 mM/L, maximal heart rate (HRmax) $\geq$ 88%, and rating of perceived exertion values $\geq$ 17. Therefore, these previous findings suggest the suitability of this HIT modality[11, 12, 14]. However, another study reported only [La^-] ~3 mM/L and 93% HRmax after a set of 40 × 25-m (100-m race-pace; 15-s recovery period)[20], suggesting different [La^-] production and removal. Hence, and considering that [La$^-$] responses are very different between athletes[16], it would be important to individually assess this aspect to further understand the metabolic responses of this type of training.

It is expected that the specific fatigue generated by USRPT would affect different performance variables. Athletes' fatigue is commonly referred to as a reduced capacity for maintaining maximal performance as evaluated with different methods[21]. In this regard, it has been suggested that athletes should be tested in well-known tests when evaluating fatigue[22]. Thus, considering that race-specific technique instruction is the most important component of USRPT[9], and that the swimming biomechanics are the strongest determinants of swimming performance[8], the analysis of swimming patterns such as arm-stroke count could give us an accurate measure of the occurrence of fatigue during race-pace training[23]. Furthermore, given that muscle power would be affected by the specific fatigue of USRPT, examination of performance in subsequent dry-land exercises would provide information on how fatigue developed to better monitor muscle power. The practice of swimming involves some aspects that require the development of strength and explosive power in dryland conditions, such as the swim start[24]. Unfortunately, these practices are seldomly controlled or assessed, thus swimmers often perform these exercises under fatigue, therefore limiting desired adaptations. In this regard, the countermovement jump (CMJ) has demonstrated to be a simple, reliable and sensitive tool to identify neuromuscular fatigue after different HIT schemes in different sports[21, 25, 26]. Considering that coaches usually include jumping exercises as a content of dry-land training given their high relationship with swimming start performance[5, 27, 28], CMJs could be also used to assess the readiness for performing strength exercises after swimming exercises of different intensities.

Therefore, the aim of this study was to compare two volume-equated race-pace sessions of short (i.e., USRPT) vs. long bouts to compare the metabolic (i.e., lactate), biomechanical (i.e., arm-strokes) and neuromuscular (i.e., CMJ) effects of fatigue during and after each training sessions. According to previous evidence in swimming[16] and other sports[3, 11], the rate of [La$^-$] depends upon the intensity and duration of the swimming effort: therefore it would be expected that the brief efforts and intermittent activity of USRPT could favour lower [La$^-$] and a reduced fatigue when compared to a longer bouts-HIT-session of equated volume.

METHODS

Subjects

Based on a previous study[15], that investigated the pre-post effects of two cycling-based SIT on CMJ-height on active men [16x5-s SIT (mean change = 0.45%, SD = 11.43% , d = 0.03 = small effect) and 4x20-s SIT (mean change = 4.19%, SD = 14.32%, d = 0.82 = mean to large effect), sample size calculations for the interaction effect between training modalities were conducted (G*Power, F tests; α error = 0.05)[29]. Assuming $\eta_p^2 = 0.21$ for a repeated measures ANOVA (within factors: protocol (RPT and USRPT), time (2 min pre-, 2 and 5 min post-), this analysis revealed a minimum of 8 subjects to achieve a statistical power > 80% (estimated correlation = 0.5). Finally, it was recruited 14 national competitive swimmers that were informed about the procedures and provided signed consent to participate in this study. Their characteristics were as follows: 18.95 ± 1.63 and 19.02 ± 0.78 years old; short course 100-m freestyle time: 56.35 ± 1.44s (males); 63.01 ± 1.60s (females) corresponding to 509 ± 39 FINA points. Swimmers under the age of 18 were asked to provide also signed parental consent forms. The experiment was conducted during the second macrocycle of the season to ensure that swimmers were aerobically fit[5]. Subjects were abstained of drinking caffeinated beverages, and they followed their normal diet during the tests. All the procedures followed the Declaration of Helsinki with respect to human research, and the study was approved by the local university ethics committee (code: 852).

Design

A counterbalanced crossover design was used to determine differences on [La$^-$], arm-strokes count, and CMJ-height between two swimming race-pace protocols. One of the protocols consisted of 10 × 100-m swimming bouts (Race-pace training [RPT]), while the other consisted of 20 × 50-m swimming bouts (i.e., USRPT). In both protocols, swimmers were given individualized target times based on specific 200-m times and followed a work-recovery ratio of 1:1. The interaction effect of [La$^-$] and CMJ-height were observed within and between groups at 2 and 5 min after each experimental protocol, while the CMJ was also collected immediately prior (2 min) to observe the pre-post daily changes in neuromuscular function[25, 30].

Procedures

Prior to testing (≥ 48 h), swimmers were tested in short-course 200-m freestyle to obtain the individual target times. This distance was chosen because its intensity and duration ensure that swimmers achieve the VO_{2max}[6] and thus, activate the glycolytic system[12, 31]. The RPT target time was individually calculated as the 95% of the 200-m time/2 (males: 65.71 ± 1.38-s; females: 71.85 ± 1.95-s), while in USRPT it was calculated as the 95% of the 200-m time/4 (males: 32.85 ± 0.65-s; females: 35.92 ± 1.10-s)[19]. To ensure a work-recovery ratio of 1:1, it was allowed a total bout time of 130-s for males and 140-s for females in RPT and 60-s for males and 70-s for females in USRPT.

The experimental setting was a 25-m indoor pool (water and air temperatures of 28.3 and 28.9º C, respectively). Prior to testing, subjects were asked to include various CMJ attempts during their regular training for familiarization purposes. On the day of the test, subjects completed a standardized 400-m in-water warm-up[32], followed by two CMJs and 10 min of rest. Subsequently, swimmers performed the first CMJs separated by 10-s, and entered the water to perform one experimental protocol (RPT or USRPT). All the efforts were monitored by a certified swimming coach who provided immediate timing feedback at the end of every effort.

Blood [La^-] samples were collected at 2 and 5 min after the tests[4, 33]. A blood lactate analyser (Lactate Pro2 LT-1730, Arkray, Inc., Kyoto, Japan) was used after collection of ~ 5 μL of capillary blood from the fingertip with a measurement range of 0.5 ~ 25.0 mM/L. The analyser was previously calibrated following the manufacturer instructions (YSI Preservative Collection Kit; Yellow Springs Inc., Yellow Springs, Ohio, USA).

Arm-stroke counts were monitored during the sets by a researcher to prevent swimmers from bias[23]. The underwater movements after the push-off from the wall were limited up to two kicks. The sum of the values of each lap was averaged over the whole bout (arm-stroke average). The CMJ-height was assessed 2 min before the experimental set, and 2 and 5 min after completing it. Two CMJs were required per time interval and subsequently averaged for comparisons[25]. An intraclass correlation coefficient was applied between the CMJs attempts (model: two-way mixed; type: absolute agreement)[34], showing high relative reliability, 0.97 [0.92 – 0.98] (2 min pre-), 0.92 [0.82 – 0.97] (2 min) and 0.96 [0.93 – 0.98] (5 min). The jumping height was calculated with the flight time of the CMJ measured by a contact platform connected to a digital timer (Newtest OY, Oulu, Finland). The subjects started from a standing position, with the trunk straight, legs extended, and both hands on the hips to minimize lateral and horizontal displacement during jumping. After a countermovement with a freely chosen knee flexion, subjects performed the highest possible vertical jump[15, 26].

Statistical Analysis

The Shapiro–Wilk test revealed that all the variables with the exception of [La$^-$] were normally distributed. Then, the differences within protocols of [La$^-$] at different time points were analysed using a two-way non-parametric ANOVA test by Friedman (factors: protocol × time). Paired comparisons were observed by Wilcoxon between time points and protocols (RPT vs. USRPT). Linear regressions were applied to observe the change trends in swimming time respective to target (%). All data points were pooled and calculated on regression for each gender and training protocol. Subsequently, the swimming times achieved in every effort were compared with the target times through a paired sample *t* test, while the difference between time increments were compared between genders with an independent t-test. A two-way repeated measures ANOVA, with two repeated-measures factors (protocol and time points) was applied to study the differences in CMJ-height (2 min pre-, 2 and 5 min post-). Paired sample *t* test was used to verify those differences between time points and protocols (RPT vs. USRPT). Linear mixed-effects models were carried out between the arm-strokes count and time achieved in every effort and repeated-measures correlations were carried out to address the repeated measures within-subjects[35]. Descriptive statistics were expressed as the mean ± standard deviation (SD) and confidence intervals (95% CI). When calculating effect sizes (d), pooled standard deviations (SD) were used as no control group was available (Cohen's d = $[\text{Mean}^a - \text{Mean}^b] / \text{SD pooled}$)[36]. These values were categorized as small if $0 \leq |d| \leq 0.5$, medium if $0.5<|d|\leq 0.8$, and large if $|d|>0.8$[37]. The relative changes (%Δ) were calculated as the percentage difference between conditions ($\%\Delta = [(\text{Mean}^b - \text{Mean}^a)/\text{Mean}^{ab}] \times 100$)[38]. All statistical procedures were performed using SPSS 23.0 (IBM, Chicago, IL, USA). The statistical significance was set at $p < 0.05$.

RESULTS

A significant protocol, time, and protocol × time interaction ($p < 0.001$) was identified for [La^-] when compared the values collected at 2 to 5 min within and between the protocols. The values obtained in RPT (2 min: 10.8 ± 2.7; 5 min: 10.1 ± 2.6 mM/L) were higher than in USRPT (2 min:8.3 ± 2.7 [$p = 0.021$]; 5 min: 7.4 ± 2.8 Mm/L [$p = 0.008$])

and both were higher at 2 min compared to 5 min ($p < 0.001$). There was a lower reduction observed in RPT (Δ = -5.47%; d = 0.22) when compared to USRPT (Δ = -11.03%; d = 0.33) ($p = 0.015$). Combining both protocols, it was observed higher [La^-] in males than in females at 2 (11.3 ± 1.6 vs 7.7 ± 2.8 mM/L; $p = 0.008$) and 5 min (10.6 ± 2.0 vs 7.0 ± 2.8 mM/L $p = 0.025$) of recovery.

(Please insert Figure 1 near here)

There was a strong linear trend towards changes in swimming time between RPT efforts, both for males ($R^2 = 0.92$, $p < 0.001$) and females ($R^2 = 0.94$, $p < 0.001$) (Figure 2A). The swimming times were slower than the targeted in RPT for females from the eighth effort onwards (1.55 ± 1.41% $p = 0.025$; 2.87 ± 1.86%, $p = 0.006$; 3.30 ± 1.53%, $p = 0.001$). In males, the ninth and tenth efforts were slower than the targeted (1.65 ± 2.24%; $p = 0.028$; 2.85 ± 2.49%; $p = 0.009$). The first and second efforts of RPT were faster than the target in males ($p = 0.042$) and females ($p = 0.021$). In USRPT, only the first effort of males was faster ($p = 0.002$). No differences on performance time were obtained between males and females in any of the protocols. The repeated-measures correlation showed that the increased number of arm-strokes was moderately associated with worse time in RPT (Males: $r = 0.58$, $p < 0.001$; Females: $r = 0.64$, $p < 0.001$) (Figure 2B). Each unit increase in time in 100-m accounted for a 0.24 and 0.20 ($p < 0.001$) increase in the number of arm-strokes for males and females, respectively. In URSPT, the increased number of arm-strokes was poorly associated in males ($r = 0.28$, $p = 0.001$) but not associated in females ($r = 0.10$, $p = 0.241$). In males, each unit increase in time in 50m accounted for a 0.30 increase ($p < 0.001$) in the number of arm-strokes.

(Please insert Figure 2 near here)

A significant time ($F_{2,26} = 22.177$, $p < 0.001$), and time × protocol interaction ($F_{2,26} = 6.951$, $p < 0.004$) was identified for CMJ-height when relative 2 min pre- to 2 and 5 min post-exercise were compared between the protocols [2 min post- vs 2 min pre- ($\Delta = -11.93\%$)] and; [2 min post- vs 5 min post- ($\Delta = 6.87\%$)] for RPT; compared to [2 min post- vs 2 min pre- ($\Delta = -6.06\%$)], and; [2 min post- vs 5 min post- ($\Delta = 10.43\%$)] for USRPT. The paired samples *t* test showed a return to baseline at min 5 in USRPT, with no differences with 2 min pre- ($p = 0.76$), and higher CMJ-height compared to RPT ($p = 0.021$). (Table 1).

(Please insert Table 1 near here)

DISCUSSION

The aim of this study was to compare two volume-equated HIT sessions of short (i.e., USRPT: 20 × 50-m) vs. long bouts (i.e., RPT: 10 × 100-m) to compare the $[La^-]$ and fatigue responses during and after each training session. Our hypothesis was that the brief efforts of USRPT could favour a lower $[La^-]$ and a reduced fatigue when compared to the longer bouts of RPT. The results showed that both protocols achieved an intensity range within $[La^-]$ 8-12mM/L, but RPT produced higher $[La^-]_{max}$ compared to USRPT.

Furthermore, deteriorations in the swimming pace, stroke patterns (i.e., arm-stroke count) and muscle power (CMJ-height) were more pronounced and persistent in RPT. Therefore, USRPT appears to be the more suitable method to include HIT aiming to replicate competitive race pace with less fatigue.

Although USRPT and RPT set the same target intensities, the magnitude of $[La^-]_{max}$ also depends on the duration of the exercise because glycolysis reaches near maximal rates after ~40-50s[10, 16], resulting in a greater impact on RPT. This was expected given that 37-63% of the energy supplied for 100-m races comes from glycolysis[17, 39]. Moreover, the ATP obtained from PCr is capable of supplying a substantial proportion of the required energy for only 5-7s, thus favouring the lower $[La^-]$ accumulation in USRPT[10, 15]. Despite the role of $[La^-]$ acidosis as the main cause of fatigue has been disregarded[3, 10], a severe reduction in pH may hinders ATP utilization when the $[La^-]$ values reach ~13-30 mM/L [1, 13]. Some swimmers obtained 12-14 mM/L of $[La^-]$ in RPT, this confirmed that the glycolytic system was highly activated through this protocol. Therefore, it can be suggested that USRPT induced an optimal range of $[La^-]$ ($\geq$ 4 mM/L <13 mM/L), thus supporting its use as an important HIT modality in swimming[11, 16].

Previously, values of $[La^-]$ ~9-10 mM/L have been reported for maximal 50-m freestyle bouts[17, 39], while values of $[La^-]_{max}$ ~11-13 mM/L for maximal 100-m freestyle bouts were observed[17, 31, 39]. Therefore, it was reasonable to expect the lower values observed in the current study by using the 200-m race-pace (USRPT: 8.3 ± 2.7 mmol/l; RPT: 10.8 ± 2.7). Nevertheless, it was also noticeable that we measured them after a total volume of 1000-m, which is in agreement with the $[La^-]$ previously reported for HIT[12].

Interestingly, it was observed a ~11% of [La$^-$] reduction in USRPT but only a ~5% in RPT. One possible explanation of this difference might be that, following RPT, some subjects may reach true peak [La$^-$] values between min 2 and 5, therefore not showing the expected reduction in [La$^-$] values (Figure 1). Further studies should examine the [La$^-$] kinetics to confirm this possibility.

In any case, active muscles contribute to a higher [La$^-$] removal during exercise and also during recovery[1, 33], whereas higher mitochondrial and capillary content contributes to obtain a higher energy fraction from muscular oxidative metabolism[11, 12]. Actually, when the recovery time between efforts declines, there is a reduction in the use of fast-twitch glycolytic fibres and an increase in the reliance on slow-twitch oxidative fibres, thus contributing to a greater [La$^-$] clearance[12]. The different recovery periods (35 vs. 15-s) may explain the [La$^-$] differences obtained by Williamson et al[19] and Gullstrand and Lawrence[20] (~11 and ~3 mM/L, respectively) while, in this current study, those differences were explained both by the different recovery and bouts duration.

The total swimming time increased in RPT but remained more stable in USRPT (Figure 2A). Thus, a lower volume at race-pace intensity was achieved in RPT. Interestingly, the repeated-measures correlation analysis conducted within-subjects showed that increasing the number of arm-strokes entailed worse times in RPT (Males: $r = 0.58$; $p < 0.001$; Females: $r = 0.64$; $p < 0.001$), whereas this relation was not evidenced in USRPT (Males: $r = 0.28$; $p < 0.001$; Females: $r = 0.10$; $p = 0.18$) (Figure 2B). For a given distance and speed, a higher number of arm-strokes would represent a higher stroke-rate and a lower stroke-length and this could be related with a reduced capacity to generate propulsive impulse per stroke[7, 23], resulting in a higher energy cost[8]. Previous studies have stated that the stroke patterns remain stable at slow to moderate speeds and in shorter distances[7, 8]; thus the deleterious effects of fatigue could be better perceived in extended bouts such as RPT. From these results, it may be suggested that the generated metabolic fatigue may have worsened the propelling efficiency by means of changes in the stroke technique[8].

Some studies have demonstrated that CMJ can be used as a useful tool for identifying acute fatigue after different high-intensity efforts. For instance, Jimenez-Reyes et al[26] showed post-exercise CMJ-height significantly lower (16.0 ± 2.5%) than pre-exercise following several repetitions of running sprints up to a loss of 3% in speed, while Benítez-Flores et al[15] showed that CMJ-height was lower (4.19%) after 4 × 20-s cycle sprints when compared to 16 x 5-s cycle sprints. Thus, the deterioration in CMJ-height observed after both protocols at min 2 was somewhat expected. However, the CMJ-capacity was quickly restored at min 5 of recovery only in USRPT, with a trend ($p = 0.07$) for a CMJ-height potentiation (Table 1). This is an important finding as a post-USRPT CMJ-height potentiation would be the result of the balance between fatigue and potentiation mechanisms[22]. In this regard, it is worth mentioning that one study on cycling-based SIT (5 s) showed that some individuals potentiated their CMJ-height after the fatiguing protocol[15]. Hence, if fatigue had a direct force-depressing effect in muscles, this was possibly counteracted by other potentiation factors that increased force to the same extent after some minutes of rest[30]. Muscles respond with varying fatigue and potentiation manifestations depending on the recent contractile history[40]. As these two elements can co-exist, the quality of muscle performance following contractile activity depends on the balance between the degree to which the muscle is fatigued and the degree to which the muscle is potentiated[41]. The deviating time course of performance enhancement is an individually regulated response that depends on the training experience and on the nature of the participant’s muscle fibre composition; thus stronger athletes could be more resistant to fatigue following a conditioning activity, responding more favourably than weaker athletes [42]. In any case, it is reasonable to expect that the fatigue effects would be eliminated after a few minutes of rest and this may have entailed greater potentiation responses in USRPT, but also in RPT. Therefore, future studies should look further for potentiation/fatigue effects during different recovery intervals after the training set leading up to the usual 15-20 min of rest given between the warm-up and the race.

This study presented some limitations. First, apart from [La^-], this study did not include other physiological measurements, such as heart rate responses; however, previous studies have already demonstrated that USRPT elicits ~88-93% of HRmax which are compatible with HIT demands[19, 20]. Second, while we equated the volume of the two conditions, it should be considered that the purpose of race-pace training is to achieve a certain total volume without fatigue-induced declines in swimming speed; therefore, in a real setting, the coach would adjust the number of sets based on the current loads and fitness level of swimmers. Third, it would have also been interesting to test swim-specific fatigue more directly by performing a maximum-effort swim (e.g., 50 m or 100 m) pre and post-training protocols. This would have allowed a very clear and valid assessment of true fatigue-performance reduction. However, such efforts may limit the conditioning state of the activities to be carried out immediately afterwards (e.g., dry-land training). Future studies should evaluate the different responses evaluated in the current study, including individualized loads and volumes to verify if this HIT modality effectively results in better chronic training adaptations.

In conclusion, for a given training volume, USRPT is better than RPT to achieve more volume at race pace, maintaining the swimming patterns with a considerably lower metabolic and neuromuscular fatigue. Therefore, it is reasonable to suggest that increasing the frequency of USRPT training with lower metabolic stress and fatigue would allow athletes to accumulate more HIT volume at race-specific velocity. Similarly, RPT could be an interesting method for long-distance swimmers to create more stress to train [La$^-$] tolerance. Future studies should test the long-term adaptations obtained through these procedures.

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DECLARATION OF INTEREST STATEMENT

Authors declare no conflict of interest to report.

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TABLE & FIGURE CAPTIONS

Figure 1. Maximal blood Lactate concentration ($[La^-]_{max}$) achieved 2 and 5 minutes after the experimental sets (n = 14). Race-pace training (RPT); Ultra-short race pace training (USRPT).

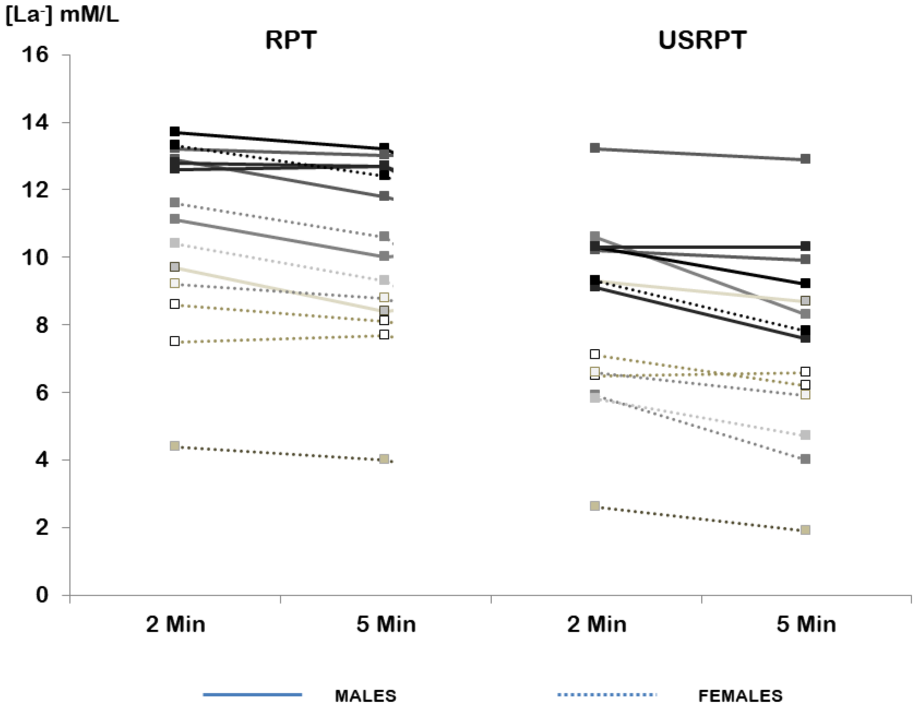

Figure 2. A – Time variation regarding target time (RPT = Race-pace training; USRPT= Ultra-short race-pace training); B – Regression Analysis between arm-stroke count and final time; C – Arm Strokes Average (per lap).

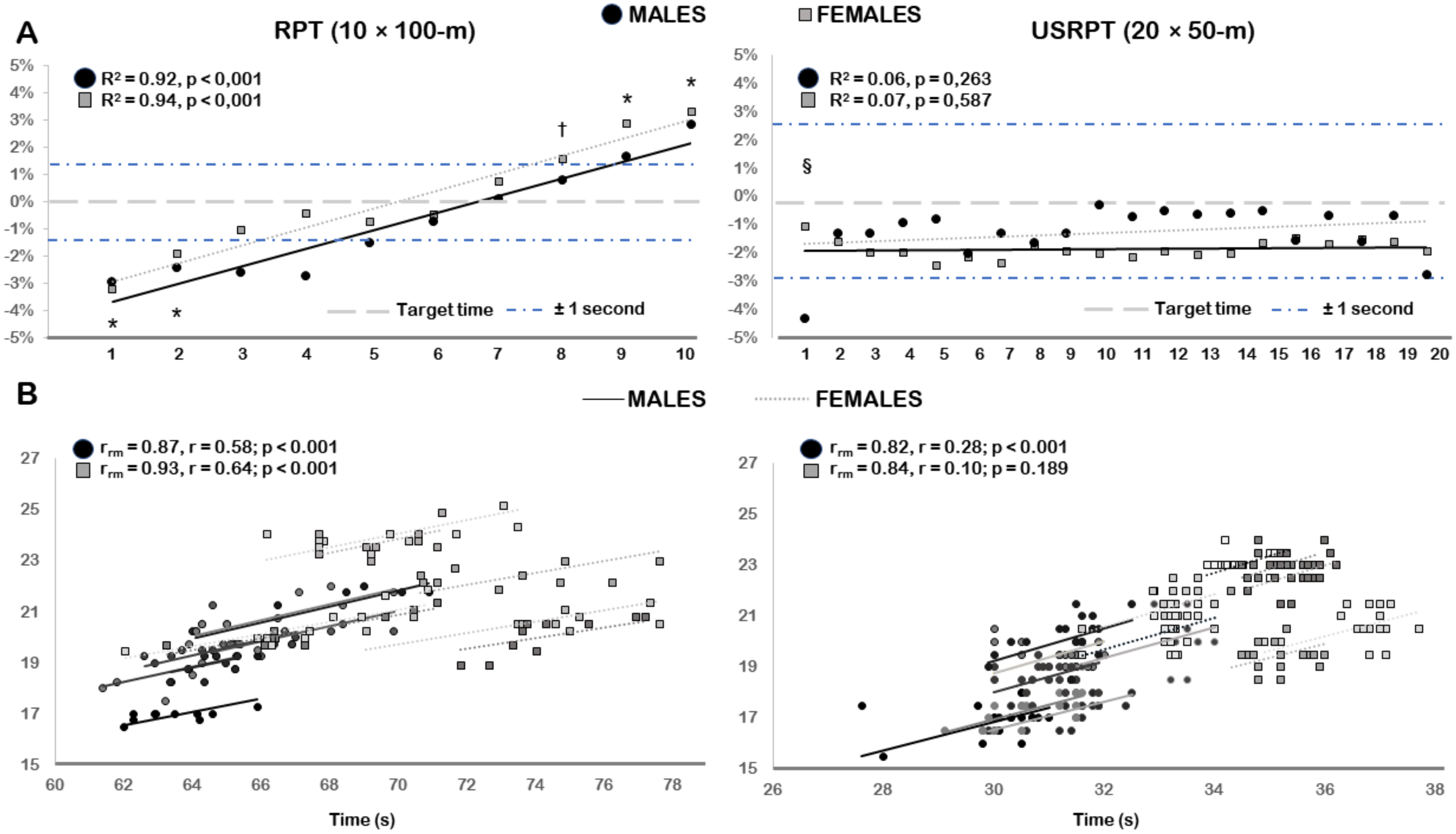

Table 1. Mean ± Standard deviation (SD), confident intervals and effect sizes of countermovement jump height (CMJ), 2 min before (Pre), and 2 and 5 min after the experimental training protocols: Race-pace training (RPT = 10×100-m); Ultra-short race-pace training (USRPT = 20×50-m).

		CMJ – Pre	**Vs**		**CMJ – 2 min**	**Vs**		**CMJ – 5 min**	**Vs (Pre-)**	
		Mean ± SD	**P**	**ES (95% CI)**	**Mean ± SD**	**P**	**ES (95% CI)**	**Mean ± SD**	**P**	**ES (95% CI)**
RPT		36.4 ± 8.4	<0.001	-0.55 (-1.62, 0.51)	32.3 ± 5.8*	<0.001	0.31 (-0.69, 1.42)	34.6 ± 6.3*#	0.026	-0.24 (-1.29, 0.81)
Vs	**p**	0.568			0.239			0.021		
	ES (95% CI)	-0.09 (-0.92, 0.56)			0.17 (-0.40, 1.09)			0.36 (-0.41, 1.13)		
USRPT		35.7 ± 6.4	<0.001	-0.28 (-1.38, 0.72)	33.6 ± 6.2*	<0.001	0.49 (-0.54, 1.59)	37.3 ± 7.5#$	0.076	0.21 (-0.83, 1.26)

* Differences respect to Pre

Differences respect to 2 min

$ Differences between protocols (RPT vs. USRPT)