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400 meters freestyle pacing strategy and race pace training in age-group swimmers

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Purpose: This study aimed to characterize the 400 m freestyle pacing strategy, the effect of post-race feedback, and individualised race-pace training. *Methods*: Twenty male swimmers (13.4 ± 1.0 years) were randomly assigned into two groups. The experimental group used training monitoring based on intensities around 400 m pace (92 and 97% of 400 m speed), while, for the control group different heart rate zones (EN2 and EN2+) were used as an intensity criterion. The training volume was the same for both groups. A maximal 400 m freestyle simulated competition was performed before and after the 3 weeks period to determine intensities and to assess changes in performance. The rate of perceived exertion and heart rate values were also evaluated. *Results*: A fast start in the first 50–100 m, then a constant speed in the middle of the race and an end-spurt during the last 50–100 m was the pacing pattern adopted by the majority of the swimmers. Significant main effects of time were observed for 400 m time ($p = 0.001$; ES 3.39; very large). Results revealed significant pre-to-post improvements from 328 ± 26.3 s to 317 ± 19.4 s in the experimental group and from 329 ± 25.2 s to 321 ± 21.1 s in the control group. *Conclusions*: All the swimmers adopted almost the same parabolic pacing strategy before and after the training program with some differences in seconds that have made the strategy of the experimental group better balanced during the post-training test. Both training methods induced significant improvements in 400 m performance, to a greater extent for the training using intensities near 400 m race pace.

Key words: *swimming, training monitoring, training zones, young competitive, pacing*

1. Introduction

To achieve optimal performance, it is essential for athletes to use their available energetic resources efficiently. To avoid wasting kinetic energy, all possible energy stores should have been used before finishing a race, but not so far from the end of the race that a meaningful slowdown can occur [7]. An optimal pacing strategy to distribute effort over the course of the race is considered a key element in the final outcome [21], [25]. Swimming is biomechanically inefficient with high drag force, therefore, appropriate swimming pace is crucial to avoid any undesirable onset of sudden fatigue, which will determine loss of stroke power, coordination and speed [14], [26]. Swimming pace can be defined as the speed at which a swimmer completes a distance, and is an important variable to be monitored to obtain a better performance [22], [26]. Pacing profiles in swimming vary by event distance as well as by stroke [15]. In short-duration sporting events lasting less than 30 s (e.g., 50 m swimming) an all-out pacing strategy is typically employed [1]. The 100 m event is also classed as a sprint event and there is some evidence characterising pacing profiles in these events [15], in which swimmers typically adopted a positive pacing strategy [13], [21]. In middle-distance events including 200 and 400 m distances, the most commonly used pacing strategies across a range of competitive levels are parabolic; a fast start that may be accounted for by the dive and 15 m underwater stroke followed by an evenly paced

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mid-section and a fast end spurt [14], [17], or fast-start even; a fast start followed by a relatively even pace [14], [21]. Similar to middle-distance freestyle events, parabolic pacing is typically utilised in freestyle events of 800 m or above, where swimming velocity is greatest at the start and end of the race [11]. Other studies in both middle and long-distance events shows the need to conserve energy at the start, swim at a consistent pace in the middle sections and then increase velocity in the latter stages [17], [21]. While pacing is important in all swimming events, it is suggested to be most noticeable in events of 400 m or longer [13] when the ability to swim at an even pace in the mid-sections followed by an end spurt in the final lap(s) is critical for a successful outcome [15]. More recently, Lipinska and Hopkins [12] in their study on 400 m pacing in elite female swimmers concluded that the proportions of swimmers who could improve performance due to changes in pacing were smaller than in their 1500 m study, probably because pacing must become less important as the duration of the event decreases and the intensity approaches maximal effort throughout the race.

There is no widespread acceptance of any pacing method for swimming [2]. Traditionally, coaches manage the swimming pace by giving visible coded signals to swimmers with their hands, while standing on the poolside. Some studies have reported that the modalities of feedback given to the swimmer could affect swimming pace [18], [28]. It is speculated that the regulation of exercise pace is dictated by a combination of the ability to resist fatigue, feedback integration, anticipatory forecasting and previous experience [27]. The optimal pacing strategy can be a learned pattern, based on extensive experience gained during training and previous competitions [8], [9]. Additionally, Skorski et al. [23] indicated that simulated competition (SC) can be used for investigating manipulations of pacing pattern during training and it can be speculated that patterns stored in the long-term memory during training can be carried into real competition (RC).

It was indicated in a recent review of Menting et al. [16] that, because of the scarcity in literature on youth swimmers' pacing behaviour, it is difficult to provide a detailed description of their pacing behaviour. No direct differences in the pacing profiles of youth and adult swimmers were found. However, pacing profiles of youth swimmers were evidently more variable, and these swimmers demonstrated difficulties in self-selecting of the most beneficial pacing profile. This could indicate that youth swimmers struggle to regulate their energy distribution in the most efficient manner [16]. Young swimmers' incompetence in stabilising their pacing behaviour may be related to the finding that pacing skills are contingent on prior experience and the level of (meta-) cognitive functioning, which require time to fully develop [6], [8]. A recently proposed model for developing athletes' pacing skills emphasises the importance of both the experiential and self-regulatory aspects of skill learning [6]. To the best of the authors' knowledge, no previous research investigated the importance of feedback and training on the pacing strategy in swimming. Thus, the aim of our study was to characterize the pacing strategy during 400 m freestyle SC, the effects of post-race feedback and individualised race pace training in age-group competitive swimmers. Our hypothesis suggests that age-group swimmers may generally adopt a pacing strategy similar to that of elite swimmers and that some individual differences may be seen among them according to their experience and/or their self-regulation methods, and that, after a specific race-pace training period, the chosen strategy will be better balanced.

2. Materials and methods

Participants

Twenty male 13–14-year old swimmers took part in our study. All participants were competitive swimmers of the same national team, had previous experience in swimming training of at least 6 years and trained approximately 5 to 6 days a week during the previous year, with a total distance of 24 to 26 km a week. Their performance level in the 400 m freestyle event is 67.2 ± 4.9% of the world record. A medical examination was carried out before the start of the study. None of the participants reported recent injuries that could interfere with study participation. The subjects and their parents were informed of the benefits and risks of the investigation prior to signing parental written informed consent. All participants were asked not to participate in other physical activities and to maintain their usual diet and sleeping habits for the duration of the study. Each measure was treated in accordance with standard ethical guidelines of the Ethics Committee of the hosting institution, which approved the experimental protocol (N-16-2018) in the spirit of the Helsinki Declaration.

Measurements

The testing sessions were undertaken before training (pre-training) and after 3 weeks of the training program (post-training). The pre-training session was performed 48 h prior to the start of the training program. The post-training session began 48 h after training cessation. All tests were conducted in the afternoon at 05:00 pm in a 50 meters indoor pool (air temperature 26 ± 1 °C, water temperature 27 ± 1°C). All anthropometric measurements were performed in the morning by the same examiner. Body mass was measured accurate to 0.1 kg, with the subject in light clothing and without shoes, using an electronic scale (Tanita HD 317). Height was determined accurate 0.5 cm with a measuring tape fixed to the wall.

Participants performed the exercise test after a standardized warm-up of 1000 m, directed by the head coach of the team. The exercise test consisted of a 400 meters freestyle SC for determination of the pacing strategy. As described by Skorski et al. [23], lap times were measured during the turn when swimmers touched the wall with their feet and final times when they touched the wall with their hand. Times were recorded using two manual stopwatches (DT2000 – Digi Sport Instruments; France). The same experienced investigators measured times for the same swimmers during each test.

Immediately upon the event completion, heart rate (HR) was measured with the HR monitor (Polar S610 HR Monitor, Polar Electro Oy, Kempele, Finland) while the swimmer was always in the water next to the wall. Before the event, all the swimmers were instructed to press the receiver on their chest upon their arrival (in the 5 s interval) and keep it pressed until the examiner who launched the polar watch instruct them to remove the receiver. A rating of perceived exertion (RPE) was assessed using the Borg 6-20 RPE scale [3] at the end of the event, immediately after measuring the HR.

Design and procedures

During our study, the participants were randomly assigned into two groups: An experimental group (EG; n =10; age 13.4 ± 1.1 years; height 152.5 ± 8.9 cm; body mass 47.4 ± 7.9 kg and BMI 20.4 ± 8.4) that followed a training program according to intensities calculated from their 400 m mean speed in relation with the critical velocity (CV) and a control group (CG; n = 10; age 13.5 ± 1.0 years; height 153.2 ± 7.4 cm; body mass 48.1 ± 7.5 kg and BMI 20.5 ± 7.4) that continued its regular training program according to HR measurement and training zones.

After the test, specific speed and time calculations were made. The experimental group (EG) attended a feed-back meeting in which swimmers were informed with the pacing strategies used by elite swimmers during international competitions. They were also informed in detail about their personal results and pacing strategies including their own results (lap and 100 m times) and the times corresponding to intensities in relation with their personal 400 m race pace. These intensities were then used during the main sets of the training sessions. The coach and his assistant followed the times and rest intervals and ensured that all the swimmers complied with the need of the set. The training program is presented in Table 1.

The EG completed 8 to 9 sessions per week during the training period (25 sessions and 105 kilometres, in total), with 3 sessions per week, in which the objective was to swim interval training main sets at intensities near to 400 m race pace (92 to 97% of the mean T400 speed). The 92% corresponds to the CV as found by Zacca et al. [30], while 97% corresponds to 105% of the CV. Exercise to rest ratio of 1:6 and 1:4 was applied for the intensity of 92 and 97%, respectively. The control group (CG) participated in the same testing protocol and swimmers were only informed about their final T400 swimming times without receiving any information about their lap times and pacing strategies. The CG also completed 8 to 9 sessions per week during the training period (25 sessions and

Table 1. Weekly training organization for both experimental and control groups

	Experimental group			Control group			EG and CG
	No. of sessions	Distance [km]	Intensities and distances of 3 sessions during each week	No. of sessions	Distance [km]	Intensities and distances of 3 sessions during each week	Examples of main sets
Week 1	8	33	1) 92% of v400: 100 m–400 m sets	8	33	1) (EN2) HR 150–170 : 100 m–400 m sets	1) 10 × 200 m R25″ or 7 × 300 m R35″
Week 2	8	35		8	35		
Week 3	9	37	2) 97% of v400: 50 m–200 m sets	9	37	2) (EN2+) HR 160–180 : 50 m–200 m sets	2) 20 × 100 m R20″ or 12 × 150 m R25″
Exercise to rest ratio	~1:6 and 1:4 for the v400 intensity of 92%, and 97%, respectively.			~1:6 and 1:4 for the EN2 and EN2+ respectively			

v400 – mean velocity during 400 m test; EN2 – endurance zone 2; EN2+ – endurance zone 2+; R – rest time between repetitions.

105 kilometres in total) based on HR intensity and training zones described by Urbanchek [29]. HR verification and recordings were completed by an assistant coach during the rest periods, each swimmer was measured thrice, one time in each one-third of the main set.

Statistical analyses

Data were expressed as mean and standard deviation (mean ± SD). Statistical analyses were performed by Statistical Package for Social Sciences (v.20. SPSS, Chicago, USA). Normality of distribution was assessed with the Shapiro–Wilk's test; the equality of variance was verified with the Levene's test. A mixed-model ANOVA was performed to analyse the differences in swimming patterns over different time points (laps) during the race (within factor), between EG and CG (between factor), for both pre-and post-training T400. Differences within and between groups were calculated using a two-way analysis of variance (ANOVA) for repeated measures. If group *x* time interactions turned out to be significant, a Newman–Keul's post hoc test was conducted. Additionally, effect sizes (ES) were determined from ANOVA output by converting partial eta-squared to Cohen's d. Moreover, within-group ES were computed using the following equation: ES = (mean post – mean pre)/pooled SD. ES were considered trivial (<0.2), small (0.2–0.59), moderate (0.6–1.19), large (1.2–1.99), very large (2.0–4.0) [10]. The level of significance was set at 5% ($p < 0.05$). In addition, the comparison was also made in the values (in seconds) to illustrate the difference in lap and 100 m times between the races more clearly.

3. Results

T400, HR, and RPE values measured before (pre-training) and after (post-training) the training program in both EG and CG are presented in Table 2.

No significant differences between groups in baseline (pre-training) were detected for any of the analysed parameters ($p > 0.05$). The main effect of *time* was found for T400 ($p = 0.001$; ES 3.39; very large). There was no *group x time* interaction for any of the analysed parameters ($p > 0.05$). Relatively important differences in the values (in seconds) in T400 were detected for both EG and CG.

Lap and 100 m times and the difference between laps and between 100 m times are presented in Table 3. Delta (Δ) corresponds to the difference between two laps (e.g., Δ lap 1–2) or between two 100 m (e.g., Δ 1^{st}–2^{nd} 100 m).

No statistical differences between EG and CG lap times (lap1 to lap 8) and in 100 m times (first to fourth 100 m) in pre-and post-training were found ($p > 0.05$). The only important differences were detected in the values (in seconds). For both EG and CG, a comparison between lap times during pre-training testing revealed a statistical difference between lap 1 and all the other laps ($p < 0.05$), the same finding was observed for lap 2 and 8. On the other hand, lap 4 was similar to lap 3 to 7 ($p > 0.05$). For EG, a comparison between lap times during post-training testing revealed a statistical difference between lap 1 and all the other laps ($p < 0.05$), the same finding was observed for lap 2 and 8. However, lap 5 was similar to lap 3 to 7 ($p > 0.05$). For CG, a comparison between lap times during post-training testing revealed a statistical difference between lap 1 and all the other laps ($p < 0.05$), the same finding was observed for lap 8. On the other hand, lap 5 was similar to lap 4 to 7 and lap 2 was similar to lap 8 ($p = 0.238$). In both EG and CG, a comparison between each 100 m time during pre-training testing revealed a statistical difference between the first 100 m and all the other ones ($p < 0.05$), the same finding was observed for the fourth 100 m. However, the second 100 m was similar to the third one ($p = 0.848$). Comparison between each 100 m time during post-training testing revealed a statistical difference be-

Table 2. T400, HR, and RPE values measured before (pre-training) and after (post-training) the training program in both EG and CG

	Experimental group			Control group			*p*-value (effect size)		
	Pre--training	Post-training	Evolution	Pre--training	Post--training	Evolution	Main effect time	Main effect group	Interaction group *x* time
T400 (s)	328.46 (26.25)	317.41 (19.39)	–3.48%	329.07 (25.24)	321.04 (21.05)	–2.50%	$p = 0.001$* (3.39)	$p = 0.76$ (0.21)	$p = 0.396$ (0.59)
HR (bpm)	183.80 (9.06)	185.40 (7.89)	+0.87%	184.20 (6.21)	185.00 (4.83)	+0.43%	$p = 0.593$ (0.36)	$p = 1.000$ (0.000)	$p = 0.790$ (0.17)
RPE (U.A)	17.90 (1.10)	18.50 (1.78)	+3.35%	18.00 (0.66)	18.20 (0.78)	+1.11%	$p = 0.318$ (0.7)	$p = 0.785$ (0.19)	$p = 0.522$ (0.44)

* – significant difference between pre and post, * $p < 0.005$; T400 – time recorded during 400 m swimming; CV – critical velocity; HR – heart rate; RPE – rating of perceived exertion.

Table 3. Differences between lap and 100 m times

		Lap 1 50 m	Lap 2 100 m	Lap 3 150 m	Lap 4 200 m	Lap 5 250 m	Lap 6 300 m	Lap 7 350 m	Lap 8 400 m	Final time 400 m (s)
		Lap 1+2 1st 100 m		Lap 3+4 2nd 100 m		Lap 5+6 3rd 100 m		Lap 7+8 4th 100 m		
EG T400-1	50 m times [s]	35.48	41.03	42.28	42.54	42.77	42.14	42.86	39.32	328.46
	Δ lap [s]		+5.55	+1.25	+0.26	+0.23	–0.63	+0.72	–3.54	
	100 m times [s]	76.52		84.82		84.92		82.18		
	Δ 100 m [s]			1st–2nd: +8.3		2nd–3rd: +0.1		3rd–4th: –2.74		
EG T400-2	50 m times [s]	35.54	39.67	40.56	40.77	41.02	41.13	40.99	37.69	317.41
	Δ lap [s]		+4.13	+0.89	+0.21	+0.25	+0.11	–0.14	–3.3	
	100 m times [s]	75.21		81.33		82.16		78.69		
	Δ 100 m [s]			1st–2nd: +6.12		2nd–3rd: +0.83		3rd–4th: –3.47		
CG T400-1	50 m times [s]	35.52	41.18	42.40	42.50	42.77	42.41	42.82	39.43	329.07
	Δ lap [s]		+5.66	+1.22	+0.1	+0.27	–0.36	+0.41	–3.39	
	100 m times [s]	76.70		84.91		85.18		82.26		
	Δ 100 m [s]			1st–2nd: +8.21		2nd–3rd: +0.27		3rd–4th: –2.92		
CG T400-2	50 m times [s]	34.86	40.10	40.80	41.35	41.50	41.70	41.49	39.23	321.04
	Δ lap [s]		+5.24	+0.7	+0.55	+0.15	+0.2	–0.21	–2.26	
	100 m times [s]	74.96		82.15		83.20		80.72		
	Δ 100 m [s]			1st–2nd: +7.19		2nd–3rd: +1.05		3rd–4th: –2.48		

T400-1 – pre-training 400 m test; T400-2 – post-training 400 m test; Δ lap – difference in seconds between two laps; Δ 100 m – difference in seconds between two 100 m.

tween all of them ($p < 0.05$) in EG, but in CG, statistical difference was found between the first 100 m and all the other ones ($p < 0.05$), the same finding was observed also for the third 100 m.

Table 4. Comparison of lap and 100 m times from pre to post-training

	Experimental group	Control group
	T400-1 vs. T400-2	T400-1 vs. T400-2
Lap 1	0.889	0.083
Lap 2	0.003*	0.008*
Lap 3	0.001*	0.000*
Lap 4	0.002*	0.009*
Lap 5	0.007*	0.002*
Lap 6	0.019*	0.003*
Lap 7	0.027*	0.014*
Lap 8	0.049*	0.815
1st 100 m	0.059	0.018*
2nd 100 m	0.001*	0.000*
3rd 100 m	0.008*	0.001*
4th 100 m	0.042*	0.225

* Significant difference from pre-to-post training ($p < 0.05$).

Comparisons of each lap time from pre- to post-training sessions are presented in Table 4. Results showed no statistical difference for lap 1 in EG and for lap 1 and 8 in CG ($p > 0.05$), while laps from 2 to 8 in EG and 2 to 7 in CG has changed ($p < 0.05$). On the other hand, when comparing 100 m times, statistical differences were found in the second, third and fourth ones in EG and in the first, second and third ones in CG ($p < 0.05$). No changes were observed in the first 100 m in EG ($p = 0.059$) and in the fourth one in CG ($p = 0.225$).

4. Discussion

According to Skorski et al. [23], no difference in the pacing profile could be observed between RC and SC. This leads to the assumption that SC can be used for investigating manipulations of pacing pattern during training. Furthermore, it can be speculated that patterns stored in the long-term memory during training can be carried into RC. Thus, the purpose of this study was to analyse the pacing strategy during a 400 m freestyle SC and the effect of post-race feedback and individualised race pace training in age-group competitive swimmers.

During the two testing sessions, swimmers in both groups showed no difference in RPE and HR values (~18 and ~184, respectively), indicating that all swam at or near their maximal capacities. During the pre-training test, both groups had the same level of performance, with 328 s for EG and 329 s for CG, which corresponds to a difference of 0.18% (0.61 s), while after the 3 weeks period EG swimmers swam by 1.13% (3.63 s) faster than those of the CG. This difference (3.63 s) observed in the 400 time-trial after the training period might play an important role in competition ranking and/or medals standings. Given that both groups followed the same periodization scheme and training content, a more important decline in T400 may be due to the importance of post-competition feedback and the training method based on intensities near the 400 m race pace. This finding is confirmed by Pyne at al. [19], who stated that the progression in performance times from the competition to the competition is presumably related to the beneficial effects of training (e.g., improvement in fitness and conditioning, swimming skills and technique, tactics and pacing strategies, and psychological skills).

Analyses of the difference between laps and between 100 m times in our study showed that, during the pre-training test, swimmers of both groups adopted the same pacing strategy: a fast start (a very fast first lap and a fast first 100 m), then a constant speed during the second and the third 100 m and, finally, a relatively fast end-spurt during the fourth 100 m, especially during the final lap. It was also noticed that the acceleration in the final lap is relatively moderate. This parabolic pacing strategy observed in our study corresponds to previous findings indicating that in middle-distance events including 200 and 400 m and longer distances. The most commonly used pacing strategies across the range of competitive levels are parabolic; a fast start that may be accounted for by the dive and 15 m underwater stroke followed by an evenly paced mid-section and a fast end spurt [14], [17], [23], or fast-start even; a fast start followed by a relatively even pace [14], [21]. These similarities between swimmers from our study and the international elite ones confirm and complement the findings of Robertson et al. [21], who studied the 16 semi-finalists and finalists in 9 international competitions over seven years and found no swimmer level-dependent difference in the overall race management pattern.

When analysing the difference between laps and between 100 m times (Table 3), we can see that, during the post-training test, all swimmers adopted almost the same parabolic pacing strategy with some differences in the values (in seconds) and a more important acceleration in the final lap in EG than in CG. Observed differences made the strategy of EG better balanced which may be due to the importance of post-competition feedback and the training method based on intensities near the 400 m race pace. It confirms that the optimal pacing strategy can be a learned pattern, based on extensive experience gained during training and previous competitions [8], [9].

Some authors described pacing as a process of decision-making [20], [24]. It was proposed that effective cognitive control during performance requires both proactive, goal-driven processes and reactive, stimulus-driven processes [4]. Additionally, other researchers consider that pacing strategy is the combination of feedback integration from physiological receptors, psychological forecasting and previous experience [27]. Swimmers from EG improved the performance of their final lap by 3.49 s vs. 1.54 s in comparison with CG and this finding is similar to those in previous research by Mytton et al. [17], who found that the last lap showed the largest differences in absolute, normalized, and relative speed between the medalists and non-medalists. The success associated with a more pronounced end-spurt suggests that medalists were able to call on reserves of energy not available to non-medalists. According to Burnley and Jones [5], this may have been possible due to a lower physiological disturbance in the medallists at this stage of the race, which, in turn, may be caused by their faster VO2 kinetics, greater critical speed and, possibly, greater aerobic capacity, meaning they could produce a slower rise in the slow component and take longer to attain their VO2max.

Coaches generally instruct their swimmers on the competition day to adopt a specific pacing strategy that is generally not applicable. Therefore, it is more judicious to pre-plan pacing strategies based on research and analysis of high-level competitions and also from prior experience of each swimmer. Pacing strategy can be a learned pattern that should be applied during training sessions by designing main sets on intensities close to those of the specific event. Some limitations of the study may be useful to inform and to conduct in future research. Arm stroke parameters, such as stroke length and stroke rate, could be assessed during testing and training sessions and could provide some extra information.

5. Conclusions

During the 400 m freestyle event, age-group competitive swimmers generally adopt pacing strategies similar to those of the elite. It means a fast start in the first 50–100 m, then a constant speed in the middle of the race and the end-spurt during the last 50–100 m. In addition, designing individualised race pace training sets at speeds near to those of the specific event are beneficial for the overall performance and for a better balanced pacing strategy

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