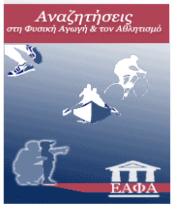
**Ερευνητική**




Αναζητήσεις στη Φυσική Αγωγή & τον Αθλητισμό
Τόμος 17 (1), 15 – 22
Δημοσιεύτηκε: Μάρτιος 2019

Inquiries in Sport & Physical Education
Volume 17 (1), 15 – 22
Released: March 2019

www.pe.uth.gr/emag

ISSN 1790-3041

# Κολύμβηση σε Ρυθμό Αγώνα: Επίδραση της Διάρκειας του Διαλείμματος σε Φυσιολογικές και Τεχνικές Παραμέτρους και Συσχέτιση με Δύναμη Χειρολαβής σε Κολυμβητές και Κολυμβήτριες

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## Περίληψη

Σκοπός της εργασίας ήταν να εξετάσει την επίδραση της διάρκειας του διαλείμματος στην συνολική επίδοση και σε στοιχεία τεχνικής στη διάρκεια κολύμβησης 200 μέτρων ελεύθερο, που εκτελείται σε ρυθμό αγώνα και η συσχέτιση της μέγιστης δύναμης χειρολαβής και της αντοχής στη δύναμη χειρολαβής με την επίδοση και τα τεχνικά χαρακτηριστικά. Στην έρευνα έλαβαν μέρος 16 κολυμβητές (8 αγόρια και 8 κορίτσια, ηλικία: 13.8 ± 1.1 ετών). Εκτέλεσαν 3 δοκιμασίες κολύμβησης μέγιστης έντασης (ρυθμό αγώνα): (α) 200μ. χωρίς διάλειμμα (200Τ), (β) 4Χ50μ. με διάλειμμα 5 δευτερόλεπτα ανάμεσα σε κάθε 50άρι (4x50-R5) και (γ) 4Χ50μ. με διάλειμμα 10 δευτερόλεπτα ανάμεσα σε κάθε 50άρι (4x50-R10). Στο τέλος κάθε δοκιμασίας μετρήθηκε η συγκέντρωση γαλακτικού (La) και η καρδιακή συχνότητα (ΚΣ). Για κάθε δοκιμασία υπολογίστηκε το μήκος (ΜΧ) και η συχνότητα χεριάς (ΣΧ), ο δείκτης αποτελεσματικότητας και η κολυμβητική ταχύτητα. Σε διαφορετική ημέρα μετρήθηκε η μέγιστη δύναμη χειρολαβής και η αντοχή στη δύναμη χειρολαβής. Η ανάλυση των δεδομένων έδειξε ότι τα αγόρια ήταν ταχύτερα σε όλες τις δοκιμασίες ($p<0.05$), ενώ η ταχύτητα ήταν σημαντικά μεγαλύτερη στο 4x50-R10 σε σύγκριση με τι άλλες συνθήκες ($p<0.001$). Δεν παρατηρήθηκαν διαφορές στη συγκέντρωση γαλακτικού, στην ΚΣ μετά την άσκηση και στο ΜΧ ανάμεσα στις συνθήκες και τα φύλα, ενώ στη συχνότητα χεριάς παρατηρήθηκε αύξηση στις συνθήκες 4x50-R5 και 4x50-R10 σε σύγκριση με την συνθήκη 200Τ ($p<0.001$), και αλληλεπίδραση συνθήκης και φύλου ($p<0.05$). Για τον δείκτη αποτελεσματικότητας παρατηρήθηκε αύξηση στις συνθήκες 4x50-R5 και 4x50-R10 σε σύγκριση με τη συνθήκη 200Τ ($p<0.001$), ενώ ήταν υψηλότερος στα αγόρια σε σύγκριση με τα κορίτσια ($p<0.05$). Η μέγιστη δύναμη χειρολαβής του χεριού προτίμησης παρουσίασε σημαντική συσχέτιση με το ΜΧ, το δείκτη αποτελεσματικότητας και την ταχύτητα στο σύνολο των κολυμβητών ($r=0.61$ και $r=0.73$ αντίστοιχα) και στα αγόρια ($r=0.74$ και $r=0.88$ αντίστοιχα). Συμπερασματικά, στο στυλ του ελευθέρου, κατά τη διαλειμματική κολύμβηση 200 μέτρων σε ρυθμό αγώνα, η διάρκεια ενός διαλείμματος μέχρι 10 δευτερόλεπτα δεν διαφοροποιεί τις φυσιολογικές παραμέτρους, αλλά έχει επίδραση σε στοιχεία της τεχνικής. Η μέγιστη δύναμη χειρολαβής, σε αντίθεση με την αντοχή στη δύναμη, συσχετίζεται με τη συνολική επίδοση.

Λέξεις κλειδιά: *μήκος χεριάς, συχνότητα χεριάς, δείκτης αποτελεσματικότητας, διαλειμματική κολύμβηση*

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**Research**

# Race Pace Interval Swimming: Effects of Rest Interval on Physiological and Technical Parameters and Correlation with Handgrip Strength in Boys and Girls Swimmers

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## Abstract

The aim of the present study was to examine the effect of continuous and intermittent race pace 200m. front crawl in overall performance, physiological and technical parameters. The correlation of maximum handgrip strength and handgrip strength endurance with performance and technical parameters during 200m. front crawl swimming performed continuously or in 4 x 50 splits with different rest intervals was also examined. Sixteen swimmers (girls, n= 8, boys, n = 8, age: 13.8 ± 1.1 years) participated in the study. Swimmers conducted three front crawl swim tests at 200m. maximum speed (race pace): (a) continuous 200-m (200T), (b) 4X50m. with 5 seconds rest between each 50m. lap (4x50-R5) and (c) 4X50m. with 10 seconds rest between each 50m. lap (4x50-R10). Lactate and heart rate (HR) were measured post-exercise. Stroke length (SL), stroke rate (SR), stroke index (SI), and swimming speed were calculated in each condition. Maximum isometric handgrip strength and strength endurance were tested in the following day. Boys were faster than girls in all conditions (main effect of gender $p<0.05$). Moreover, swimming speed was higher in 4x50-R10 compared to the other two conditions ($p<0.001$). Blood lactate and post-exercise heart rate were no different between conditions and genders ($p>0.05$). Stroke length was no different between conditions and genders ($p>0.05$), while stroke rate was increased in 4x50-R5 and 4x50-R10 conditions compared to 200T ($p<0.001$), and a significant “condition” x “gender” interaction was observed ($p<0.05$). Stroke index was increased in 4x50-R5 and 4x50-R10 conditions compared to 200T ($p<0.001$) and was higher in boys ($p<0.05$). Maximum handgrip strength of the preferred hand was correlated with SL, SI and speed only in the whole group (r=0.61 and r=0.73 respectively) and in the boys' group (r=0.74 and r=0.88 respectively). In conclusion, during a maximum intensity swimming at 200-m race pace, a rest interval up to 10 seconds between laps does not differentiate physiological parameters, but affects technical parameters. Maximum handgrip strength but not strength endurance correlates with overall performance.

Keywords: *stroke length, stroke rate, swimming index, interval swimming*

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**Introduction**

Coaches have been using interval training at or near race pace since the 1950s (Billat, 2001). Particularly in swimming, race pace training is used as a tool to replicate and train specific bioenergetic processes and identify optimal stroke length (SL) and stroke rate (SR) (Maglischo, 2003). It has been shown that different patterns for SL and SR are used for different swimming events, with the 200-m pace separating the long- and mid-pace pattern from the sprint pace pattern (Seifert, Chollet, & Rouard, 2007). (Costill et al., 1985)Furthermore, it has been shown that technical parameters are strongly related with the performance of young swimmers, especially in sprinting events (Morais et al., 2016), while accumulating fatigue during high-speed swimming deteriorates such parameters (Figueiredo, Sanders, Gorski, Vilas-Boas, & Fernandes, 2013).

In parallel, the handgrip test has been systematically used in general (Gerodimos, Karatrantou, Psychou, Vasilopoulou, & Zafeiridis, 2017) and athletic populations (Garrido et al., 2012) as health and performance indicators. Particularly in young swimmers, maximum handgrip test has been used as a method to predict performance especially for swimming events ranging from 50 to 200m. (Garrido et al., 2012; Geladas, Nassis, & Pavlicevic, 2005; Gomez-Bruton et al., 2016). However, in an event such as the 200m. front crawl, the component of endurance is of great importance and maintenance of speed and stroking parameters during the last stages of the race can differentiate medalists from non-medalists in competition (Mytton et al., 2015). Hence, strength endurance could also serve as a predictor of performance and/or stroke components such as SL or SR.

Only one study examined the acute effect of rest interval during race pace interval swimming on physiological and technical parameters (Beidaris, Botonis, & Platanou, 2010) without however discriminating genders and without examining the effect of handgrip strength endurance on these parameters and overall performance during 200m. front crawl. The aim of our study was (a) to examine the effect of rest interval duration in overall performance and stroke parameters and (b) to correlate maximum handgrip strength and handgrip strength endurance with performance and stroke parameters during swimming 200m. front crawl with different rest intervals.

**Method**

***Participants***

Sixteen age group swimmers (8 boys and 8 girls) with national level competitive experience were recruited from three regional swimming clubs. Anthropometric of the participants are presented in Table1. The swimmers and their parents received detailed information about the risks and procedures and were asked to sign an informed consent document before the beginning of the study. The study was approved by the University of Thessaly local ethical committee.

**Table 1.** Descriptive statistics for participants' anthropometric characteristics.

| Group | Age (years) | Body height (cm) | Body mass (kg) |
|---|---|---|---|
| Total (n=16) | 13.8 ± 1.1 | 167.8 ± 7.3 | 58.0 ± 6.4 |
| Boys (n=8) | 13.4 ± 1.1 | 167.1 ± 3.7 | 56.7 ± 4.6 |
| Girls (n=8) | 14.3 ± 1.0 | 168.5 ± 10.0 | 59.3 ± 7.9 |

***Procedure***

The study was completed approximately 20 days before the winter age group national championship. All testing procedures were completed in a 25m. indoor swimming pool. To avoid disturbances of swimmers' training routine, all tests were conducted before the initiation of typical workouts on three different training days, with 48 hours between each testing. In order to avoid cross-over effects, the order of swimming trials, as well as handgrip testing of the "preferred" and the "nonpreferred" hands were randomized.

*Handgrip testing*. In the first day of the study, the examiners assessed the hand preference of the swimmers. After instructed to maintain the adopted testing position (standing with arm extended by the side of the body), the swimmers' were familiarized with the portable digital hand-held dynamometer Takei (Takei 5401, Digital dynamometer, Japan) by performing a standardized warm-up (3-5 handgrip trials of very low intensity) (Gerodimos et al., 2017). After the warm-up, the swimmers were asked to perform three maximal trials, lasting 5 seconds each, on each hand with 1-minute rest between trials (Gerodimos et al., 2017). The best trial was recorded for further analysis. After the maximum trials testing, the handgrip strength endurance was assessed using the same testing position. The dynamic protocol consisted of twelve (12) consecutive maximal isometric contractions of 3 seconds duration, with a 5 seconds rest between repetitions. From the evaluation of the dynamic endurance protocol, Fatigue Index (FI) was calculated with two different equations (Gerodimos et al., 2017):

Equation 1:

$$FIi(\%) = \frac{\text{First repetition} - \text{Last repetition}}{\text{First repetition}} X\ 100$$

Equation 2 (percentage change):

$$FIii(\%) = \frac{\text{Mean of the first 50\% of the total repetitions}}{\text{Mean of the last 50\% of the total repetitions}}\ X\ 100$$

*Swimming testing*. All swimming testing protocols were conducted after a standardized warm-up (~ 1000m. low to moderate swimming, including drills, kicking and small sprints), using the front crawl technique. During testing, after each turn, the swimmers were instructed not to perform underwater dolphin kick and to emerge from the water and start swimming before the turning flags. All swimmers were instructed to swim 200m. at race pace, in three different conditions:

Condition 1: continuous 200m. (200T)

Condition 2: 4 X 50m. with 5 seconds rest between each split (4x50-R5)

Condition 3: 4 X 50m. with 10 seconds rest between each split (4x50-R10)

Time to complete each distance and resting interval time was assessed by two examiners as if in a regular workout, using a commercial stopwatch (TYR Z-100). It's worth noting that all examiners had substantial swimming coaching and/or swimming experience and also the swimmers' coach was present during each testing. Before the warm-up and after each testing condition, resting and post-exercise blood lactate (La) concentration was measured (Lactate Scout, EKF Diagnostics). Post-exercise heart rate (HR) was measured during the first 10 seconds of recovery by carotid artery palpation.

In each swimming condition, average SR (cycles per minute) and swimming speed (V) were measured, and SL was calculated as the quotient of speed with SR (Dalamitros et al., 2016). Stroke index ($m^2 \cdot s^{-1} \cdot cycles^{-1}$) was calculated by multiplying the swimming speed by SL (Jurimae et al., 2007).

***Statistical analysis***

All data are presented as mean values ± SD. A two – way [gender (boys vs girls) by condition (no rest vs. 5 seconds rest vs. 10 seconds rest)] analysis of variance (ANOVA) and Bonferroni post hoc test was used to assess differences in variables between condition and gender. A three-way analysis was used for blood lactate comparisons (gender x conditions x sampling points [pre vs post]). Correlations between the variables of handgrip scores and swimming parameters were tested using Pearson's correlation test. Significance level set at $p<0.05$.

**Result**

Swimming speed was higher in 4x50-R10 compared to the other two conditions (main effect of condition $p<0.001$), and in boys compared to girls (main effect of gender $p<0.05$, Table 2). Blood lactate was no different between conditions but there was a main effect of sampling point ($p<0.001$) and a three-way "condition" x "gender" x "sampling point" interaction ($p<0.05$, Figure 1).

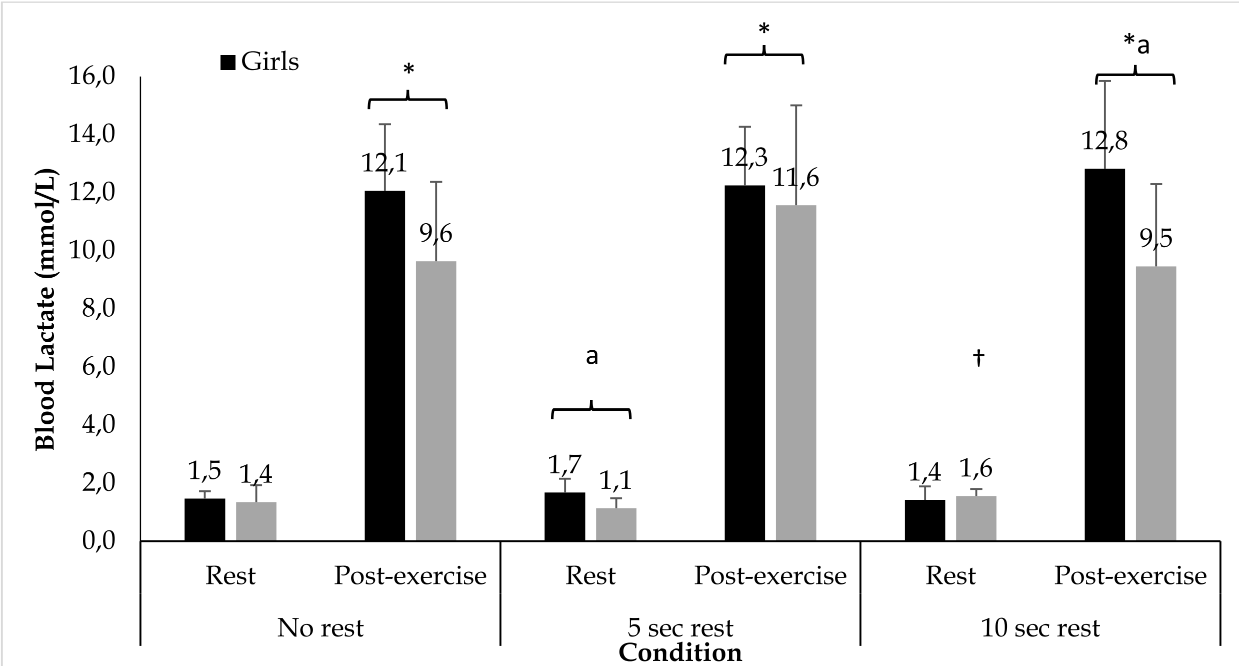


**Fig 1.** Lactate concentration in all three swimming test conditions. * denotes significant difference from corresponding resting values, a denotes significant difference between genders, † denotes significant difference from corresponding values of the second condition (p<0.05).

Post-exercise heart rate was no different between conditions and no gender or "gender" x "condition" interaction were observed (girls, 200T: 194.3 ± 24.0, 4x50-R5: 185.3 ± 30.0, 4x50-R10: 184.5 ± 24.6; boys, 200T: 191.3 ± 17.4, 4x50-R5: 194.3 ± 14.7, 4x50-R10: 190.5 ± 18.4 b·min-1, all p>0.05).

SL was no different between the conditions and no gender or "gender" x "condition" interaction were observed (p>0.05). SR was increased in 4x50-R5 and 4x50-R10 compared to 200T (p<0.001), and only a two-way "condition" x "gender" interaction was observed (p<0.05). Stroke was increased in intermittent conditions compared to 200T, (p<0.001) and was higher in boys compared to girls (main effect of gender p<0.05). SL, SR and stroke index data are presented in Table 2.

**Table 2.** Swimming parameters in the three swimming conditions in both genders. *a* denotes significant difference from the 200T condition, *b* denotes significant difference from the 4x50-R5 condition, * denotes significant difference between genders (p<0.05).

| Index | Group | Condition | | |
|---|---|---|---|---|
| | | 200T | 4x50-R5 | 4x50-R10 |
| Stroke Length ($m \cdot cycles^{-1}$) | All | 2.02 ± 0.25 | 1.98 ± 0.15 | 1.98 ± 0.20 |
| | Girls | 1.94 ± 0.18 | 1.95 ± 0.14 | 1.91 ± 0.14 |
| | Boys | 2.10 ± 0.28 | 2.02 ± 0.16 | 2.05 ± 0.23 |
| Stroke Rate ($cycles \cdot m^{-1}$) | All | 32.36 ± 3.31 | 34.50 ± 2.86 a | 35.04 ± 3.21 a |
| | Girls | 32.40 ± 3.18 | 33.77 ± 3.09 a | 34.97 ± 2.97 ab |
| | Boys | 32.31 ± 3.66 | 35.24 ± 2.60 a | 35.11 ± 3.64 a |
| Stroke Index ($m^2 \cdot s^{-1} \cdot cycles^{-1}$) | All | 2.72 ± 0.44 | 2.82 ± 0.34 | 2.86 ± 0.40 |
| | Girls | 2.51 ± 0.27 | 2.65 ± 0.19 a | 2.65 ± 0.23 a |
| | Boys | 2.94 ± 0.48 * | 2.99 ± 0.37 * | 3.07 ± 0.43 * ab |
| Speed ($m \cdot s^{-1}$) | All | 1.35 ± 0.09 | 1.42 ± 0.10 a | 1.44 ± 0.09 ab |
| | Girls | 1.30 ± 0.05 | 1.36 ± 0.05 a | 1.39 ± 0.06 ab |
| | Boys | 1.40 ± 0.09 * | 1.48 ± 0.10 * a | 1.49 ± 0.09 * ab |

Results from maximum handgrip strength and handgrip endurance strength are presented in Table 3. Regarding correlations, only in the total group and in the boys' group, maximum handgrip strength of the preferred hand correlated significantly with SL, SR, and speed. The correlation coefficients among swimming parameters obtained from the three swimming test conditions and the handgrip test are presented in Table 4.

**Table 3.** Descriptive statistics for participants' handgrip maximum strength and fatigue endurance, in total group and by gender. (P = preferred, NP = non-preferred, Rep = repetition, FI = fatigue index).

| | Group | | |
|---|---|---|---|
| | Total (n=16) | Boys (n=8) | Girls (n=8) |
| P hand | 32.3 ± 8.7 | 36.8 ± 10.0 | 27.8 ± 4.1 |
| NP hand | 29.5 ± 7.9 | 33.6 ± 9.0 | 25.3 ± 3.9 |
| Rep 1 (kg) | 29.5 ± 7.9 | 34.1 ± 8.5 | 24.8 ± 3.4 |
| Rep 2 (kg) | 28.5 ± 8.6 | 33.5 ± 9.4 | 23.5 ± 3.3 |
| Rep 3 (kg) | 26.8 ± 7.9 | 31.8 ± 8.6 | 21.9 ± 2.0 |
| Rep 4 (kg) | 26.1 ± 7.7 | 30.6 ± 8.5 | 21.7 ± 2.9 |
| Rep 5 (kg) | 25.4 ± 8.0 | 30.0 ± 9.1 | 20.7 ± 2.6 |
| Rep 6 (kg) | 24.3 ± 7.5 | 28.5 ± 8.3 | 20.1 ± 3.1 |
| Rep 7 (kg) | 23.3 ± 6.7 | 27.1 ± 7.8 | 19.6 ± 1.7 |
| Rep 8 (kg) | 22.8 ± 7.6 | 27.2 ± 8.6 | 18.3 ± 2.2 |
| Rep 9 (kg) | 22.7 ± 6.9 | 26.8 ± 7.7 | 18.7 ± 2.3 |
| Rep 10 (kg) | 22.0 ± 6.6 | 25.9 ± 7.4 | 18.2 ± 2.2 |
| Rep 11 (kg) | 21.5 ± 7.1 | 25.9 ± 7.6 | 17.1 ± 2.6 |
| Rep 12 (kg) | 21.9 ± 6.3 | 25.6 ± 6.7 | 18.1 ± 2.5 |
| FIi | 25.3 ± 8.6 | 24.5 ± 7.7 | 26.1 ± 9.9 |
| FIii | 118.4 ± 8.0 | 117.9 ± 8.7 | 119.0 ± 7.8 |

**Table 4.** Descriptive statistics for participants' handgrip maximum strength and fatigue endurance, in total group and by gender. (P = preferred, NP = non-preferred, Rep = repetition, FI = fatigue index).

| | | Condition | | |
|---|---|---|---|---|
| Index | Group | 200T | 4x50-R5 | 4x50-R10 |
| SL | All | 0.61* | 0.56* | 0.62* |
| | Girls | -0.18 | -0.03 | -0.16 |
| | Boys | 0.74* | 0.74* | 0.72* |
| SR | All | -0.25 | 0.09 | -0.18 |
| | Girls | -0.08 | -0.20 | -0.15 |
| | Boys | -0.37 | 0.00 | -0.27 |
| SI | All | 0.73* | 0.79* | 0.75* |
| | Girls | -0.39 | -0.33 | -0.42 |
| | Boys | 0.88* | 0.93* | 0.89* |
| V | All | 0.61* | 0.72* | 0.60* |
| | Girls | -0.60 | -0.56 | -0.60 |
| | Boys | 0.70 | 0.84* | 0.69 |

**Discussion**

The study examined the effect of the rest interval during race pace interval swim, on physiological and technical parameters as well as the correlation of those parameters with maximum handgrip strength and endurance. The main findings of the study indicate that the boys were faster in all swimming tests and there was no difference in physiological responses and stroke length in continuous compared to intermittent race pace swimming. However, the stroke rate was higher in the intermittent compared to continuous 200m. swimming. Moreover, handgrip strength was correlated with stroke length in all conditions.

The results are in agreement with previously reported studies, documenting faster swimming speeds for boys compared to girls in this age group (Silva et al., 2012; Zamparo, 2006). Regarding lactate and heart rate, our results indicate that a rest period with a duration up to 10 seconds does not differentiate the lactate concentration and heart rate during 4 laps of 50m. at race pace (Beidaris et al., 2010), suggesting a successful replication of race conditions. It is interesting to note that despite similar metabolic and cardiac responses, the swimmers achieved greater speed in the intermittent conditions.

Moreover, stroke length was well maintained in all conditions. Such an outcome suggests that a series of up to four 50m. is a safe intermittent set for stroke length maintenance, as such a technical parameter has been shown to be critical for speed maintenance (Mytton et al., 2015) and a fundamental skill to develop in young swimmers (Silva et al., 2012). Although there were no differences between genders in swimming technique parameters, boys had higher stroke index values, which is in accordance with previously reported data (Silva et al., 2012) suggesting that other factors such as anthropometry and/or strength are contributing for such a result. Furthermore, boys are able to maintain an efficient stroke rate during race pace swimming with a 5 seconds rest between each 50m. lap, partially contributing to a higher speed during this event. However, when considering the overall group, the maintenance of an optimal stroke rate in training, a minimum rest of 10 seconds is required. It has to be noted that all swimming technique variables measured in the present study, improve with maturation and training/competitive status (Aujouannet, Bonifazi, Hintzy, Vuillerme, & Rouard, 2006; Figueiredo et al., 2013; Figueiredo, Zamparo, Sousa, Vilas-Boas, & Fernandes, 2011).

Another important finding is that handgrip strength endurance doesn't correlate with swimming performance or any of the swimming technique variables studied here and that maximum handgrip strength is a better predictor for such variables as described elsewhere (Garrido et al., 2012; Gomez-Bruton et al., 2016). However, such a relationship between handgrip strength endurance couldn't be excluded in endurance swimming distances such as the 400 to 1500m. freestyle events.

The present study indicates that a short interval of 5 or 10 seconds can be used to facilitate a higher race pace for 200m. in young swimmers. Applying this approach swimmers reach similar metabolic responses and maintain stroke efficiency at a higher speed compared to continuous swimming.

**Significance for Sport**

The results of the present study provide to swimming coaches important information on the technical and metabolic strain, imposed on swimmers during interval race pace swimming. Such information can help in constructing race pace sets as well as interpreting performance during practicing such swimming sets.

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