

Backstroke Technical Characterization of 11-13 Year-Old Swimmers

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Abstract

The aim of this study was to characterize the backstroke swimming technique of 11-13 year-old swimmers when performing at very high intensity. A sample of 114 swimmers was divided into four groups regarding maturational and gender effect, who performed 25-m backstroke swimming at 50-m pace. Using two underwater cameras the general biomechanical parameters (speed, stroke rate, stroke length and stroke index), the arm stroke phases and two indexes of arm coordination (Index of Coordination 1, which characterizes the continuity between propulsive phases of each arm and Index of Coordination 2 that evaluates the simultaneity between the beginning of the pull of one arm and of the recovery of the other arm) were measured. Post-pubertal swimmers achieved higher values of speed (1.06 ± 0.14 and 1.18 ± 0.14 m·s⁻¹ for pubertal and 1.13 ± 0.14 and 1.24 ± 0.12 m·s⁻¹ for post-pubertal girl and boy swimmers, respectively), stroke length (1.64 ± 0.26 and 1.68 ± 0.25 m·cycle⁻¹ for pubertal and 1.79 ± 0.22 and 1.75 ± 0.27 m·cycle⁻¹ for post-pubertal girls and boys, respectively) and stroke index. Regarding genders, male were faster than female swimmers. Boys also showed a higher stroke rate and stroke index than girls, who achieved higher results in the ratio between stroke length and arm span. As it was expected, no hand lag time was noticed in young swimmers. Although no differences were noticed between genders, the Index of Coordination 1 was in catch-up mode (-9.89 ± 3.16 and -10.16 ± 3.60 % for girls and -9.77 ± 2.93 and -10.39 ± 2.44 % for boys pubertal and post-pubertal, respectively) and the Index of Coordination 2 was in superposition mode (1.86 ± 4.39 and 2.25 ± 2.25 % from girls and 1.72 ± 2.62 and 1.95 ± 2.95 % for boys, pubertal and post-pubertal, respectively).

Key words: Swimming, backstroke, age group, kinematics, coordination.

Introduction

Swimming performance is mainly analysed through the swimming speed, which is the product of stroke length (SL) and stroke rate (SR). Therefore, swimming skills were traditionally evaluated through changes in these parameters and also in stroke index (SI), being this latter the combination of speed and SL (Girolid et al., 2001; Pelayo et al., 1996; Seifert et al., 2010). Complementarily, to reach a high-level of performance, Maglischo (2003) noticed that the ideal inter-arm coordination in front crawl and backstroke should conform to the opposite coordination model, which provides continuous propulsion between the two arm actions.

In fact, special attention has been given to the modifications in the temporal organization of arm stroke phases in front crawl and backstroke in the last decade. Firstly for front crawl, Chollet et al. (2000) created the Index of Coordination (IdC) to measure the lag time between the propulsive phases of each arm, expressing three different coordination modes: (i) opposition (IdC = 0), evidencing continuity between two propulsive phases; (ii) catch-up (IdC < 0), corresponding to a lag time between propulsive phases of the two arms; and (iii) superposition (IdC > 0), describing an overlap of the propulsive phases. A number of studies were conducted trying to characterize the IdC in front crawl for different velocities and swimmers of distinct levels and genders (for a review see Chollet and Seifert, 2011; Seifert and Chollet, 2008).

Then, the IdC was adapted to backstroke by Lerda and Cardelli (2003) aiming to quantify the continuity between the propulsive phases of the two arms, being observed that it presented negative values (varying from -25% to -5%) whatever the swimming pace and the swimmers level and gender, i.e., a catch-up coordination mode (Chollet et al., 2008; Lerda and Cardelli, 2003; Lerda et al., 2005). This catch-up coordination is the result of anatomical characteristics, in particular the limited shoulder flexibility (Richardson et al., 1980), and may be more pronounced with an incorrect alternating body-roll movement (Maglischo, 2003; Psycharakis and Sanders, 2010). This insufficient body-roll could lead to an additional phase, the hand lag time at the thigh (Chollet et al., 2008), leading to a discontinuity between the propulsive actions of the two arms, and to significant intra-cycle speed fluctuations. Barbosa et al. (2008) evidenced that higher intra-cycle speed fluctuations lead to superior energy cost, suggesting that even if catch-up coordination is the only mode possible in the backstroke technique, swimmers should minimize the lag time. Nevertheless, Lerda and Cadelli (2003) and Lerda et al. (2005) did not report this phase in these studies.

Complementarily, Chollet et al. (2008) emphasized that, for swimmers with a "two-peak stroke pattern", an additional phase between the push phase and the above-water recovery (i.e., the clearing phase) imposes a catch-up mode of inter-arm coordination. Schleihauf et al. (1988) reported that the clearing phase could be used by swimmers with particular anatomical characteristics (hyperlaxity of the shoulder), - which Alves (1996) called a second upsweep - increasing propulsion and decreasing intra-cycle speed fluctuations. However, this "three-peak

stroke pattern" (with a second upsweep) is not usual (Maglischo, 2003).

Considering that age-group swimmers have different physical and biological characteristics, as well as different body height and arm span, which are related to better swimming performance (Lätt et al., 2009) and a naturally reduced history of training, it is challenging to analyze their specific stroke-technique parameters and inter-arm coordination to adapt training. The aim of this study was to characterize the backstroke swimming technique through the stroke parameters (speed, SR, SL and SI) and the inter-arm coordination (IdC) in young swimmers performing at very high intensity. It was hypothesized that age-group swimmers show a catch-up inter-arm coordination mode at fast backstroke, without any hand lag time at the thigh. In addition, regarding maturation status and gender, it was hypothesized that post-pubertal swimmers show kinematical and coordinative values closer to those previously published for adults than pubertal ones due to their higher anthropometrical features.

Methods

One hundred and fourteen swimmers from the same competitive swimming age group category (girls of 11-12 and boys of 12-13 years of age), participating in a training campus, volunteered for this study. Before beginning the measurements, the protocol was fully explained to the participants and their respective coaches. The local Ethics Committee approved the experimental procedures and the swimmers' parents signed a consent form, in which the protocol was described. It was implemented in the preparatory period of the first macrocycle of the training season. Their mean values related to frequency and percentages of swimmers in the different Tanner maturation stages are described in Table 1, being possible to observe that there are 60 pubertal (stages 2 and 3) and 54 post-pubertal swimmers (stages 4 and 5), corresponding to 52.6 and 47.4%.

Complementarily, and following Tanner and Whitehouse (1982), a maturation evaluation was made dividing swimmers in three stages: pre-pubertal swimmers (stage 1), pubertal swimmers (stages 2 and 3), and post-pubertal swimmers (stage 4 or higher). The swimmers maturation evaluation was made by presenting images to them related to the development of secondary sexual characteristics – genital (boys), breast (girls) and pubic hair (boys and girls) – and a self-evaluation rating was carried on. The images were also presented to swimmers' parents and coaches, with the final result expressed as the mean value of these three evaluations.

For the kinematical evaluation, swimmers performed 25-m backstroke at the 50-m race pace. Each subject started in the water and swam alone, without the pressure of opponents, to reduce the drafting or pacing

effects (Barbosa et al., 2010). Afterwards, swimmers were informed of their performance time, which was expected to be within $\pm 2.5\%$ of the targeted race speed; when the time was unexpected, the subject repeated the trial after a 30 min interval. Two underwater video cameras (Sony® DCR-HC42E, 1/250 digital shutter, Nagoya, Japan), placed in the sagittal and in the frontal planes inside a sealed housing (SPK – HCB waterproof box, Tokyo, Japan), recorded two complete underwater arm stroke cycles. A bi-dimensional images calibration structure (6.30m², and 13 calibration points) was used to transform the virtual coordinates into the real ones. Kinematical analysis was performed using APASystem software (Ariel Dynamics, San Diego, USA), digitizing the skin markers manually and frame by frame (at 50 Hz) to have more objective analysis. The aerial phase was measured through the time that the arm was out of water. The hip (femoral condyle) and, on both sides of the body, the distal end of the middle finger, the wrist, the elbow, the shoulder and the ankle were digitized using the Zatsiorsky and Seluyanov's model, adapted by de Leva (1996); the digitized-redigitized reliability was very high (Intra Class Correlation coefficient of 0.982).

The backstroke arm action was divided into six phases (Chollet et al., 2008): (i) entry and catch, from the entry of the hand into the water to the beginning of its backward movement; (ii) pull, starting when the hand begins the backward movement and ending with its arrival in a vertical plane to the shoulder (the first part of propulsive phase); (iii) push, from the position of the hand below the shoulder to the end of the hand's backward movement (the second propulsive phase); (iv) hand lag time, corresponding to the time when the hand stops at the thigh after the push phase and before the clearing; (v) clearing, from the hand release upward to the beginning of the exit from the water; and (vi) recovery, from the point of water release to the water re-entry of the arm. Each phase was expressed as a percentage of the duration of a total arm stroke. The duration of the propulsive phases was defined as a sum of the pull and push phases, and the duration of the non-propulsive phases the sum of the entry and catch, hand lag time, clearing and recovery phases.

However, as stated previously, the clearing phase could also be considered as a propulsive phase if the swimmer sweeps his hand up, back, and in to his thigh, pushing water back with the palm of the hand and the underside of the forearm, called "three-peak stroke pattern" swimmers (Alves, 1996; Chollet et al., 2008; Maglischo, 2003; Schleihauf et al. 1988). From there, as it is unclear if young swimmers mostly exhibited two or three-peak stroke pattern, the inter-arm coordination was assessed by two Indexes of Coordination (IdC1 and IdC2), which quantifies the lag time between the possible propulsive phases of the left arm and the right arm (Lerda

Table 1. Frequency and percentages of swimmers in the different Tanner maturation stages.

	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
	N	%	N	%	N	%	N	%	N	%
Boys	0	0	16	28.6	20	35.7	9	16.1	11	19.6
Girls	0	0	6	10.3	18	31.1	29	50.0	5	8.6

Table 2. Mean (\pm SD) values of the swimmers' anthropometric, sexual maturation status and training frequency characteristics.

	Boys (n = 56)		Girls (n = 58)	
	Pubertal (n = 36)	Post-Pubertal (n = 20)	Pubertal (n = 24)	Post-Pubertal (n = 34)
Age (years) ^a	12.42 (.08)	12.65 (.11)	11.08 (.08)	11.71 (.08)
Body Mass (kg) ^{a, b}	47.61 (1.25)	54.35 (1.46)	40.42 (1.44)	46.98 (1.17)
Height (m) ^{a, b}	1.54 (.01)	1.64 (.01)	1.48 (.01)	1.55 (.01)
Arm Span (cm) ^{a, b}	157.19 (1.34)	166.60 (1.81)	147.55 (1.62)	156.61 (1.08)
Years of Practice	3.75 (.87)	3.75 (1.25)	3.38 (.77)	3.35 (1.07)
Training Frequency (training units/week) ^b	5.33 (.08)	5.70 (.11)	5.18 (.08)	5.76 (.08)

^a (boys > girls), ^b (post-pubertal > pubertal) ($p \leq 0.05$)

and Cardelli, 2003): IdC1 corresponds to the time between the end of the push phase of one arm and the beginning of the pull phase of the other arm and IdC2 was the time between the end of the clearing phase of one arm and the beginning of the pull phase of the other arm. These time gaps were computed for the right and left arms, then averaged and expressed as percentage of the mean duration of a stroke cycle. In other words, IdC1 measured the continuity of the propulsive phases with two-peak, and IdC2 assessed the propulsive continuity in case of swimmers with three peak stroke pattern.

Speed values were computed through the ratio of the displacement of the hip in an arm cycle and its total duration, and SL was determined by the horizontal distance traveled by the hip during a complete stroke cycle. The hip forward movements were used because it provides a good estimate of the swimmer's horizontal velocity and displacement which is relevant for diagnostic purposes, especially to assess swimming efficiency (Fernandes et al. 2012). SR corresponded to the number of arm cycles performed per minute and SI was achieved through the product of velocity and SL (Costill et al., 1985).

Data were tested for normality of distribution using the Skewness test. The statistical analysis performed was based on exploratory data analysis. Mean and SD were calculated for all measured parameters. To compare genders and maturation, the analysis of independent measures ANOVA was applied. As no interaction between genders

and maturation status was observed, a separated analysis was made by conducting a one-way ANOVA was conducted comparing maturation status regarding genders. The statistical significance was set at $p \leq 0.05$ (SPSS Statistics version 18.0). This statistical analysis was applied for all subjects (independently of their maturation and gender), according to the maturation group (independently of their gender), and by gender (independently of maturation group). Finally, the relation between all parameters analyzed was observed by determining the momentum Pearson correlation coefficient.

Results

The mean and SD values regarding the swimmers' anthropometric, sexual maturation status and training frequency characteristics are described in Table 2. Results indicated that boys are older, heavier and taller, and have higher arm span than girls. Furthermore, post-pubertal swimmers are heavier, taller and showed a higher arm span than pubertal ones. All swimmers were engaged in 3-4 years of swimming competitive practice.

The mean and SD values for the stroking and coordinative parameters (speed, SR, SL and SI, as well as the two Indexes of Coordination – IdC1 and IdC2 – and the relative arm phases) are presented in Table 3.

When comparing maturation stages (independently of gender), the post-pubertal group showed significant higher speed, SL, and consequently, SI values. Boys

Table 3. Mean (\pm SD) values of speed, Stroke Rate, Stroke Length, Stroke Length/ Arm span, Index of Coordination 1, Index of Coordination 2, Entry and catch, Pull, Push, Hand Lag Time, Clearing, Recovery, Propulsive Phases and Non Propulsive Phases for the entire sample, according to genders and maturation.

	Girls (n = 58)		Boys (n = 56)	
	Pubertal (n = 36)	Post-Pubertal (n = 20)	Pubertal (n = 24)	Post-Pubertal (n = 34)
Speed (m·s ⁻¹) ^{a, b}	1.06 (.14)	1.13 (.14)	1.18 (.14)	1.24 (.12)
Stroke Rate (cycle·min ⁻¹) ^a	39.50 (5.88)	38.43 (5.92)	42.65 (5.46)	43.35 (5.80)
Stroke Length (m·cycle ⁻¹) ^b	1.64 (.26)	1.79 (.22)	1.68 (.25)	1.75 (.27)
Stroke Length/ Arm Span ^c	1.10 (.16)	1.15 (.13)	1.07 (.15)	1.05 (.16)
Stroke Index (m ² ·s ⁻¹ ·cycle ⁻¹) ^{a, b}	1.76 (.43)	2.03 (.37)	2.01 (.45)	2.20 (.46)
Index of Coordination 1 (%)	-9.89 (3.16)	-9.77 (2.93)	-10.16 (3.60)	-10.39 (2.44)
Index of Coordination 2 (%)	1.86 (4.39)	1.72 (2.62)	2.25 (2.25)	1.95 (2.95)
Entry and catch (%)	14.68 (4.41)	17.04 (4.63)	17.39 (7.21)	15.87 (4.55)
Pull (%)	14.35 (2.22)	13.37 (2.39)	12.76 (7.34)	14.82 (3.47)
Push (%)	21.06 (4.95)	21.79 (4.00)	22.43 (4.08)	20.52 (3.51)
Hand Lag Time (%)	0.00 (.00)	0.00 (.00)	0.00 (.00)	0.00 (.00)
Clearing (%)	18.69 (3.76)	17.53 (3.59)	17.91 (3.24)	18.35 (2.87)
Recovery (%)	31.23 (4.45)	31.35 (6.97)	29.52 (4.13)	30.44 (2.87)
Propulsive Phase (%)	36.70 (7.89)	35.16 (4.12)	36.33 (4.20)	35.34 (4.33)
Non Propulsive Phase (%)	63.30 (10.71)	64.84 (4.12)	63.67 (4.20)	64.66 (4.33)

^a (boys > girls), ^b (post-pubertal > pubertal), ^c (girls > boys) ($p \leq 0.05$).

presented higher speed, SR and SI and lower SL values than girls. There were no significant differences between maturation and gender groups regarding IdC and stroke phase's values. In particular, IdC1 was negative, meaning that age-group swimmers adopt a catch-up coordination when performing backstroke at very high intensity, which is explained by the greatest relative duration of the non-propulsive phases (~64% with the recovery the longest phase and the pull phase the shortest). The IdC2, which was positive, showed superposition of the beginning of pull phase of one arm and the recovery in the other arm, revealing, in the male group, a trend to achieve higher values comparing to female counterparts. No hand lag time was noticed in any swimmer.

In addition, moderate and high relationships were observed for pubertal swimmers between speed and SR ($r = 0.57$, $p < 0.01$ and $r = 0.47$, $p < 0.05$, for boys and girls, respectively) and with SI ($r = 0.85$, $p < 0.01$ and $r = 0.85$, $p < 0.01$, for boys and girls, respectively). On the other hand, post-pubertal swimmers showed a high relationship between speed and SI ($r = 0.78$, $p < 0.01$ and $r = 0.77$, $p < 0.01$ for boys and girls, respectively); post-pubertal girls also showed a high relationship between speed and SL ($r = 0.68$, $p < 0.01$). These results suggest that pubertal swimmers reached high speeds mainly through an increase in SR, and that post-pubertal swimmers (especially girls) increase speed through an increase in SL.

Discussion

The aim of this study was to characterize the backstroke swimming technique, in young swimmers, performing at very high intensity (using stroking and coordinative parameters) regarding maturation status and gender. An important finding was that age-group swimmers did not present a hand lag time between the clearing and the recovery phases, suggesting that this technical error might have been a constant concern of these age-group swimmers' coaches. Indeed, Chollet et al. (2008) showed that elite backstrokers were characterized by absence or low hand lag time at the thigh; $1.8 \pm 0.4\%$ of the stroke duration.

Results did not evidence any statistical differences of inter-arm coordination (IdC1 values) between maturation status and gender; moreover, the IdC1 values are close to those described in the literature for adult swimmers (Chollet et al., 2008; Lerda and Cardelli, 2003), exhibiting a catch-up coordination mode. The absence of statistical differences between groups could be explained by the maturational perspective on motor development of Newell (1986), who argued that three categories of constraints interact and determine the individual optimal pattern of coordination: organismic, environmental and task constraints. Thus, although in the current study the organismic constraints could reveal some differences (e.g. anthropometrical characteristics and maturity state), the swimmers' tasks were similar, as they exhibit the same competitive level and training frequency.

Maturational effect

Post-pubertal swimmers presented higher values of speed, SL and SI than pubertal ones that could be explained by their proper anthropometric characteristics, since taller swimmers usually show a larger arm span leading to a higher swimming efficiency (Saavedra et al., 2010). These authors added that chronological age was the main swimming performance determinant, being the strongest predictive variables related to the anthropometric (particularly in males), specific fitness (aerobic speed and endurance), and technical domains (particularly in females). However, this fact could be explained by an improvement in technique, as stroking parameters are correlated to performance (especially SI values, which are considered the best single performance predictor) (Lätt et al., 2010; Saavedra et al., 2010).

Andrews et al. (2011) noticed that elite swimmers showed a greater entry of shoulder angle than non-elite swimmers, being closer to the optimum suggested (180°). According to Vorontsov (2011), during puberty a rapid rise in production of sexual hormones induces growth of muscle mass, maturation of all physiological systems and creates the optimal biological background for development of the anaerobic energy system, maximal power, specific muscular endurance, and speed-strength abilities. In this sense, as young swimmers are developing their physical capacities and their technical abilities, they could exhibit a shoulder angle similar to non-elite swimmers.

Moreover, higher SI values, which are considered an indicator of swimming economy, since it describes the swimmer's ability to move at a given speed with the fewest number of strokes (Costill et al., 1985), may also resemble a decrease in hydrodynamic drag. Indeed, reduction in the shoulder angle entry – which was considered a major fault in backstroke swimming – leads to increased form and wave drag, reducing performance (Maglischo, 2003). Nevertheless, these observed differences in SL do not seem to be related with somatic growth because the ratio SL and arm span was not statistically significant between these two maturity stages. Thus, the higher SL values of post-pubertal swimmers suggest higher swimming efficiency (Lerda et al., 2005). Regarding SR values, it was observed that males reached values close to those presented by elite males when swimming at the same race pace (Chollet et al., 2008).

Gender effect

The results of the present study showed higher values of speed, SR, SI, and ratio between SL and arm span for males than for females, confirmed by a high positive correlation between speed and SR. Indeed, Chollet et al. (1996) have previously showed that the highest speed of males in 100- and 200-m events was due to their greatest SL. However, in the study of Lerda et al. (2005), centered on elite swimmers performing 100-m backstroke, SR differences between genders were not shown.

In swimming, performance has been related to higher SI and arm span (e.g. Lätt et al., 2009) and SI and SR (e.g. Lätt et al., 2010). However, although girls showed lower arm span than boys, the higher values in the SL and arm span ratio suggested that girls are able to a

better use of their arms than boys. Indeed, girls also showed lower SR values suggesting that girls tried to increase speed with an increase in SL as these parameters showed a positive correlation to each other ($r = 0.33$ for pubertal and $r = 0.68$, $p < 0.01$, for post-pubertal girls). In the backstroke swimming technique, SR was lower than in the butterfly, front crawl and breaststroke, and SL was higher in backstroke and front crawl techniques, suggesting that it is one of the most relevant performance determinant variables (Chollet et al., 2008). This technical adjustment – increased SL – could translate a longer propulsive force application and a less drag, thus reducing energy cost. Comparing to a study of Lerda et al. (2005), SR values in fastest women (38.1 ± 5.4 cycle·min⁻¹) are similar to our results in girls, but in males there is a difference of almost 7 cycles per minute for faster men (34.9 ± 5.8 cycle·min⁻¹) and about 11 cycles per minute for slower men (31.1 ± 4.9 cycle·min⁻¹), with boys showing higher SR values. These differences are probably related to anthropometric characteristics and strength differences, being adult swimmers taller, with an arm span higher than young swimmers and with more strength. Moreover, according to Lerda et al. (2005), in a study with the same swimming technique, a higher speed of the faster swimmers can be explained by variations in SL for men and in SR for women, however, in young swimmers, SL seems to be more related to speed in girls ($r = 0.50$, $p < 0.01$) and SR in boys ($r = 0.53$, $p < 0.01$).

Index of coordination

Even when swimming backstroke at high intensity, age-group swimmers adopted a catch-up coordination mode. These results are according to other studies conducted with older swimmers (Chollet et al., 2008; Lerda and Cardelli, 2003; Lerda et al., 2005), which stated that backstroke inter-arm coordination is necessarily in catch-up mode, and that an increase in SR does not imply a change in coordination as it is observed for front crawl technique (Barbosa et al., 2010; Millet et al., 2002). In the present study, boys noticed an IdC1 similar to faster adult male swimmers (-10.1 ± 3.9), but girls showed a different result than faster female swimmers (-3.4 ± 3.7) presented in a study of Lerda et al. (2005). However, girls showed a trend to have an IdC1 slightly higher than boys, although not statistically different. Similar results were noticed for adult swimmers (Lerda and Cardelli, 2003).

Similarly, there were no differences between genders as well as between maturity stages for the IdC2. However, it is possible to observe a trend similar to the results obtained by adults, namely, the post-pubertal group showing slightly lower values in IdC2 than the pubertal group. In adult swimmers, this index – which quantifies simultaneity between the beginning of the pull of one arm and the beginning of the aerial recovery of the other arm – was lower than young swimmers, being related to an increase of clearing phase duration ($r = 0.86$, $p < 0.05$) and was negatively correlated with durations of entry and catch ($r = -0.66$, $p < 0.05$), pull ($r = -0.50$, $p < 0.05$) and recovery ($r = -0.67$, $p < 0.05$) (Lerda and Cardelli, 2003). Furthermore, it was indicated that an increase in skill is characterized by a shorter duration

between the beginning of pull of one arm and the recovery of the other arm – IdC2 (Lerda and Cardelli, 2003; Lerda et al., 2005). Likewise, young swimmers showed positive correlation between IdC2 and clearing phase duration ($r = 0.40$, $p < 0.01$) and negative correlation with the duration of the entry and catch phase ($r = -0.41$, $p < 0.01$). No significant correlation was noticed between IdC2 and pull duration, but with the push phase duration this correlation occurred ($r = 0.25$, $p < 0.01$).

Catch-up appears to be the exclusive coordination mode in this technique due to anthropometrical actions at the shoulder level of constraining flexibility (Richardson et al., 1980). The alternating body-roll seems to play a relevant part in this stroke characteristic (Maglischo, 2003; Richardson et al., 1980). These two technical aspects of the backstroke impose a particular coordination between the two arms, and an additional phase in the arm stroke, the clearing phase (Lerda and Cardelli, 2003). This phase is shortly in studies published with adult women ($20.0 \pm 4.6\%$) than in adult men swimmers ($27.1 \pm 9.0\%$), in opposite to what happens with the entry and catch phase duration ($8.3 \pm 8.5\%$ and $4.5 \pm 3.7\%$ for women and men, respectively). However, in this study there were no differences between genders in the duration time of these two phases, as it was described for adult swimmers by Lerda et al., (2005). Following these authors, in adult swimmers, the differences between genders in these two phases were related to the effect of flotation, and that is higher in women than in men. The better flotation of women may explain their greater aptitude to maintain a horizontal body position and consequently the lengthening of the entry and catch to reduce drag (Chatard et al., 1990). This observation confirms that the durations of stroke phases are not due to chance but related to anthropometric criteria, as Chatard et al. (1990) stated. However, this explanation is true when reporting to the static position, which could not be related with movement, when swimming. As the stage of maturation shows, the age-group swimmers whom participate in this study are still growing. So, these results suggest that the differentiation between genders occurs only when maturation is fully complete. However, the differences in anthropometric characteristics between genders, as well as the height and the arm span, seem to be decisive to reach higher performances (Lerda et al., 2005).

According to Lerda et al., (2005) a longer entry and catch phase in adults can streamline the body and limit imbalances, thus reducing drag. This characteristic was considered as the best predictor of the performance in both genders. However, when comparing age-group to adult swimmers, it is possible to observe that although age-group had a longer entry and catch phase, this could be more related to a lower level of coordination, due to the maturity stage that they across, and not to reduce drag. Furthermore, these swimmers may increase the effectiveness of stroke by increasing the pull phase duration, that is lower than adult faster swimmers ($19.07 \pm 3.93\%$), and is a characteristic of slower swimmers ($16.13 \pm 2.47\%$) as Lerda and Cardelli (2003) noticed. These results led to a lower sum of propulsive phases duration in young swimmers, comparing to adult results obtained in previously

published papers ($40.0 \pm 3.9\%$) and a longer sum of non-propulsive phases than adults ($60.0 \pm 3.9\%$) (Chollet et al., 2008).

Conclusion

Age-group swimmers, performing backstroke at high intensity, presented catch-up arm coordination and showed no hand lag time phase. Age-group swimmers showed similar IdC1 to studies conducted in adults. Complementarily, post-pubertal group showed higher values of speed, SL and SI than their pubertal peers. Hence, speed and SL were lower in young swimmers compared to studies conducted with adults. However, these differences could be related to growth and mainly to maturation. In fact, these ages seems to be very important to improve technique instead of focusing on heavy physical conditioning. In this sense, when training young swimmers, coaches should spend more time with technique drills and giving feed-backs about their technique and, consequently, to their coordination.

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Key points

- Young swimmers adopt the catch-up arm coordination when swimming backstroke.
- These swimmers present lower stroking parameters than those published for older and higher level swimmers.
- No hand lag time at the thigh was noticed, meaning that young swimmers perform the final phase of their arm cycle without inducing discontinuity between the propulsive actions of the two arms

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