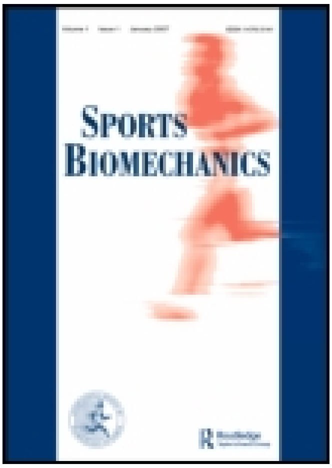

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Growth influences biomechanical profile of talented swimmers during the summer break

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Growth influences biomechanical profile of talented swimmers during the summer break

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Abstract
This study aimed to analyse the effect of growth during a summer break on biomechanical profile of talented swimmers. Twenty-five young swimmers (12 boys and 13 girls) undertook several anthropometric and biomechanical tests at the end of the 2011–2012 season (pre-test) and 10 weeks later at the beginning of the 2012–2013 season (post-test). Height, arm span, hand surface area, and foot surface area were collected as anthropometric parameters, while stroke frequency, stroke length, stroke index, propelling efficiency, active drag, and active drag coefficient were considered as biomechanical variables. The mean swimming velocity during an all-out 25 m front crawl effort was used as the performance outcome. After the 10-week break, the swimmers were taller with an increased arm span, hand, and foot areas. Increases in stroke length, stroke index, propelling efficiency, and performance were also observed. Conversely, the stroke frequency, active drag, and drag coefficient remained unchanged. When controlling the effect of growth, no significant variation was determined on the biomechanical variables. The performance presented high associations with biomechanical and anthropometric parameters at pre-test and post-test, respectively. The results show that young talented swimmers still present biomechanical improvements after a 10-week break, which are mainly explained by their normal growth.

Keywords: *Training/conditioning, swimming, performance, kinematics*

Introduction

In recent years, substantial attention has been given to the expertise, identification, and development of talented performers. Research on the topic suggested a multidisciplinary approach, identifying the range of interacting constraints that impinge on performance potential of individual athletes (Philips, Davis, Renshaw, & Portus, 2010). As such, the

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interaction between training and growth is a major concern while assessing the individual pathway to expertise.

Young talented swimmers usually have several weeks of school break during summer, where they take several months off from swim training (e.g. detraining) until the beginning of the following season. The effects of detraining are dependent on several factors such as the duration of the detraining period, sport characteristics, competitive level, and chronological age (Mujika & Padilla, 2000a, 2000b). A long-term detraining period adversely changes muscle biochemistry (Costil, Fink, et al., 1985), endurance fitness (Ormsbee & Arciero, 2012), and increases in fat mass (Alméras, Lamieux, Bouchard, & Tremblay, 1997) in adult swimmers. In the case of young talented swimmers, there is a lack of information regarding the effects of a detraining period from one season to another. Sambanis (2006) reported decreases in pulmonary function and performance of young male swimmers after 50 days of detraining. Conversely, Garrido et al. (2010) determined unchanged muscle strength and hydrodynamic characteristics, but improved performance among young swimmers after 6 weeks of strength detraining. Despite these previous findings, researchers should take a multidisciplinary approach when investigating the effects of detraining.

Young talented swimmers, as any other children, experience physical changes as part of their normal biological development. Body mass, height, and therefore limb length/area are some of the anthropometric features that change with normal growth (Malina & Bouchard, 1991). It is well documented that success in many sports may depend on the physical characteristics of young athletes (Baxter-Jones, Helms, Mafulli, Baines-Preece, & Preece, 1995). Bi-variate research reported that arm span was the anthropometric feature with highest association ($R^2 = 0.45$) to the 400 m performance in young male subjects (Jürimäe et al., 2007), and hand and foot areas have been found to be positively correlated with young swimmers' 100 m performance (Helmuth, 1980). Furthermore, multivariate analysis also reported that anthropometrics (height and arm spam) in boys are reliable measures for performance prediction in swimming events (Saavedra, Escalante, & Rodriguez, 2010).

At younger ages, physical development (i.e. growth and maturation) may also lead to changes in the stroke mechanics and efficiency (Komar et al., 2012). In the past years, some links between biomechanical profile and performance also have been established. Between two major championships, the improvement in the swimming speed of age group swimmers depended mainly on stroke length increases and stroke rate decreases, resulting in part from the anthropometric growth (e.g. height, arm span, and length of foot and hands; Tella, Llana, Madera, & Navarro, 2002). A higher stroke efficiency expressed by stroke index (Jürimäe et al., 2007) and propelling efficiency (Barbosa, Costa, et al., 2010; Kilika & Thorland, 1994) was also found to be a good predictor of performance in young swimmers. A large number of coaches still reduce as much as possible the summer vacation period to avoid substantial losses in the ability of their swimmers. Thus, understanding the interaction between growth and technical ability is a major concern at younger ages.

The aim of this research was to analyse the effects of growth on young swimmers' biomechanical profile after a 10-week summer break. It was hypothesized that, despite the absence of swim training, anthropometric growth would cause an improvement during that period in the biomechanical ability.

Methods

Participants

Twenty-five talented swimmers including 12 boys (12.8 ± 0.9 years old; 50.09 ± 10.13 kg) and 13 girls (12.0 ± 0.9 years old; 49.42 ± 7.47 kg) were recruited to participate in this study. At the beginning of data collection, swimmers had 3.18 ± 0.52 years of training experience and Tanner stages 1 and 2 by self-evaluation. They were swimmers with regular presence in regional and national level competitions, including national champions and national record holders for their age-group. Coaches, parents, and/or guardians gave their consent for the children to participate in this study. All procedures were in accordance to the Helsinki Declaration regarding human research. The Institutional Review Board of the University of Trás-os-Montes and Alto Douro approved the study protocol.

Study design

A longitudinal research design was carried out. Repeated measures of several anthropometric and biomechanical measures were obtained in two different moments. Field tests were conducted for 2 days at the end of the 2011–2012 season (pre-test) and 10 weeks later at the beginning of the 2012–2013 season (post-test). Anthropometric and kinematic tests were conducted in the morning. Hydrodynamic tests were carried out in the afternoon of the same day. Twenty-four hours later, performance measures were collected based on a 25-m maximal trial. The swimmers experienced the summer break between both time point measurements. No specific swim training with energetic workloads and technical drills was conducted during this time. Subjects were also instructed by their coaches and researchers to avoid any type of vigorous/controlled water programme during the summer. Potential uncontrolled leisure-oriented activities (e.g. sea bathing, play team games) were not specific enough to be considered swim training.

Anthropometric data collection

Swimmers were only wearing a textile swimsuit and a cap during all anthropometric tests. Height, arm span, hand surface area, and foot surface area were considered as anthropometric features. The height (in cm) was obtained with the swimmer in anthropometric position, by measuring the distance from the vertex to the floor with a digital stadiometer (SECA, 242, Hamburg, Germany). For the arm span measurement (in cm), the subjects stayed in an upright orthostatic position with arms and fingers fully extended in lateral abduction at a 90° angle with the trunk. The arm span was considered as the distance between the third finger-tip of each hand and was measured with a flexible anthropometric tape (RossCraft, Canada). The test/retest evaluation (i.e. intra-class correlation coefficient (ICC) for arm span was high (ICC = 0.98). Both surface areas were computed using digital photogrammetry. The swimmers put their dominant hand and foot, respectively, on the scan surface of a copy machine (Xerox 4110, Norwalk, CT, USA) near a 2D calibration frame (Morais et al., 2012). Thereafter, the perimeter of the hand surface area and foot surface area was digitized in the Xerox machine, and files were converted to PDF format. The areas (in cm^2) were computed using a specific software program (Universal Desktop Ruler, v3.3.3268, AVPSoft, USA) as reported elsewhere (Morais et al., 2012). The test/retest ICCs of the hand and foot areas were 0.99 and 0.97, respectively.

Biomechanical data collection

Each swimmer performed three 25-m front crawl swims with an underwater start. Trials were separated with at least 30 min to ensure full recovery of the swimmers. Stroke frequency and stroke length were computed during the middle of the 25 m and, for further analysis, the average value of the three trials was computed. To avoid the starting effect, the mean swimming velocity was assessed visually while the head passed a marker between the 11th and 24th m from the starting wall and was calculated through a 15-m distance:

$$v = \frac{d}{t}, \tag{1}$$

where v is the mean swimming velocity (in m/s), d is the distance covered (in m), and t is the elapsed time (in s). Stroke frequency (in cycles/min) was measured with a chrono-frequency counter during three consecutive strokes by two expert evaluators (ICC = 0.97). The stroke frequency values were then expressed in Hz (cycles/s). Stroke length was calculated as follows (Craig & Pendergast, 1979):

$$\mathrm{SL} = \frac{v}{\mathrm{SF}}, \tag{2}$$

where SL is the stroke length (in m), v is the mean swimming velocity (in m/s), and SF is the stroke frequency (in Hz).

Efficiency variables (i.e. representing overall swimmer's technical ability) were calculated from kinematic data. Stroke index was computed as follows (Costill, Kovaleski, et al., 1985):

$$\mathrm{SI} = v\mathrm{SL}, \tag{3}$$

where SI represents stroke index (in m^2/s), SL represents stroke length (in m), and v is the mean swimming velocity (in m/s). The propelling efficiency was computed as follows (Zamparo, Pendergast, Mollendorf, Termin, & Minetti, 2005):

$$\eta_{\mathrm{p}} = \left(\frac{0.9v}{2\pi\mathrm{SF}l}\right)\frac{2}{\pi}, \tag{4}$$

where η_{p} is propelling efficiency (in %), v is the swimming velocity (in m/s), SF is the stroke frequency (in Hz), and l is the distance between the shoulder and tip of the third finger during the in-sweep length (in m) measured trigonometrically. The average elbow angles during the insweep during the arm pull were obtained from Zamparo (2006) for subjects of the same age and competitive level.

Active drag and active drag coefficient were computed as hydrodynamic variables using the velocity perturbation method (Kolmogorov & Duplishcheva, 1992). Each swimmer performed two maximal 25 m trials of front crawl swim with push-off start. The first trial was performed without carrying the perturbation device and the second one with the device (Marinho et al., 2010). Trials were performed with no other swimmer in the lane or nearby lanes to reduce drafting or pacing effects. Active drag was calculated from the difference between the swimming velocities with and without towing the perturbation buoy (Marinho et al., 2010). The drag of the perturbation buoy was computed from the manufacturer's calibration of the buoy-drag characteristics and its velocity (Kolmogorov & Duplishcheva, 1992). Swimming velocity was assessed visually while the head passed a marker between the 11th and 24th m from the starting wall. The time spent to cover this distance was measured with a stopwatch (Golfinho Sports MC 815, Aveiro, Portugal) by two highly expert evaluators. Both evaluators walked with the swimmer to have a perfect line of sight when the swimmer passed the specific point of measurement. The ICC for both evaluators was very high (ICC = 0.96). Active drag was computed as follows (Kolmogorov & Duplishcheva, 1992):

$$D_\mathrm{a} = \frac{D_\mathrm{b} v_\mathrm{b} v^2}{v^3 - v_\mathrm{b}^3}, \tag{5}$$

where D_a is the swimmer's active drag (in N), D_b is the resistance of the perturbation buoy (in N), and v_b and v are the swimming velocities with and without the perturbation device (in m/s), respectively. Active drag coefficient (C_da) was computed as follows (Kolmogorov & Duplishcheva, 1992):

$$C_\mathrm{da} = \frac{2D_\mathrm{a}}{\rho S v^2}, \tag{6}$$

where D_a is the swimmer's active drag (in N), ρ is the water density (assumed to be 1,000 kg/m^3), v is the swimmer's velocity from hydrodynamic trials (in m/s), and S is the swimmer's projected frontal surface area (in cm^2) photographed with a digital camera (DSC-T7, Sony, Tokyo, Japan) in the transverse plane from above simulating the hydrodynamic position (Caspersen, Berthelsen, Eik, Pâkodzi, & Kjendlie, 2010).

Performance data collection

Based on the assumption that a competitive swimmer would try to travel a given distance as fast as possible, performance was assessed through an all-out 25-m front crawl effort from the starting block. The velocity (in m/s) was used as a "performance" measure and was computed using Equation (1).

Statistical analysis

Kolmogorov–Smirnov and the Levene tests were used to assess normality and homoscedasticity assumptions, respectively. Box plots with quartile data from all variables were calculated for each period.

Repeated measures ANOVA were conducted for all dependent variables with "testing session" (pre-test and post-test) being a within-subject factor. ANCOVA was also computed controlling the effect of the growth rate (i.e. height difference between post-test and pre-test) in each biomechanical variable. All assumptions to perform the ANOVAs and ANCOVAs were considered (i.e. independence, normality, and homoscedasticity). The level of statistical significance was set at $p \leq 0.05$.

Effect sizes (η^2) were computed and interpreted as follows, following Ferguson (2009): without effect, if $0 < \eta^2 < 0.04$; minimum, if $0.04 < \eta^2 < 0.25$; moderate, if $0.25 < \eta^2 < 0.64$; and strong, if $\eta^2 > 0.64$. Data were reported to have a "meaningful variation" if significant ($p \leq 0.05$) with a moderate or strong effect size ($\eta^2 > 0.25$), and a "significant variation" if significant ($p \leq 0.05$) with a small effect size ($\eta^2 \leq 0.25$) (Winter, 2008). Pearson correlation coefficients were calculated to assess associations between performance and remaining variables in each testing session ($p \leq 0.05$).

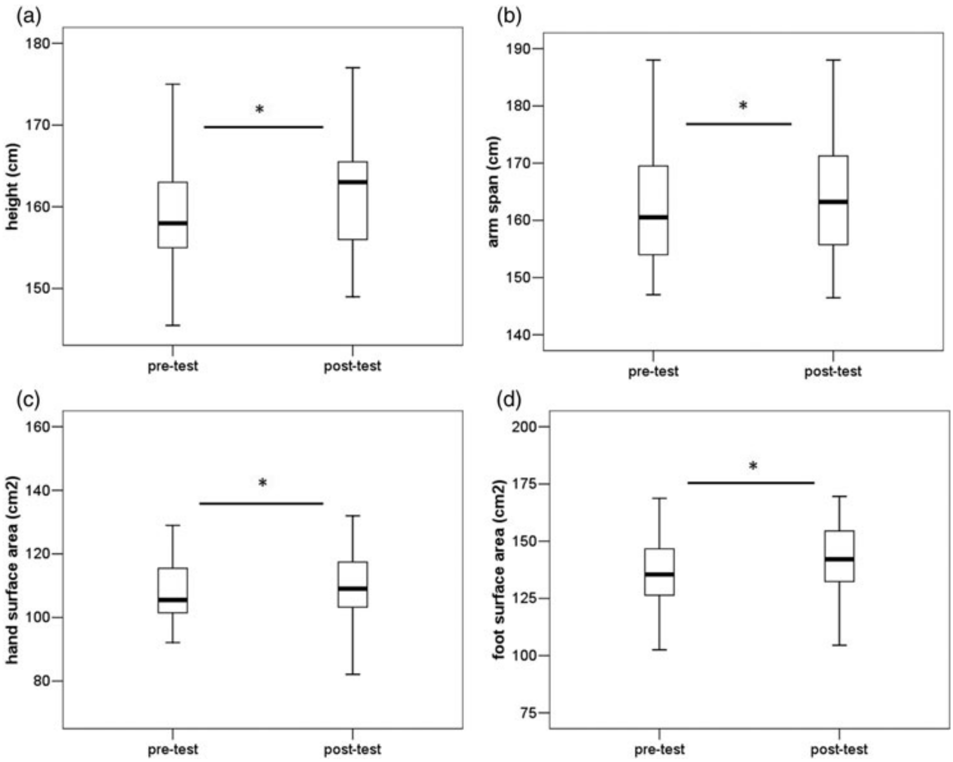

Figure 1. Variation of (a) height, (b) arm spam, (c) hand surface area, and (d) foot surface area during the detraining period between the end of one season and the beginning of the following one. *Significant variations between pre-test and post-test ($p < 0.05$).

Results

Figure 1 presents the box plots with quartile data of the anthropometric traits during the detraining period. ANOVA presented significant increases in height ($F_{1,24} = 22.299$; $p < 0.001$; $\eta^2 = 0.04$) and arm span ($F_{1,24} = 23.687$; $p < 0.001$; $\eta^2 = 0.07$), whereas hand surface area ($F_{1,24} = 18.428$; $p < 0.001$; $\eta^2 = 0.92$) and foot surface area ($F_{1,24} = 24.315$; $p < 0.001$; $\eta^2 = 0.66$) demonstrated meaningful increases.

Figures 2 and 3 present the box plots with quartile data of the biomechanical and performance variables, respectively. Meaningful increases were determined for stroke length ($F_{1,24} = 21.139$; $p < 0.001$; $\eta^2 = 1.00$), stroke index ($F_{1,24} = 21.816$; $p < 0.001$; $\eta^2 = 1.00$), and propelling efficiency ($F_{1,24} = 20.907$; $p < 0.001$; $\eta^2 = 1.00$). Stroke frequency ($F_{1,24} = 2.056$; $p = 0.17$; $\eta^2 = 1.00$), active drag ($F_{1,24} = 1.468$; $p = 0.24$; $\eta^2 = 0.95$), and active drag coefficient ($F_{1,24} = 2.465$; $p = 0.13$; $\eta^2 = 1.00$) remained unchanged. A meaningful variation was also determined for performance ($F_{1,24} = 19.265$; $p < 0.001$; $\eta^2 = 1.00$) from pre-test to post-test. When the growth rate was used as a covariate in the ANCOVA, all biomechanical variables presented non-significant variations (stroke length: $F_{1,24} = 0.669$, $p = 0.42$; stroke frequency: $F_{1,24} = 0.124$, $p = 0.73$; stroke index: $F_{1,24} = 0.857$, $p = 0.37$; propelling efficiency: $F_{1,24} = 0.593$, $p = 0.45$; performance:

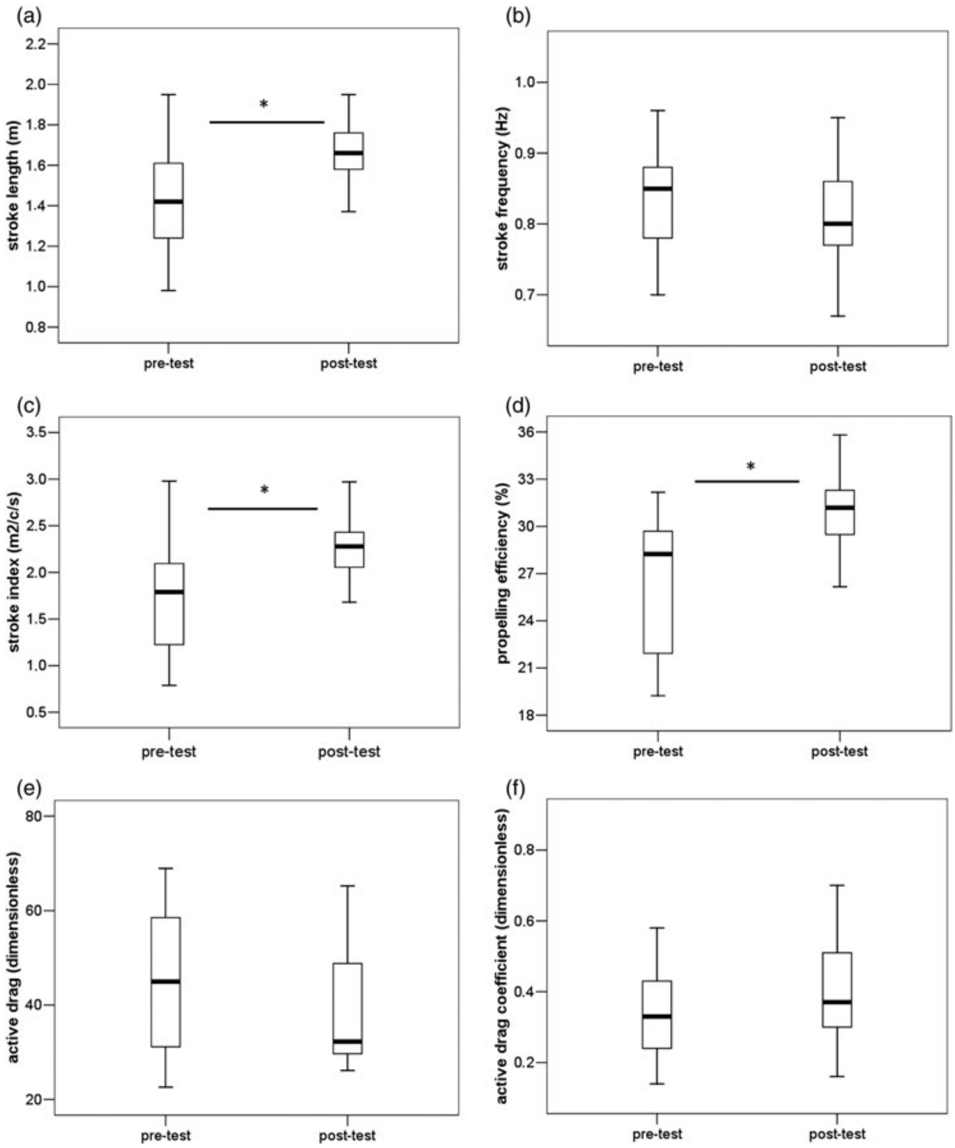

Figure 2. Variations of (a) stroke length, (b) stroke frequency, (c) stroke index, (d) propelling efficiency, (e) active drag, and (f) active drag coefficient during the detraining period between the end of one season and the beginning of the following one. *Significant variations between pre-test and post-test ($p < 0.05$).

$F_{1,24} = 0.473$, $p = 0.50$; active drag: $F_{1,24} = 0.022$, $p = 0.88$; active drag coefficient: $F_{1,24} = 0.178$; $p = 0.68$).

Table I presents the associations between anthropometric, kinematic, efficiency, and hydrodynamic variables and performance. High and significant associations were determined between technical skills (stroke length, stroke index and propelling efficiency) and performance at pre-test. Conversely, high and significant associations were most notable

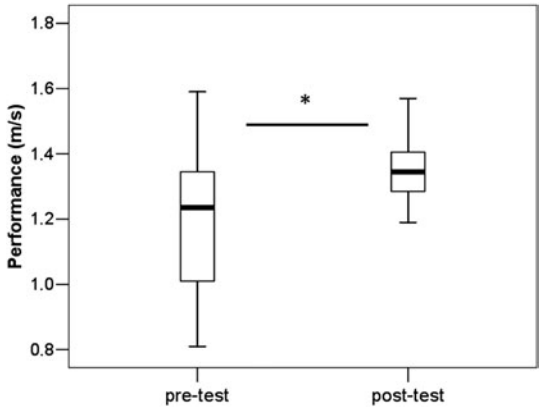

Figure 3. Variation of performance during the detraining period between the end of one season and the beginning of the following one. *Significant variations between pre-test and post-test ($p < 0.05$).

between the anthropometric features and performance at post-test. At post-test, both stroke length and stroke index presented a moderate and high relationship with performance, respectively.

Discussion and implications

The aim of this research was to analyse the effects of growth during a summer break on talented swimmers' biomechanical profile. There was an improvement in the biomechanical ability after the summer break which was mainly explained by the physical development (i.e. growth).

The participants (young boys and girls) were pooled together in this study because gender gap is not an issue at this age group (pre-adolescence). In a sample of 202 pre-adolescent subjects that were examined on a battery of anatomical and physiological tests, no significant interaction between age, sex, and sporting involvement was found, which indicated sex differences to be independent of age and training group (Blanksby, Bloomfield, Elliot, Ackland, & Morton, 1986). A solid body of knowledge also exists about the absence of a

Table I. Pearson correlation coefficients between performance and select anthropometric and biomechanical variables.

	Pre-test	Post-test
Anthropometrics		
Height	0.28 ($p = 0.17$)	0.72 ($p < 0.01$)
Arm span	0.27 ($p = 0.22$)	0.69 ($p < 0.01$)
Hand surface area	0.31 ($p = 0.14$)	0.72 ($p < 0.01$)
Foot surface area	0.15 ($p = 0.50$)	0.59 ($p < 0.01$)
Kinematics		
Stroke length	0.89 ($p < 0.01$)	0.52 ($p < 0.01$)
Stroke frequency	0.27 ($p = 0.20$)	0.26 ($p = 0.21$)
Efficiency		
Stroke index	0.97 ($p < 0.01$)	0.85 ($p < 0.01$)
Propelling efficiency	0.82 ($p < 0.01$)	0.13 ($p = 0.55$)
Hydrodynamics		
Active drag	0.40 ($p = 0.06$)	0.52 ($p = 0.08$)
Active drag coefficient	0.39 ($p = 0.06$)	-0.07 ($p = 0.55$)

gender gap in pre-pubertal swimmers (e.g. Ratel & Poujade, 2009; Seifert, Barbosa, & Kjendlie, 2010; Zuniga et al., 2011). Gender gap is most notable near puberty when growth spurt, hormonal profile, and strength development start to play a determinant role (Malina & Bouchard, 1991).

After the summer break, the swimmers were taller with a longer arm span and surface areas (hands and feet). These findings were consistent with the literature, at least when comparing the values of physical characteristics of young swimmers from other longitudinal samples (Latt et al., 2009a, 2009b; Morais et al., 2012). Several researchers in the past tried to understand the effects of training on a child's growth, but limited information was reported about detraining in young talented swimmers. Anthropometric growth is not influenced by physical activity or sports participation (Baxter-Jones et al., 1995; Malina, 1994) but by a pre-determined biological process involving complex structural/anatomical changes that children experience throughout formative years (Malina & Bouchard, 1991).

In the participants in this study, growth spurt was more evident for hand and foot areas than for height and arm span. The development of anthropometric proportions should be viewed as a set of different stages of growth. Anthropometric growth starts from the outside of the body, with an earlier expansion of the hands and feet and ends with the development of the longest bones (Ulijaszek, Johnston, & Preece, 1998). The hands and feet dimensions experience an accelerated growth during the initial stages of development, while the increase in arm spam and height are more evident near the later height spurt that occurs at age of 14 years (Blanksby et al., 1986). Indeed, the participants in this study were far away from the typical height spurt, which can explain the inconsistent developments in the various anthropometric sets.

Despite the prolonged absence of regular technical drills during the detraining period, the kinematic aspects of the stroke still improved. While the stroke length increased, the stroke frequency remained unchanged after the break. Tella et al. (2002) found that stroke length increased, but stroke frequency decreased in a group of swimmers from similar age and competitive level. This discrepancy can be explained by the scope of the intervention. The athletes from the study of Tella et al. (2002) were evaluated while exposed to swim training, where stroke frequency decreases are important adaptations for stroke optimization. Nevertheless, it is not clear if the stroke rate should decrease so sharply as reported by Tella et al. On the other hand, the participants of this study were assessed through detraining. The loss of water sensibility can be hypothesized as the main reason for the stroke frequency maintenance observed after the break.

Moreover, there is a very unique and individual stroke length-stroke frequency relationship for each swimmer. It is known that increases in velocity can be reached using different combinations between stroke frequency and stroke length in adults (Barbosa, Bragada, et al., 2010; Barbosa, Fernandes, Keskinen, & Vilas-Boas, 2008; Craig & Pendergast, 1979) and young swimmers (Barbosa, Costa, et al., 2010). At earlier ages, increases in stroke frequency without technique degradation are limited, mainly because of the muscle properties of the swimmers. The abrupt increase in muscle strength during growth usually starts 12–15 months after the appearance of the height peak (Bloomfield, Blanksby, & Ackland, 1990). At least one study reported unaltered strength levels of young swimmers after a 6-week detraining period (Garrido et al., 2010). It is clear that the swimmers from the present sample have not reached their height peak yet. Thus, increases in stroke frequency while maintaining stroke length were not possible. Instead, the improvement in velocity was based in stroke length increases, which can be explained by an increased arm span. Hence, the number of full strokes to perform the distance decreased.

The swimming efficiency improved as well. Meaningful increases in the stroke index and propelling efficiency are explained because both variables are rough estimations based on the kinematic and anthropometric measures. Increases in stroke length due to limb dimensions led to a markedly increase in performance and consequently in the stroke index. The stroke frequency maintenance and the upper limb growth promoted an improvement in propelling efficiency. So, special attention should be given to the anthropometric growth as it may define swimming efficiency during the detraining phase.

Both active drag and active drag coefficient remained unchanged from pre-test to post-test. A similar finding was reported for young swimmers after a season's break of 6 weeks (Garrido et al., 2010). Apparently, hydrodynamic characteristics are not so sensitive to detraining than other biomechanical outcomes in this age group. Eight weeks of swim training through a general training phase were not sufficient to statistically change active drag in young swimmers (Marinho et al., 2010). Conversely, 1 week of hydrodynamics training mainly with specific visual and kinesthetic feedbacks was sufficient to decrease active drag coefficient in pubescent swimmers (Havriluk, 2006). So, it appears that anthropometric growth is not the primary factor determining the hydrodynamic characteristics of young swimmers in shorter training periods. Fast hydrodynamic improvements can be achieved with rigorous training sets with proper feedback (at least according to swimmer's competitive level). When considering longer periods (e.g. longer than 10 weeks), other factors (e.g. chest perimeter or trunk transverse area) that were not considered for analysis may start to play a determinant role and change hydrodynamic characteristics of the swimmers.

Despite detraining, the swimmers were able to swim faster at the beginning of the new season. The few existing studies about this topic demonstrate contradictory findings. The 25- and 50-m front crawl performances of young swimmers still improved after 6 weeks of strength detraining (Garrido et al., 2010). Nevertheless, 50 days without swim training led to small decreases in the 100-m front-crawl performance of young male subjects (Sambanis, 2006). This inconsistency in the literature may be related to the distances selected to measure the performance. The detraining effects might be more evident in longer swimming distances than in shorter ones. A more severe loss may occur in the aerobic system than in the anaerobic one, which may explain such a phenomenon. Further research should clarify this issue to expand the detraining effects on young swimmer population.

When controlling the effect of the growth rate, no significant variations were found for the selected variables. Previous interventions reported that anthropometric traits had an impact on performance and several stroking parameters during periods of training in swimmers from similar age and competitive level (Latt et al., 2009a, 2009b; Pelayo, Wille, Sydney, Berthoin, & Lavoie, 1997; Tella et al., 2002). The covariance analysis results confirmed that physical growth was the major factor responsible for biomechanical improvement of talented swimmers through the summer vacation.

Correlation coefficients were computed to determine the variables with higher associations with performance at both testing occasions. While the biomechanical characteristics were the ones with higher associations with performance at pre-test, the anthropometric traits were the ones defining performance 10 weeks later. At these ages, a large part of the swimming sessions comprise technical drills to improve biomechanics. The maturation of the central nervous system allows the acquisition of specific tasks related to each sport (Fogassi et al., 2005). In swimming, regular practice improves skill-induced performance, which is more obvious at the end of the season. At this point, faster swimmers are expected to be the ones with a more "refined" technical ability. Conversely, at the beginning of the new season, the growth factor may play a major role.

As water is not the natural environment for human locomotion, perhaps the absence of swimming drills during a summer vacation may lead to a reduction in neural adaptations acquired in a previous training period and the loss of "water sensibility" as it is called by practitioners. To our knowledge, technical literature fails to have empirical data regarding this issue in young swimmers. However, evidence that physical loss after detraining periods could be attributed to neural alterations exists (Gondin, Guette, Ballay, & Martin, 2006). Thus, the faster swimmers at the beginning of the new season are expected to be the ones with higher anthropometric dimensions.

The main limitations of this research are as follows: (i) the absence of rigorous control of the summer activities engaged by the swimmers; (ii) the need to expand the multidisciplinary analysis including other performance determinant variables (e.g. speed fluctuation, index of coordination, and aerobic and anaerobic capacity); and (iii) the lack of genetic assessment to discriminate high from slow responders to the training and detraining. This study is largely restricted to research involving young swimmers, so our findings are only generalizable to swimmers who have the same anthropometric changes over a break from swimming.

Conclusion

It was concluded that young talented swimmers still improved their swimming biomechanics despite the absence of swim training after a 10-week summer break. Those improvements were mainly explained by the anthropometric growth. Thus, coaches may give their young athletes a reasonably long training break (i.e. 10 weeks) to recover and motivate for the next season, without worrying about biomechanical changes during the break.

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