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How does 11-week detraining affect 11-12 years old swimmers' biomechanical determinants and its relationship with 100 m freestyle performance?

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ABSTRACT

The aim of this study was to analyse the detraining process that occurs during a season break, and its influence on the performance, anthropometrics, and biomechanics of young swimmers. The sample included 54 young swimmers (22 boys: 12.79 ± 0.71 years; 32 girls: 11.78 ± 0.85 years). Performance for the 100 m freestyle and anthropometric and biomechanical variables were evaluated as main determinants. Performance impaired significantly for boys (2.17%) and girls (1.91%). All anthropometric variables increased between moments of assessment for boys and girls. Overall, the boys enhanced all biomechanical variables during the detraining period, and girls showed mixed results. For both sexes, the stroke index was the variable with the highest increase (boys: $\Delta = 16.16\%$; $d = 0.89$; $p = 0.001$; girls: $\Delta = 19.51\%$; $d = 1.06$; $p = 0.002$). Hierarchical linear modelling showed that the height retained the amount of impairment in the performance. One unit of increase in the height (cm) led to less 0.41 s impairment in the performance. Present data indicated that during an 11-weeks detraining period, young swimmers impaired their performance, but the determinant factors showed an impaired relationship. This increase in the determinant factors is mainly related to the increase in the swimmers' anthropometrics. Moreover, the increase in height was responsible for retaining the performance impairment.

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Introduction

Young swimmers' training programmes are usually designed to make swimmers achieve two to three performance peaks (i.e., macro-cycles) over the year (Morais, Silva, Garrido, Marinho, & Barbosa, 2018; Zacca et al., 2020). In this sense, coaches, swimmers, and researchers are used to designing the training load according to such macro-cycles.

After a peak-performance, swimmers undergo what is known as short-term detraining where they are submitted to insufficient training stimulus (less than four weeks) (Mujika & Padilla, 2000). In this case, in-water training load might be decreased, replaced, or

complemented by dry-land strength and conditioning programmes (Amaro, Marinho, Marques, Batalha, & Morouço, 2017; Garrido et al., 2010). By contrast, training cessation is characterised by a temporary break from the systematic training programmes (Mujika & Padilla, 2000). This may occur in the time between the finish of one season and the beginning of the following one. However, the effects of the duration of training cessation and the hypothetical repercussions or impacts this can have on performance and its determinant factors have not been deeply researched in youth swimmers.

In adult and elite counterparts, stroke biomechanics are already consolidated. Hence, detraining is mainly and highly associated with a decrease of the physiological response (Costill et al., 1985a; Ormsbee & Arciero, 2012). Conversely, few studies can be found about this topic in young swimmers (Moreira et al., 2014; Sambanis, 2006; Zacca et al., 2019a). In two studies, a significant increase in body dimensions was found after the break period (Moreira et al., 2014; Zacca et al., 2019a). Indeed, young swimmers, just as any other children, grow even during short periods of time (a few weeks). However, different findings have been reported about kinematics and efficiency based on different detraining approaches. The literature indicates that longer periods of detraining (or training break) are associated with an impairment in the performance, and kinematic and efficiency determinants (Mujika & Padilla, 2000). Thus, it can be suggested that young swimmers are also under this phenomenon.

However, one study showed a decrease in the kinematic (swim velocity, stroke frequency, and stroke length) and efficiency (stroke index) variables during four weeks of detraining (Zacca et al., 2019a), and another reported an increase in swimming kinematics (swim velocity and stroke length), and efficiency (stroke index and propelling efficiency) after ten weeks of break (Moreira et al., 2014). Hence, one might claim that these contradictory findings could be explained by growth and maturation in different age groups of swimmers. Anthropometrics are strongly related to young swimmers' performance (Geladas, Nassis, & Pavlicevic, 2005; Morais, Silva, Marinho, Lopes, & Barbosa, 2017).

Moreover, deterministic models showed that swimming performance depends on several complex and dynamic interactions (Barbosa et al., 2010a). Anthropometrics (namely body mass and height) presented a strong and positive correlation to young swimmers' 100 m freestyle performance (Geladas et al., 2005). However, such anthropometric variables do not only have a direct effect on performance, they also have a direct effect on other kinematic/efficiency variables (related to stroke mechanics) (Morais et al., 2012). Thus, it is of major importance to understand how an increase (children can significantly grow in short periods of time) in body dimensions will affect young swimmers' biomechanics and performance after a detraining period.

The aim of this study was to analyse the variations in performance, anthropometrics, and biomechanics after a season break to gather insights on the detraining process at such early ages. It was hypothesised that anthropometric variables would increase due to growth and maturation, while performance and biomechanics would impair.

Methods

Participants

Fifty-four young swimmers (22 boys: 12.79 ± 0.71 years old, FINA points at short course 100 m freestyle: 297.58 ± 87.72 ; 32 girls: 11.78 ± 0.85 years old, FINA points at short

course 100 m freestyle: 330.35 ± 79.80 ; maturation stage: Tanner 1–2) were recruited for this study. The swimmers were enrolled in a talent identification and development programme at local clubs and national teams. The sample included national champions, national record holders, and swimmers racing regularly at national and regional competitions. Parents or guardians, and the swimmers themselves, signed an informed consent form. All procedures were in accordance with the Declaration of Helsinki regarding human research, and the University of Beira Interior Ethics Board approved the research design.

Research design

A longitudinal research model was designed where swimmers were evaluated in two different moments (M_i). The first evaluation moment ($M1$) was during the last peak-performance of a competitive season. The second moment ($M2$) was during the first week of training of the following competitive season (an 11-week break took place—training cessation). To ensure a proper reproduction of the experimental trials, all swimmers underwent a familiarisation process for the in-water testing. During this process, swimmers were instructed not to engage in competitive swimming events and training. Biomechanical factors explained about 60% to 85% of young swimmers' performance (Morais et al., 2012; Zacca et al., 2020). Thus, it seems of major importance to understand how such determinants influence the performance after a breaking period. So, a set of hydrodynamic, mechanical power, kinematic, efficiency, and anthropometric variables were evaluated.

Performance

The 100 m freestyle event ($M1$: official race, $M2$: 100 m time-trial; in short course metre pool, i.e., 25 m length) was selected for the performance outcome.

Anthropometrics

The height (H , cm) was measured with a digital stadiometer (SECA, 242, Hamburg, Germany) and the body mass (BM , kg) with a digital scale (SECA, 884, Hamburg, Germany). The arm span (AS , m), trunk transverse surface area ($TTSA$, cm^2), hand surface area (HSA , cm^2), and foot surface area (FSA , cm^2) were measured by digital photogrammetry (Morais et al., 2012). The AS was measured as the distance between the third fingertip of each hand. For the $TTSA$, the swimmers were instructed to put their arms fully extended above the head, one hand over the other, fingers extended and close together with the head in a neutral position. They were photographed with a digital camera (Sony Alpha 6000, Tokyo, Japan) in the transverse plane (downwards view) on land simulating such a streamlined position. For the HSA and FSA , swimmers were instructed to put their dominant hand and foot in a scanning machine. Afterwards, the files were converted into PDF files and the respective areas were computed. All these variables (AS , $TTSA$, HSA and FSA) were measured using specific software (Udruler, AVPSOft, USA) (Morais et al., 2012).

Kinematics and efficiency

After a standard 1000 m warm-up (Neiva, Marques, Barbosa, Izquierdo, & Marinho, 2014), swimmers were instructed to perform three maximal trials of 25 m performing the front-crawl with a push-off start. Between each trial, they had a 30 minutes rest to ensure a full recovery. Data was collected by a mechanical apparatus (Swim speedo-meter, Swimsportec, Hildesheim, Germany). The acquisition, transfer, and signal handling were performed as reported elsewhere (Barbosa et al., 2015). The mean swim velocity (v , m/s) was measured between the 11th and 24th metre. A camera (Sony x3000, Tokyo, Japan) was used to record the swimmer's stroke frequency (SF). Afterwards, two expert evaluators calculated the SF by the number of cycles per unit of time, from the time it takes to complete one full cycle ($f = 1/P$; where P is the period), and afterwards converted to Hz (ICC = 0.990). The stroke length (SL, m) was calculated as $SL = v/SF$, where SL is the stroke length (m), v the swim velocity (m/s), and SF the stroke frequency (Hz) (Craig & Pendergast, 1979). The intra-cyclic variation of the swim velocity (dv , %), was computed as:

$$dv = \frac{\sqrt{\frac{\sum_i (v_i v) \cdot F_i}{n}}}{\frac{\sum_i v_i \cdot F_i}{n}} \cdot 100 \quad (1)$$

where dv is the intra-cyclic variation of the swim velocity (%), v is the mean swimming velocity (m/s), v_i is the instant swimming velocity (m/s), F_i is the acquisition frequency, and n is the number of observations (Barbosa et al., 2010a). The stroke index (SI, m²/s) was computed as $SI = v \cdot SL$, where SI is the stroke index (m²/s), v the swim velocity (m/s), and SL the stroke length (m) (Costill et al., 1985b). The Froude efficiency (η_F , %) was calculated as:

$$\eta_F = \left(\frac{v \cdot 0.9}{2\pi \cdot SF \cdot l} \right) \cdot \frac{2}{\pi} \cdot 100 \quad (2)$$

where η_F is the Froude efficiency (%), v the swim velocity (m/s), SF the stroke frequency (Hz), and l the shoulder to hand average distance (m) (Zamparo, 2006). The l distance was measured by digital photogrammetry (between the acromion and tip of the third finger).

Hydrodynamics

The active drag (D_a , N) and the coefficient of active drag (C_{Da} , dimensionless) were computed by the Velocity Perturbation Method (Kolmogorov & Duplishcheva, 1992). Swimmers were invited to perform two maximal trials in front-crawl. In one trial, swimmers were towing a hydrodynamic body (perturbation device) (Kolmogorov & Duplishcheva, 1992). The swim velocity was calculated between the 11th and 24th metre as $v = d/t$. The D_a was computed as:

$$D_a = \frac{D_b v_b v^2}{v^3 - v_b^3} \quad (3)$$

where D_a is the swimmer's active drag at maximal velocity (N), D_b is the resistance of the hydrodynamic body (N), v_b and v are the swim velocities with and without the perturbation device (m/s). The C_{Da} was computed as:

$$C_{Da} = \frac{2 \cdot D_a}{\rho \cdot TTSA \cdot v^2} \quad (4)$$

where C_{Da} is the active drag coefficient (dimensionless), D_a is the active drag (N), ρ is the density of the water (being 1000 kg/m^3), $TTSA$ is the trunk transverse surface area (m^2), and v is the swim velocity (m/s). The Froude number (Fr , dimensionless) was computed as:

$$Fr = \frac{v}{\sqrt{g \cdot H}} \quad (5)$$

where Fr is the Froude number (dimensionless), v is the swim velocity (m/s), g is the gravitational acceleration (9.81 m/s^2), and H is the swimmer's height (m) (Kjendlie & Stallman, 2008). The hull velocity (v_{hull} , m/s) was computed as:

$$v_{hull} = \sqrt{\frac{g \cdot H}{2 \cdot \pi}} \quad (6)$$

where v_{hull} is the hull velocity (m/s), g is the gravitational acceleration (m/s^2), and H is the height (m) (Vogel, 1994). The Reynolds number (Re , dimensionless) was computed as:

$$Re = \frac{v \cdot H}{\nu} \quad (7)$$

where Re is the Reynolds number (dimensionless), v is the swim velocity (m/s), H is the height (m), and ν is the water kinematic viscosity (being $8.97 \times 10^{-7} \text{ m}^2/\text{s}$ at 26°C) (Kjendlie & Stallman, 2008).

Mechanical power

The power to overcome drag (P_d , W) was computed as:

$$P_d = D_a \cdot v \quad (8)$$

where P_d is the power to overcome drag (W), D_a is the swimmers' active drag at maximal velocity, and v is the swim velocity (m/s) (Kolmogorov & Duplishcheva, 1992).

The external mechanical power (P_{ext} , W) and the mechanical power to transfer kinetic energy to water (P_k , W) were computed respectively as:

$$P_{ext} = \frac{P_d}{\eta_F} \quad (9)$$

where P_{ext} is the external mechanical power (W), P_d is the power to overcome drag (W), and η_F is the Froude efficiency (dimensionless, described in the kinematics/efficiency section) (Barbosa, Bartolomeu, Morais, & Costa, 2019).

$$P_k = P_{ext} - P_d \quad (10)$$

where P_k is the mechanical power to transfer kinetic energy to water (W), P_{ext} is the external mechanical power (W), and P_d is the power to overcome drag (W) (Barbosa et al., 2019).

The total power input (\dot{E}_{tot} , W) was estimated as:

$$\dot{E}_{tot} = \frac{P_d}{\eta_m \cdot \eta_F} \quad (11)$$

where \dot{E}_{tot} is the total power input (W), P_d is the power to overcome drag (W), η_F is the Froude efficiency (dimensionless), and η_m the mechanical efficiency (dimensionless) (Barbosa et al., 2019). It was assumed an average value of 0.2 for the η_m as reported elsewhere (Pendergast et al., 2003).

Statistical analysis

The Kolmogorov and Levene tests were applied to verify the normality and homoscedasticity assumptions, respectively. Mean plus one standard deviation and the variation between moments (Δ , in %) were computed as descriptive statistics. The t-test paired samples ($p \leq 0.05$) was run to assess the differences between moments. The mean difference (SI units) and respective 95% confidence interval (95CI) were also computed. Cohen's d was selected as a standardised effect size and deemed as: (i) small effect size if $0 \leq d \leq 0.2$; (ii) medium effect size if $0.2 < d \leq 0.5$ and; (iii) large effect size if $d > 0.5$ (Cohen, 1988).

Since repeated measures were nested within participants, the longitudinal data set was treated as hierarchical, and the change associated with the detraining between the two moments was analysed by hierarchical linear modelling (HLM). Two models were computed. The first model included the time effect, the sex effect, and the interaction between the time and sex to see if there were any changes over time, differences between sexes, and differences in the changes between sexes, respectively. In the second model, anthropometrics, hydrodynamics, kinematics, mechanical power, and efficiency variables were tested as potential predictors. The final model only included significant predictors. Maximum likelihood estimation was calculated on HLM7 software (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011). As the first model indicated significant differences between the sexes, descriptive and inferential data were presented separately for boys and girls.

Results

Overall, all anthropometric variables increased significantly (moderate to large effects) between M1 and M2 (Table 1 and Figure 1). The HSA was the variable showing the largest and most significant increase in boys (M1: $113.48 \pm 13.49 \text{ cm}^2$, M2: $119.09 \pm 13.21 \text{ cm}^2$; $\Delta = 4.71\%$; $d = 0.42$; $t = 6.47$; $p < 0.001$), and the BM in girls (M1: $45.94 \pm 7.10 \text{ kg}$, M2: $47.89 \pm 7.20 \text{ kg}$; $\Delta = 4.07\%$; $d = 0.27$; $t = 7.94$; $p < 0.001$).

Boys increased all hydrodynamic and mechanical power variables, except the P_k . The R_e was the hydrodynamic variable with the highest significant increase (M1: $2.37 \times 10^6 \pm 3.98 \times 10^5$, M2: $2.61 \times 10^6 \pm 3.37 \times 10^5$; $\Delta = 9.26\%$; $d = 0.66$; $t = 4.80$; $p < 0.001$) (Table 1 and Figure 2). Conversely, there were mixed results across several variables for girls between evaluation moments (Table 1 and Figure 2). Again, the R_e was the variable with the largest significant increase (M1: $1.99 \times 10^6 \pm 2.81 \times 10^5$; M2:

Table 1. Descriptive statistics and paired t-test data, for boys' and girls' variation between M1 and M2 for all anthropometric, hydrodynamic, hydrodynamic, mechanical power, kinematic, and efficiency variables, and performance.

	Boys (M1 vs M2)			Girls (M1 vs M2)		
	Mean difference (95CI)	t-test (p value)	Δ (d)	Mean difference (95CI)	t-test (p value)	Δ (d)
Age [years]	0.47 (0.22;0.72)	4.02 (0.001)	3.57 (0.73)	0.37 (0.13;0.61)	3.24 (0.005)	3.03 (0.50)
BM [kg]	2.41 (1.87;2.94)	9.36 (<0.001)	4.58 (0.28)	1.95 (1.45;2.45)	7.94 (<0.001)	4.07 (0.27)
H [cm]	3.67 (2.67;4.67)	7.64 (<0.001)	2.23 (0.35)	1.72 (0.97;2.47)	4.68 (<0.001)	1.10 (0.29)
AS [m]	0.02 (0.01;0.03)	5.87 (<0.001)	1.44 (0.20)	0.01 (0.007;0.016)	5.45 (<0.001)	0.78 (0.29)
TTSA [cm ²]	31.86 (2.78;60.93)	2.29 (0.033)	4.60 (0.35)	13.68 (-7.05;34.43)	1.35 (0.187)	2.04 (0.14)
HSA [cm ²]	5.61 (3.80;7.41)	6.47 (<0.001)	4.71 (0.42)	2.00 (0.37;3.63)	2.52 (0.018)	1.96 (0.20)
FSA [cm ²]	4.18 (2.28;6.08)	4.59 (<0.001)	2.85 (0.26)	3.11 (0.71;5.51)	2.67 (0.013)	2.41 (0.24)
SF [Hz]	-0.02 (-0.04;0.01)	-1.36 (0.191)	-1.97 (0.25)	0.018 (-0.023;0.06)	0.89 (0.379)	2.21 (0.23)
SL [m]	0.17 (0.08;0.26)	3.79 (0.001)	10.30 (0.79)	0.17 (0.05;0.29)	2.92 (0.007)	10.75 (0.79)
v [m/s]	0.10 (0.05;0.16)	3.76 (0.001)	7.29 (0.68)	0.13 (0.06;0.19)	4.08 (<0.001)	10.21 (1.11)
dv [%]	0.09 (-1.12;0.94)	0.18 (0.856)	1.06 (0.50)	0.25 (-0.46;0.96)	-0.72 (0.476)	0.41 (0.00)
D _a [N]	2.49 (-8.00;12.98)	0.49 (0.624)	4.48 (0.09)	-2.03 (-7.46;3.39)	-0.77 (0.447)	-5.86 (0.16)
C _{Da} [dimensionless]	0.05 (-0.02;0.11)	1.54 (0.140)	11.75 (0.27)	0.08 (-0.02;0.19)	1.60 (0.122)	22.37 (0.42)
F _r [dimensionless]	0.02 (0.008;0.04)	3.39 (0.003)	6.43 (0.95)	0.03 (0.01;0.05)	4.01 (<0.001)	9.59 (0.95)
R _e [(x 10 ⁵)]	2.42 (1.37;3.47)	4.80 (<0.001)	9.26 (0.66)	2.51 (1.29;3.72)	4.25 (<0.001)	11.18 (1.03)
V _{hull} [m/s]	0.02 (0.01;0.02)	7.67 (<0.001)	1.16 (0.50)	0.006 (0.002;0.01)	2.93 (0.007)	0.42 (0.00)
P _d [W]	9.12 (-5.43;23.68)	1.31 (0.204)	11.17 (0.20)	3.11 (-2.39;8.62)	1.16 (0.255)	7.00 (0.21)
P _{ext} [W]	8.59 (-41.25;58.45)	0.36 (0.721)	3.13 (0.06)	-6.29 (-30.92;18.33)	-0.52 (0.602)	-4.37 (0.14)
P _k [W]	-0.53 (-36.73;35.67)	-0.03 (0.976)	-0.27 (0.01)	-9.56 (-29.40;10.28)	-0.99 (0.329)	-9.49 (0.28)
E _{tot} [W]	42.99 (-206.28;292.26)	0.36 (0.721)	3.13 (0.06)	-31.47 (-154.64;91.69)	-0.52 (0.602)	-4.37 (0.14)
η [%]	2.47 (0.91;4.03)	3.21 (0.004)	8.15 (0.95)	3.10 (0.96;05.24)	2.98 (0.006)	10.19 (0.75)
SI [m ² /s]	0.39 (0.18;0.59)	3.97 (0.001)	16.16 (0.89)	0.39 (0.16;0.61)	3.56 (0.002)	19.51 (1.06)
100 m Performance [s]	1.52 (0.47;2.57)	3.03 (0.007)	2.17 (0.24)	1.46 (0.37;2.55)	2.77 (0.010)	1.91 (0.20)

BM—body mass; H—height; AS—arm span; TTSA—trunk transverse surface area; HSA—hand surface area; FSA—foot surface area; SF—stroke frequency; SL—stroke length; v—swim velocity; dv—intra-cyclic variation of the horizontal velocity of the hip; D_a—active drag; C_{Da}—coefficient of active drag; F_r—Froude number; R_e—Reynolds number; V_{hull}—hull velocity; P_d—power to overcome drag; P_{ext}—external mechanical power; P_k—mechanical power to transfer kinetic energy to water; E_{tot}—total power input; η _p—Froude efficiency; SI—stroke index; 100 m Performance—100 m freestyle performance at short course metre. Mean difference—SI units; 95CI—95% confidence interval; t—t-test value; p—significance value; Δ —relative difference in %; d—Cohen's d.

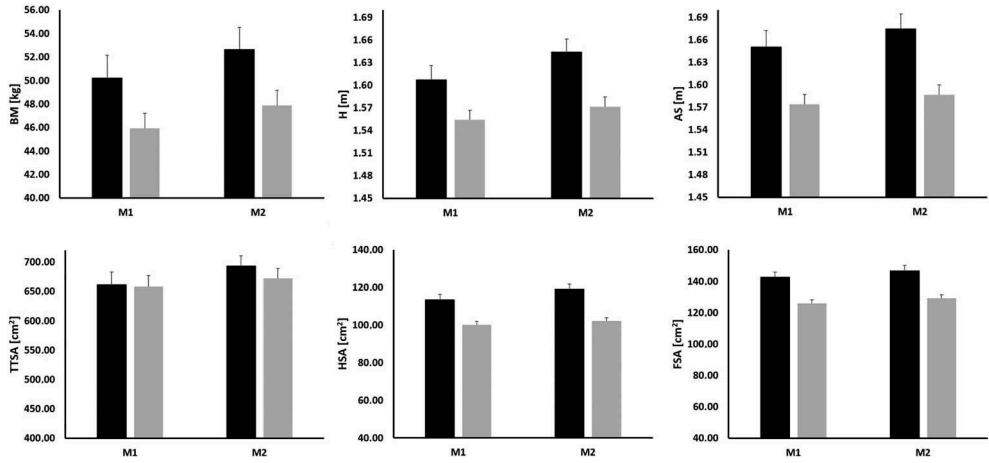


Figure 1. Anthropometrics variation between M1 and M2. The mean plus standard error are presented. BM—body mass; H—height; AS—arm span; TTSA—trunk transverse surface area; HSA—hand surface area; FSA—foot surface area. Black columns—boys’ variation; grey columns—girls’ variation.

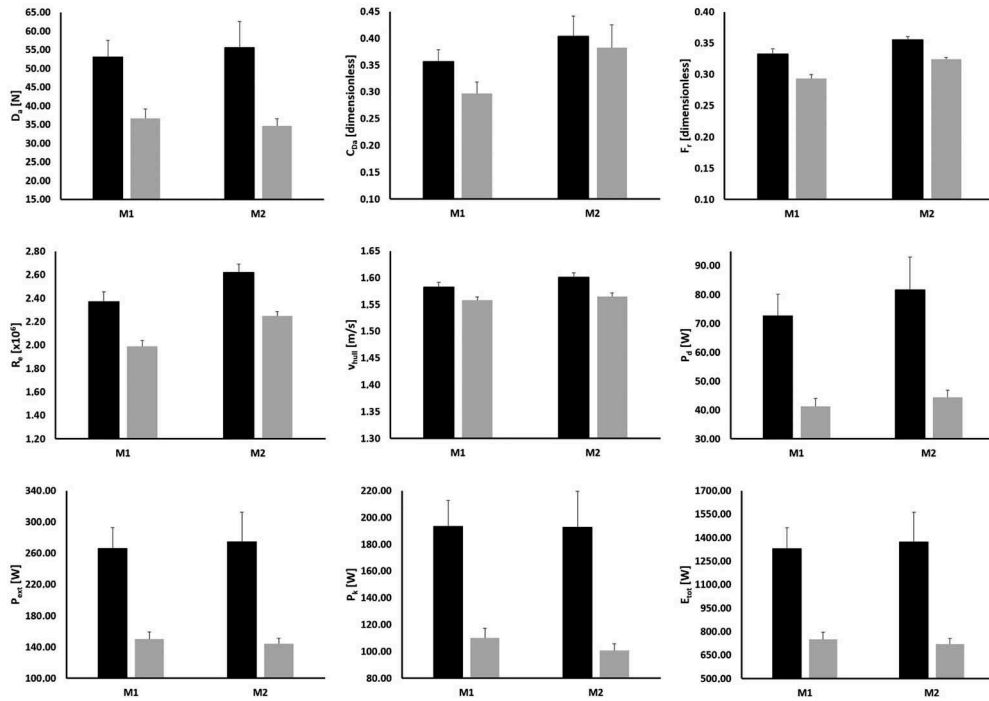


Figure 2. Hydrodynamics and mechanical power variation between M1 and M2. The mean plus standard error are presented. D_a —active drag; C_{D_a} —coefficient of active drag; F_r —Froude number; R_e —Reynolds number; v_{hull} —hull velocity; P_d —power to overcome drag; P_{ext} —external mechanical power; P_k —mechanical power to transfer kinetic energy to water; E_{tot} —total power input. Black columns—boys’ variation; grey columns—girls’ variation.

$2.24 \times 10^6 \pm 1.97 \times 10^5$; $\Delta = 11.18\%$; $d = 1.03$; $t = 4.25$; $p < 0.001$) (Table 1 and Figure 2).

Swim velocity, SL, and efficiency in boys increased between moments. The SI presented the highest significant increase (large effect) (M1: 2.02 ± 0.50 m²/s, M2: 2.41 ± 0.37 m²/s; $\Delta = 16.16\%$; $d = 0.89$; $t = 3.97$; $p = 0.001$) (Table 1 and Figure 3). Girls kept or increased the kinematics and efficiency. The SI also presented the highest and significant increase (large effect) (M1: 1.61 ± 0.42 m²/s, M2: 2.01 ± 0.33 m²/s; $\Delta = 19.51\%$; $d = 1.06$; $t = 3.56$; $p = 0.002$) (Table 1 and Figure 3).

However, boys' (M1: 68.53 ± 6.81 s, M2: 70.05 ± 5.84 s; $\Delta = 2.17\%$; $d = 0.24$; $t = 3.03$; $p = 0.007$;) and girls' (M1: 75.07 ± 7.84 s, M2: 76.53 ± 6.44 s; $\Delta = 1.91\%$; $d = 0.20$; $t = 2.77$; $p = 0.010$) performance impaired significantly (minimum to moderate effect) between moments (Table 1 and Figure 1).

The first HLM model yielded significant differences between the sexes at baseline (M1) (Table 2). Similar changes between the two moments were verified in all swimmers, despite sex (i.e., it was similar in both sexes). The final model output is portrayed in Table 2. At baseline, the model showed that boys were, on average, 4.14 s faster than girls. There was a significant impairment in the performance between the two moments (2.49 s, i.e., time effect). The only predictor retained was the height (H). Each unit of increase in the height (in cm) led to a 0.41 s impairment in the

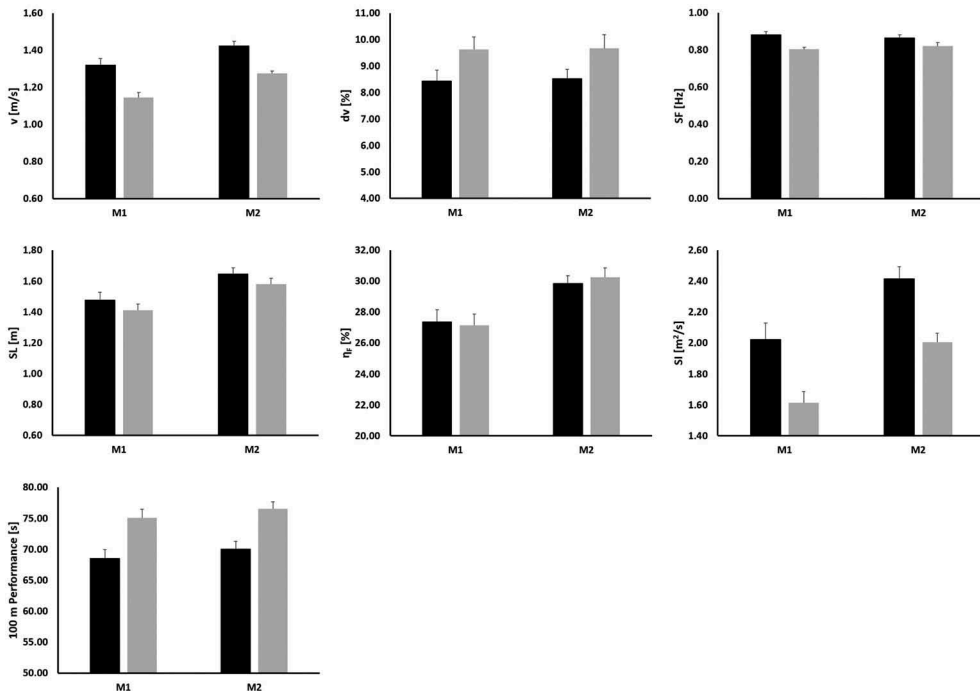


Figure 3. Kinematics, efficiency and performance variation between M1 and M2. The mean plus standard error are presented. v —swim velocity; dv —intra-cyclic variation of the horizontal velocity of the hip; SF —stroke frequency; SL —stroke length; η_F —Froude efficiency; SI —stroke index; 100 m Performance—100 m freestyle performance at short course metre. Black columns—boys' variation; grey columns—girls' variation.

Table 2. Fixed parameters of the final model computed with standard errors (SE) and 95% confidence intervals (95CI).

Parameter Fixed Effect	Estimate (SE)	95CI	p value
Intercept	74.27(1.31)	71.70;76.84	<0.001
Sex	-4.14(1.57)	-7.22;-1.06	0.011
Time	2.49(0.37)	1.76;3.24	<0.001
Height	-0.41(0.07)	-0.57;-0.26	<0.001

performance (i.e., an increase of height minimised the performance impairment during the break period).

Discussion and implications

The aim of this study was to analyse the variation in young swimmers' performance and its determinants over a season break (11-weeks). Boys and girls significantly impaired (minimum effect) their performance (i.e., more time to cover the distance). However, both sexes grew significantly over the break (i.e., anthropometrics increased). Moreover, the biomechanical variables increased in boys. Girls presented the same trend, except for the D_a , P_{ext} , P_k , and E_{tot} where decreases were observed.

Swimming performance impaired significantly in both boys (2.17%) and girls (1.91%) after an 11-week training break (M1vsM2). A study found similar results for boys' 100 m performance (1.86%) during a 50-day break (Sambanis, 2006). Moreover, for boys and girls aged 14.50 ± 0.80 and 14.20 ± 0.60 years old, respectively, a study also showed an impairment (3.80%) in performance in the 400 m freestyle event (Zacca et al., 2019a). Increasing the race distance makes the performance more dependent on physiological response than on biomechanics performance (Vescovi, Falenchuk, & Wells, 2011). Moreover, the sample was composed of young athletes but in Tanner stages IV (late-pubertal) and V (post-pubertal) (Zacca et al., 2019a). So, one might claim that such swimmers presented a profile more similar to adults than to young swimmers (pre-pubertal) where growing peaks do not occur quite as often.

In our research, swimmers grew, on average, 3.67 cm for boys and 1.72 cm for girls (Table 1). Moreover, the study conducted by Zacca et al. (2019a) also verified a decrease in the kinematics and efficiency variables (i.e., decrease in v , SF, SL, and SI). Indeed, it is suggested that detraining or training cessation induces a negative effect on young athletes' physical patterns for sports in general (Giada et al., 1998; Melchiorri et al., 2014). By contrast, data from our research revealed that boys were prone to increase their hydrodynamic, mechanical power, kinematics, and efficiency variables after an 11-week training break. Girls showed a similar trend, except for a few hydrodynamic and mechanical power variables (Table 1 and Figure 2). A study conducted by Moreira et al. (2014) also verified an increase in the kinematics and efficiency in pre-pubertal swimmers (12 boys: 12.80 ± 0.90 years old; 13 girls: 12.0 ± 0.90 years old) during a summer break. The authors suggested that an increase in body traits (e.g., anthropometrics, such as the height, arm span, and foot and hand surface areas) was the main responsible factor for the kinematics enhancement.

Indeed, deterministic models indicate that anthropometrics have a positive and direct effect on the swimmers' kinematics and efficiency (i.e., an increase in body traits will lead

to an increase in kinematic and efficiency variables) (Barbosa et al., 2010b; Morais et al., 2017). Nonetheless, in the present data, performance did impair significantly for both boys and girls despite the determinant factors increasing. The performance outcome selected was the 100 m freestyle event (in a 25 m length swimming pool) instead of a short 25 m time-trial used in the study by Moreira et al. (2014). The former (100 m event) includes all the major aspects of the swimming race: start, turns, clean swim, and finish (Morais, Marinho, Arellano, & Barbosa, 2019). For adult/elite swimmers, it was suggested that in the 100 m events, the start and turns might account for nearly 33% of the total race time (Morais et al., 2019). So, one might claim that the variables related to stroke mechanics are not the only factors responsible for the 100 m performance. For instance, lower limb strength and power, and passive drag (glide) also play an important role in the start and turns (Jones, Pyne, Haff, & Newton, 2018).

The 100 m event comprises four times the kinematic data retrieved from a 25 m trial (4×25 m). So, it might be suggested that young swimmers were not able to keep their kinematics and efficiency during a 100 m event. This indicates that physiological response also plays a determinant role in young swimmers' performances. A study showed that young swimmers subjected to a 50-day detraining period decreased the pulmonary function variables (Sambanis, 2006). Although the physiological variables were not assessed, the C_{Da} increase between M1 and M2 may reflect the swimmers' need for a higher physiological power to overcome drag at a given swim velocity at M2 in comparison to M1 (Table 1 and Figure 2). Energetics also plays an important role in young swimmers' performance (Zacca et al., 2019b). Hence, it can be suggested that after a detraining period: (i) the anthropometrics increase is determinant on young swimmers' biomechanics maintenance or enhancement, and; (ii) the performance impairment occurs due to an energetic decline (since a physiological response is necessary to maintain the amount of energy necessary during a 100 m event) (Barbosa et al., 2019).

Hydrodynamic and mechanical power variables increased in boys, while girls showed increases and decreases (Table 1 and Figure 2). The D_a is computed based on the v and TTSA (Equation (3)); therefore, whenever an increase in the latter variables is verified, the former will increase too (Barbosa et al., 2015; Marinho et al., 2010). Despite the v increase, girls did decrease slightly for the D_a . The C_{Da} increased between the moments (boys and girls), but this is less dependent on the v and TTSA. The C_{Da} changes based on shape, orientation, and the Reynolds number, representing the swimmers' hydrodynamic profile (Marinho et al., 2009). So, one might argue that swimmers lose some of their hydrodynamic skills as denoted by the C_{Da} increase.

Overall, the remaining hydrodynamic and mechanical power variables (F_r , R_e , v_{hull} , P_d , P_{ext} and E_{tot}) also increased in boys, except for the P_k . This occurred due to the growing process, where an increase in body traits led to an increase in the swimmers' kinematics, and hence in these specific variables (Barbosa et al., 2019). As a consequence of what was discussed earlier, different findings were observed between boys and girls for the mechanical power variables. Girls conversely decreased P_{ext} , P_k , and E_{tot} . Such decrease might be related to the magnitude of anthropometrics increase. Our data showed that girls did not increase their body traits as much as boys (Table 1 and Figure 1). So, it might be suggested that such differences (boys' versus girls' magnitude of body traits increase) could be responsible for the mechanical power variables output.

Usually, pre-pubertal swimmers of both sexes are pooled together (Barbosa et al., 2015; Moreira et al., 2014). The literature reports that for pre-pubertal children or athletes, participants from both sexes could be analysed in the same cohort group since non-significant differences might be found in anthropometrics, kinematics, and energetics or efficiency (Geladas et al., 2005; Greco & Denadai, 2005). However, HLM procedure pointed out that boys and girls differ in performance at M1 (peak-performance) (i.e., significant sex effect) (Table 2). As mentioned earlier, 100 m performance at an official/trial event relies on the start, clean swim, turn(s), and finish. So, other variables like lower limb strength and passive drag may represent an important factor for a hypothetical sex differentiation. Thus, we chose to present the data separately. Nevertheless, several variables from each set did not show differences between sexes (e.g., anthropometrics: TTSA; kinematics: dv ; hydrodynamics: C_{Da} ; efficiency: η_F). Moreover, HLM did not yield an interaction between sex and time. This suggests that both boys and girls have been under the same amount of detraining. Considering the 11-week break, it can be pointed out that boys and girls impaired (each week) their performance by 0.14 s (95CI: $-0.25;0.53$) and 0.13 s (95CI: $-0.35;0.61$), respectively.

Height was the main predictor for the performance variation (Table 2). One unit (in cm) of height increase led to a 0.41 s improvement in the performance. Indeed, height has a positive and significant correlation for young swimmers' performance (Geladas et al., 2005). Additionally, in this particular case, it seems that growing over the break period can be deemed as a way to trade-off the performance impairment. So, this study confirmed that anthropometric variables were the key-determinant in such early ages (11–13 years old). Indeed, it was shown that anthropometric traits like the ones in this study are highly associated to young swimmers' performance (Barbosa et al., 2010b; Morais et al., 2017). Altogether, if young swimmers undergo a growth spurt over a break period, the performance impairment will be attenuated. They may undergo growth and maturation spurts that will lead to an increase in body traits and decelerate the rate of performance impairment over 11-weeks (in this particular case). Our data showed that boys and girls grew, on average, 3.67 cm and 1.72 cm, respectively. This increase had a positive effect on their biomechanics performance. Coaches and practitioners must be aware of the importance of monitoring a hypothetical increase in body traits during long detraining periods.

This research highlights the importance of monitoring young swimmers, even during training cessation (11-weeks). During a long detraining period, like the one in this study (11-weeks), swimming performance impaired significantly in both sexes and with a similar magnitude. Nevertheless, this impairment was traded off by an increase in anthropometrics and improvements in biomechanics. Coaches should be concerned if swimmers decrease their biomechanics during a training cessation when a significant increase in their anthropometrics is verified. It can be suggested that an increase in height may function as a performance retainer. Thus, coaches of age group athletes are advised to monitor their swimmers' heights during a training cessation period in order to understand the swimmers' biomechanics variation. Additionally, they should put the focus on technical training so that swimmers 're-learn' their stroke mechanics after a body dimensions increase. Our data showed that an increase in height had a positive effect on young swimmers' biomechanics (especially in boys). As the main limitations, it might be pointed out: (i) despite coaches did not provide the training workload, they were instructed to follow the same training guidelines during the season but this was not possible due to the varying training loads in different programmes, and; (ii) the somewhat 'uncontrolled' breaking period regarding

other sport and leisure activities. Nonetheless, swimmers were instructed not to practice competition swimming (i.e., events and/or training).

Conclusion

As a conclusion, during training cessation (11-weeks), young swimmers' performance impaired significantly. Conversely, swimming biomechanics improved over the same period of time. Such improvement is related to growth spurts. Indeed, it was noted that the height increase was responsible for attenuating the rate of the performance impairment. That is, if swimmers did not grow, the likelihood of what should be expected as a larger performance impairment would be verified.

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