Effects of Swim Training on Energetics and Performance

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Effects of Swim Training on Energetics and Performance

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Key words
- tracking
- elite swimmers
- testing
- annual changes
- swimming

Abstract

The aim of this study was to determine the effect of several months of training on performance and energetic profile of elite swimmers. 9 elite swimmers were evaluated at 3 different time periods during the 2010–2011 calendar. Swimming performance was assessed based on lists of times for the 200 m freestyle event. An incremental set of 7×200 m swims was applied to obtain the energetic data. Measurements and/or estimations were made for the: velocity at 4 mmol l^{-1} of lactate concentrations, highest value of lactate concentrations, maximal oxygen consumption, minimum swimming velocity where the maximal oxygen consumption is reached and total energy expenditure (E_{tot}). The performance and most of the energetic variables assessed presented no significant variations during the study period. The only exception was the E_{tot} with significant differences between all measurements. Correlation coefficients suggested a high stability for all variables. Cohen's Kappa tracking index demonstrated high variability in the individual adaptations to training. It is concluded that elite swimmers demonstrate a slight improvement in performance and energetic profile in response to several months of training. Each subject has an individual way of adapting to the training load, combining the different energetic confounders to enhance performance.

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Introduction

The evaluation of performance and energetic adaptations in cyclic and closed sports are critical elements of testing for the coach and athlete. The ability to monitor annual changes provides fundamental information on the response of swimmers to their training periodization. Since performance depends on energetic profile [7], there are some variables that can provide, in a simplified point of view, an important feedback on training progress and in competition conditions [1]. Among those variables are the velocity at 4 mmol of blood lactate concentrations (V4), the highest value of lactate concentration (La_{peak}) and the maximal oxygen consumption (VO_{2peak}). Earlier observations reported that there is a trend for elite swimmer's V4 improvement with training [1, 13, 33–35]. The highest degree of change occurred during the months where an increase in training volume was evident [34, 35]. Annual increases in the La_{peak} seem to be consistent as well [1, 9, 16, 37]. However, in this case, the adaptations appear to occur from mid phases of the season until its end [16]. The VO_{2peak} of elite swimmers seems to remain unchanged with training [13, 24]. Despite the absence of improvement reported for this cohort, significant adaptations were already observed for less skilled swimmers [29].

Generally, the annual training plan is divided into smaller and more manageable parts to ensure correct peaking for the main competitions within the year. Contents such as volume, intensity and frequency are among the factors described by coaches in their periodization design [32]. Indeed, to ensure progressive and optimal adaptations, the combination of those aspects constantly changes within the year. Most of the earlier longitudinal interventions conducted on this topic were exclusively based on high volume training programs. Such studies rarely presented a meaningful variation in the training intensity applied. Simultaneously, the evidences about the energetic variations of national/international level subjects throughout larger training periods remain scarce.

Another important aspect of training diagnosis is the individual response to periodization. The assessment of individual trends on performance and energetic measures facilitates the adequate prescription for further adaptations. To the best of our knowledge one single study has examined the elite individual responses throughout a considerable period of training. Anderson et al. [1] observed high variability between sex and competitive level in energetic responses throughout 6 consecutive seasons of training.
Therefore, the present study aimed to determine the effect of several months of training on performance and energetic profile of elite swimmers. In addition, we tried to verify, within and between swimmers, the adaptations variability to training periodization. It was hypothesized high stability for performance and energetic variables during the training period along with high variability between swimmers adaptations to the same training load.

Methods
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Subjects

11 swimmers were recruited to participate in the present study. 2 swimmers were excluded because of an acute injury (n=1) and sports withdrawal (n=1). A total of 9 male swimmers (21.0±3.30 years of age; 1.80±0.06 m of height; 74.49±6.74 kg of body mass; 23.06±1.94 kg m^{-2} of body mass index; 1.86±0.07 m of arm span; 115.03±3.97 s of personal record in the 200 m long course freestyle event) were considered for further analysis. 4 subjects had regular presence in international meetings representing the National Swimming Team, whereas the remaining 5 swimmers were Top-20 nationally ranked in the 200 m freestyle distance. All the swimmers had as a main competitive goal during the study period to enhance the 200 m freestyle performance in individual and/or relay events. All subjects gave their written informed consent before participation. The procedures were performed in accordance with the ethical standards proposed by Harris and Atkinson [23].

Study design

The swimmers were studied on 3 occasions during the 2010–2011 calendar. The 3 tests were conducted at the end of the following time periods: (i) October-December 2010 (TP_1); (ii) January-March 2011(TP_2) and; (iii) April-June 2011(TP_3). Those were pre-taper periods (i.e., where the swimmers were not tapering for the major competition). In the time period before tests the swimmers completed a full training preparation. Weekly volume averaged 44±7 km wk^{-1} (▶ **Fig. 1**). Swim training applied before each evaluation point generally consisted of 9 sessions per week involving low, medium and high aerobic tasks, intense sprint work and technical drills. There was an intensity variation throughout the season namely in: (i) intensity corresponding to their aerobic capacity (TP_1: 1.88±1.68 km wk^{-1}; TP_2: 3.08±2.01 km wk^{-1}; TP_3: 3.24±2.32 km wk^{-1}); (ii) intensity corresponding to their aerobic power (TP_1: 1.50±0.49 km wk^{-1}; TP_2: 1.68±1.05 km wk^{-1}; TP_3: 1.78±0.76 km wk^{-1}) and; (iii) anaerobic capacity training (TP_1: 1.04±0.63 km wk^{-1}; TP_2: 1.30±0.54 km wk^{-1}; TP_3: 1.52±0.21 km wk^{-1}).
In the day prior to data collection, the swimmers completed a low intensity training session in order to avoid data bias due to fatigue. On the testing day, the swimmers performed an intermittent set of 7×200 m front crawl, with increasing velocity as described elsewhere [18]. This intermittent protocol has already been shown to be a valid and reliable method for the VO_{2max} assessment [6, 18]. The velocities increased by 0.05 m s^{-1} so that swimmers would attain their best performance in the last trial. Underwater pacemaker lights (GBK-Pacer, GBK Electronics, Aveiro, Portugal), on the bottom of a 50 m swimming pool, were used to control the swimming velocity and to help the swimmers keep an even pace along each lap and step. A 30 s resting period was used between trials to collect blood samples and oxygen uptake measurements for further energetic analysis.

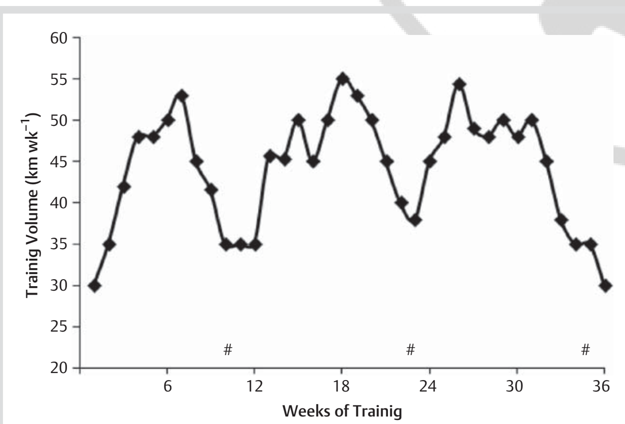

Fig. 1 Total weekly volume throughout the competitive season. # indicates the testing occasions.

Performance data collection

Whenever possible, swimming performance was assessed based on times lists for the 200 m freestyle event during official long course competitions at local, regional, national and/or international level. However, in earlier months of the study most of the competitions took place at short course swimming pools. The most easy and operational way to convert the short course race times into long course race times was to use specific software tool (FINA converter). This is a common approach used for most of the Swimming National Federations to "convert" race times for national and international meetings. The time between the official competition performances and the testing day never exceeded 2 weeks.

Energetics data collection

To determine the V4 and La_{peak}, capillary blood samples were collected from the ear lobe in order to assess the lactate concentrations with an auto-analyzer (YSI 1500 l, Yellow Springs, Ohio, USA). Collecting process occurred during the 30 s resting period between trials, immediately following and in the 3rd, 5th, and 7th min after the intermittent protocol. The individual V4 (m s^{-1}) was obtained by interpolating the average lactate value (4 mmol l^{-1}), with the exponential curve of lactate/velocity. The La_{peak} (mmol l^{-1}) was considered to be the highest blood lactate concentration in post exercise condition [37].
Absolute oxygen uptake was measured immediately after each trial with a portable gas analyzer (Cortex, Model MetaLyzer 3B, Leipzig, Germany). Swimmers were instructed to take their last breathing cycle before touching the wall. After finishing the trial, the swimmer leaned on the wall, while an operator fixed a portable mask for land-based locomotion on his face during all recovery. No breathing cycle was made until the portable mask was on the swimmer's face. The time gap for this transition and

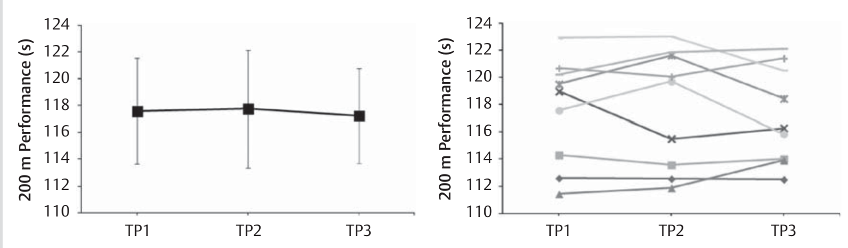

Fig. 2 Mean and individual variation of the 200 m freestyle performance throughout the competitive season.

the first breathing cycle never exceeded 3 s. The VO_2 (ml kg^{-1} min^{-1}) reached during each step of the protocol was estimated using the backward extrapolation of the O_2 recovery curve [25]. The VO_{2peak} was considered to be the mean value in the 6 s after the VO_2 detection during the recovery period [25]. The first measure of VO_2 values before the highest VO_2 measurement was not considered, which corresponded to the device adaptation to the sudden change of respiratory cycles and of O_2 uptake. The device adaptation never exceeded 2 s. Other backward extrapolation methods have already been reported [27,31] and have been shown valid for the VO_{2peak} measurement. The vVO_{2peak} (m s^{-1}) was considered to be the swimming velocity corresponding to the first stage that elicited the VO_{2peak} [19].

The total energy expenditure (E_{tot}) can be described on its metabolic elements in terms of aerobic and anaerobic contributions [41]. In the present study, the E_{tot} (kJ) was calculated in the last 200 m trial of the incremental test, corresponding to the swimmer's maximal effort. Due to logistic and training reasons, while conducting longitudinal designs, the methods applied should be easy to operate. Despite the La_{peak} values of the incremental test being in accordance with those reported earlier for an all-out effort of comparable length and intensity [37], these findings should be interpreted carefully. The blood lactate increases in the first stages of the incremental test may influence the post exercise lactate value and as a consequence overestimate E_{tot}. Nevertheless, E_{tot} was obtained according to the equation:

$$E_{tot} = Aer + AnS \quad (1)$$

where Aer represents the aerobic contribution (kJ) based on the total oxygen volume and AnS represents the anaerobic contribution (kJ) based on the blood lactate variation.

The total oxygen volume (l) consumed during the last trial was estimated from the following equation:

$$VO_2 = VO_2net \cdot t \quad (2)$$

where VO_2net (l kg^{-1} min^{-1}) is the difference between the oxygen uptake measured and the oxygen at rest, t (min) is the total duration of the effort. Aerobic contribution was then expressed in kJ assuming an energy equivalent of 20.9 kJ l O_2^{-1} [41].

The O_2 equivalent (ml O_2) for the lactate variation was obtained according to the equation:

$$O_2Eq = La_{net} \cdot 2.7 \quad (3)$$

where La_{net} represents the difference between the lactate measured and the lactate at rest, 2.7 is the energy equivalent (ml O_2 $mmol^{-1}$ kg^{-1}) for lactate accumulation in blood [15]. Thus, the anaerobic contribution (ml O_2) was expressed in kJ assuming an energy equivalent of 20.9 kJ l O_2^{-1} [41].

Statistical procedures

All assumptions to conduct the ANOVA (normality, independency and homoscedasticity) were checked-out. Since the assumptions failed, non-parametric procedures were adopted. Longitudinal assessment was made based on 2 approaches: (i) mean stability and; (ii) normative stability. For mean stability, mean plus one standard deviation and quartiles were computed for each time period. Data variation was analyzed with Friedman Test, and also the Wilcoxon Signed-Rank Test to assess differences between time periods. Normative stability was analyzed with the Ranking Spearman Correlation Coefficient. Qualitatively, stability was considered to be: (i) high if $r \geq 0.60$; (ii) moderate if $0.30 \leq r < 0.60$ and; (iii) low if $r < 0.30$, adapted from [30]. The Cohen's Kappa (K) plus one standard deviation, with a confidence interval of 95 % [9] was also computed as another normative stability parameter to detect inter-individual differences. The qualitative interpretation of K values was made according to Landis and Koch [26] suggestion, where the stability is: (i) excellent if $K \geq 0.75$; (ii) moderate if $0.40 \leq K < 0.75$ and; (iii) low if $K < 0.40$. All statistical procedures were conducted with SPSS software (v. 13.0, Apache Software Foundation, Chicago, IL, USA). However, the K value was computed with the Longitudinal Data Analysis software (v. 3.2, Dallas, USA). The level of statistical significance was set at $P \leq 0.05$.

Results

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▶ **Fig. 2** presents the mean and individual 200 m freestyle performance variations during the 3 consecutive time periods. No significant variations were verified for this variable throughout the study (200 m perfomance$_{TP1}$ = 117.58 ± 3.94 s; 200 m performance$_{TP2}$ = 117.75 ± 4.37 s; 200 m performance$_{TP3}$ = 117.22 ± 3.54 s; p = 0.90). Wilcoxon ranking tests also demonstrated no significant differences between pair wised time periods.

▶ **Fig. 3** demonstrates the mean and individual trends of energetic profile throughout training. Most of the variables presented no significant variations ($V4_{TP1}$ = 1.44 ± 0.05 m s^{-1}; $V4_{TP2}$ = 1.45 ± 0.06 m s^{-1}; $V4_{TP3}$ = 1.45 ± 0.05 m s^{-1}; p = 0.56; $La_{peakTP1}$ = 11.37 ± 2.66 mmol l^{-1}; $La_{peakTP2}$ = 12.77 ± 2.08 mmol l^{-1}; $La_{peakTP3}$ = 12.88 ± 2.78 mmol l^{-1}; p = 0.72; $VO_{2peakTP1}$ = 71.91 ± 11.60 ml kg^{-1} min^{-1}; $VO_{2peakTP2}$ = 73.61 ± 8.23 ml kg^{-1} min^{-1}; $VO_{2peakTP3}$ = 76.35 ± 6.12 ml kg^{-1} min^{-1}; p = 0.24; $vVO_{2peakTP1}$ = 1.56 ± 0.04 m s^{-1}; $vVO_{2peakTP2}$ = 1.56 ± 0.07 m s^{-1}; $vVO_{2peakTP3}$ = 1.57 ± 0.05 m s^{-1}; p = 0.17). The only exception was the E_{tot} with a significant increase during the study period (E_{totTP1} = 234.71 ± 22.53 kJ; E_{totTP2} = 242.96 ± 24.88 kJ; E_{totTP3} = 262.86 ± 22.48 kJ; p = 0.01). Body weight increased slightly but non-significantly from the first to the last measurement (TP_1 = 73.22 ± 6.90 kg; TP_2 = 73.42 ± 7.02 kg; TP_3 = 74.49 ± 6.74 kg).

▶ **Table 1** presents the Spearman Correlation Coefficient values for pair wised time periods. Associations were significant

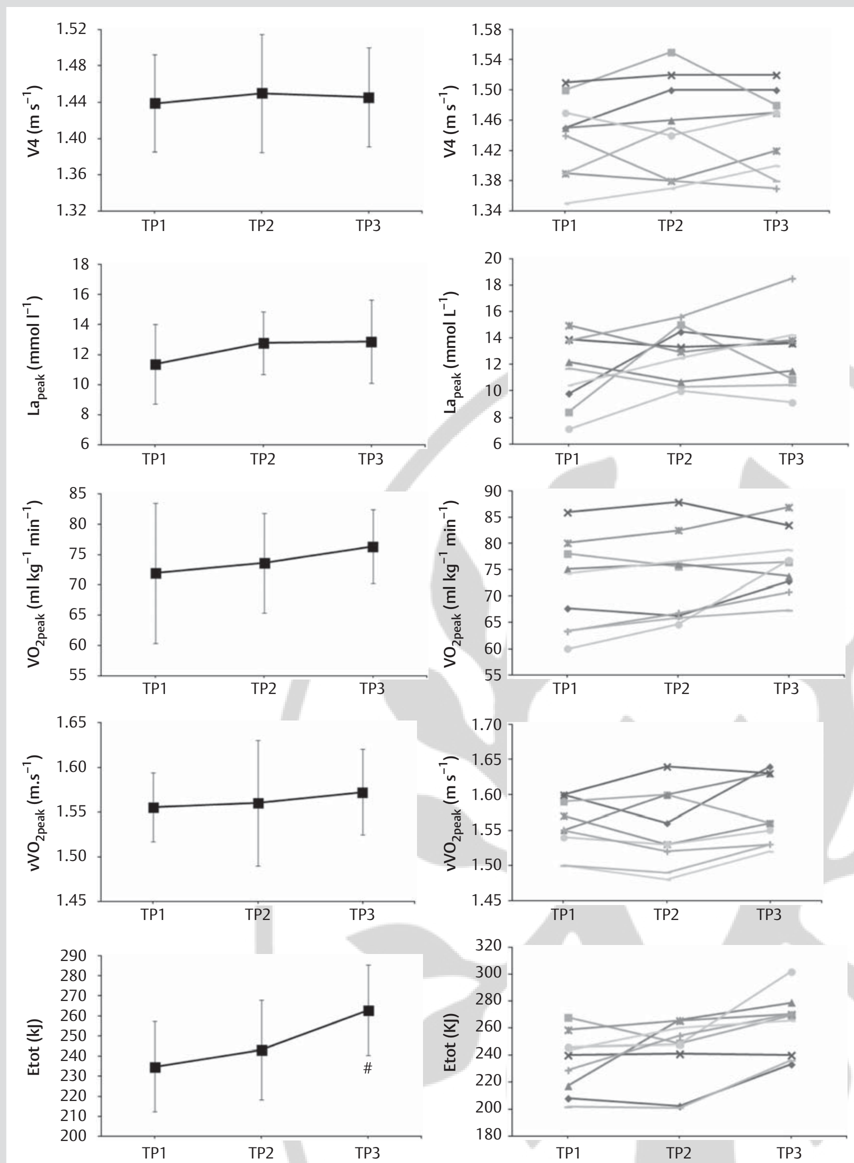

Fig. 3 Mean and individual variation of energetic variables throughout the competitive season. # indicates significantly different from TP_1 and TP_2.

Table 1 Interperiod Spearman Correlation Coefficients of performance and energetic variables measured at the time periods of training.

Variable	TP_1 vs. TP_2	TP_2 vs. TP_3	TP_1 vs. TP_3
200 m (s)	0.93**	0.88**	0.92**
V4 (m s⁻¹)	0.81**	0.78*	0.79*
La_{peak} (mmol L⁻¹)	0.22	0.60	0.53
VO_{2max} (ml kg⁻¹ min⁻¹)	0.88**	0.70*	0.63
vVO_{2max} (m s⁻¹)	0.79*	0.80**	0.84**
E_{tot} (kJ)	0.42	0.68*	0.50

*p<0.05

**p<0.01

between variables in almost all paired data. Most variables presented high stability ($r_s > 0.60$) in response to training.

The K values for a 95 % confidence interval were rather low for the La_{peak} (K = 0.17 ± 0.27) and E_{tot} (K = 0.39 ± 0.27). Moderate values were verified for the V4 (K = 0.44 ± 0.27), VO_{2peak} (K = 0.44 ± 0.27) and vVO_{2peak} (K = 0.44 ± 0.27). Only in the 200 m freestyle performance swimmers demonstrated a high inter-individual stability (K = 0.78 ± 0.27).

Discussion

The aim of this study was to determine the effect of several months of training on performance and energetic profile of elite swimmers. The main result was that no significant variations were observed in performance and most of the energetic variables assessed. Indeed, most variables presented high stability values throughout the 10 months of training. Added to that, each swimmer demonstrated an individual way of responding to training.

In the present study the 200 m freestyle performance slightly improved (~0.36 s). In percentage terms, the mean variation in performance time was −0.32 ± 1.56 %. This magnitude of change was similar to that reported in earlier observations [10, 33] in subjects from similar competitive level (−0.30 %). Due to maturational and physiological reasons, elite swimmers already start to demonstrate a lack of meaningful improvement in freestyle performance at the age of 16 years [11]. From this moment onward, the relative changes in performance are not so obvious. So, from a statistical point of view it becomes very difficult to verify significant differences in race times from one year to another.

Tracking the factors affecting performance in an elite population presents an extra challenge [14]. Several papers determined an absence and/or a slight improvement in the energetic variables after several longitudinal assessments [1,10,13,24,33]. This might be explained by the great energetic status of elite athletes at the career peak due to several years/decade of systematic and hard training. They have reached, or are getting closest to their predetermined genetic limit, and any margin for further adaptations is quite small [24]. Most of energetic variables assessed did not change significantly throughout the course of the study. However, from a general point of view, slight changes were observed for each one.

Traditionally, the anaerobic threshold is determined based on the averaged value of 4 mmol.L^{-1} of blood lactate concentration. Not only in competitive swimming but in several other sports lactate is used, and steady state values were presented in the individual anaerobic threshold near to the 4 mmol.L^{-1} [3]. However, great controversy still exists about this thematic. In the last few decades, several methods have been developed to assess the anaerobic threshold. All procedures are based on some kind of interpolation or similar mathematical approach. There is some interesting evidence suggesting the use of velocity at 3.5 mmol.L^{-1} or even to use lower values of blood lactate giving an individual background of the anaerobic threshold assessment in swimmers [22]. Added to that, some evidence suggests that the standard 4 mmol.L^{-1} value does not take into account considerable inter-individual differences, it may sometimes underestimate (particularly in anaerobically trained subjects) or overestimate (in aerobically trained athletes) real aerobic capacity [17]. Thus, some limitations should be taken into account while using the 4 mmol.L^{-1} reference. However, in intervention studies like this one, the traditional anaerobic threshold calculation based on V4 allow coaches to use the data for their training control, since they are more used to working and planning their training bouts with it. The V4 increased from TP_1 to TP_2 and remained stable until TP_3. Usually, the highest degree of change in the aerobic capacity happens in the first months where an increase in the training volume is evident [34,35]. At that stage of the season, the muscle is more sensitive to adaptations becoming more effective in producing energy aerobically [28]. An increasing training volume might decrease the glycogen stores. As a consequence swimmers demonstrate lower lactate concentrations. That could be the reason for higher V4 in the TP_2. This fact has already been shown in a lot of glycogen depletion and loading studies [12,13]. However, when the personal aerobic peak is reached, not even additional increases in volume seem to promote significant changes in aerobic capacity [34]. Probably the personal peak of the swimmers was reached somewhere between the TP_2 suggesting an inability to increase the V4 from that point on.

The VO_{2peak} and vVO_{2peak} are considered important variables for constant intensities above the aerobic capacity. Such parameters are commonly used to express the aerobic power in the 200 m efforts [19,21,36]. The VO_{2peak} showed a non-significant increase with training. Although the capacity both to transport and utilize oxygen increased as the result of training, it was not sufficient to be improved from a statistical point of view. A similar trend was already reported for elite university swimmers [24].

Up to now no research has been conducted regarding the vVO_{2peak} status in a longitudinal perspective. The vVO_{2peak} showed a non-significant increase within the year. The additional time spent on training at the intensity corresponding to their aerobic power from TP_2 to TP_3 was able to bring slight benefits in vVO_{2peak}. However, they were unable to deliver their energy more effectively than in the earlier months of training probably because VO_{2peak} increased as well. As demonstrated in ▶ **Fig. 2**, both performance and vVO_{2peak} adaptations showed a similar trend. Cross-sectional evidences have already demonstrated strong correlations between vVO_{2peak} and efforts requiring prolonged aerobic power such as the 200 m freestyle distance [18], although data suggested that swimmers presenting higher vVO_{2peak} showed lower capacity to sustain an intensity corresponding to this velocity (vVO_{2peak}) [20]. This can suggest that adaptations in the vVO_{2peak} can be a useful tool for coaches to understand the changes in their swimmers' 200 m freestyle performances.

The La_{peak} is related with sprinting performance and was already used to assess the maximal anaerobic capacity in 200 m distances [2]. In the present study, an increase in the anaerobic training was effective to promote a slight increase in the La_{peak}. With training the muscle suffers some adaptations that allow reaching higher velocities at an increased oxygen debt and reduced muscle fatigue [37]. The La_{peak} is also dependent on the motivational commitment with the exercise. The marginally higher La_{peak} can be due to a higher motivation resulting in a higher effort. So, this energetic measure is extremely sensitive and should be interpreted with caution.

The E_{tot} expresses the total energy expenditure for a given event [4,5]. A significant increase was determined for this variable during the study period. E_{tot} can be described on the basis of its metabolic elements in terms of aerobic and anaerobic contributions [41]. A large part of the training is made to improve those different energy production systems [38]. The slight increases in VO_{2peak} indicated a higher ability to produce energy from the aerobic source. Simultaneously, the annual development in the anaerobic qualities was achieved by a non-significant change in La_{peak}. Thus, the non-meaningful increases in the VO_{2peak} and La_{peak} may have led to a significant change in E_{tot}.

The E_{tot} increases exponentially with an increase in swimming velocity due to an increase in drag force [15]. Elite swimmers' training should improve the ability to apply power to propulsion in an efficient manner to decrease the E_{tot} at higher velocities. In this study it was verified that swimming velocity slightly improved, but the E_{tot} increased significantly. However, such additional energy was not used in an efficient manner. There was a trend towards male swimmers becoming stronger (i.e., an increase in body volume) within the year. At least one study determined such phenomena in male swimmers at this competitive level throughout several years of training [1]. A similar trend was demonstrated for the swimmers of the present study, by the slight increase in body weight from TP_1 (73.22 ± 6.90 kg) to TP_3 (74.49 ± 6.74 kg). So, it is possible that an increase in body weight led to a higher trunk and limbs area and consequently more energy was spent to overcome higher drag forces. Nevertheless, the eventual increases in drag associated to changes in body volume and/or shape are also related to the power increase. Probably, training promoted a compensatory propulsive gain that imposed an increase in the gross efficiency and allowed to slightly enhance performance. However, those are factors that were not considered for analysis, and therefore a conclusion cannot be drawn. Further research should include those mechanical elements to understand their behaviour in a longitudinal perspective.

The longitudinal assessment based on auto-correlation coefficients showed high stability for the performance and for the majority of the variables assessed. Malina [30] demonstrated that the inter-correlations values tend to increase after adolescence. This confirms earlier observations that reported a stable energetic profile [10] and a greater consistency in competitive performance [10, 39] in elite adult swimmers.

The tracking based on K values was computed as another normative stability parameter. Through computing the K we can observe the trend of a subject in remaining on a specific curve of growth (called "track") and if it reflects stability within that standard. It is possible to obtain in a more accurate way the relevant aspects of performance kinetics, and to verify the change of the individual curve along with the inter-individual differences. For the energetic variables assessed, the K values demonstrated low-moderate stability. This suggests that, in the main curve pattern that all swimmers share, based on what is considered as the "energetic growth", several individual changes are verified expressing their own adaptations. This data can be confirmed by the individual trends demonstrated in both ▶ **Fig. 2** and ▶ **Fig. 3**. Each swimmer used the most freely chosen energetic combination (e.g., an increased aerobic capacity and lower anaerobic one; or vice versa) to maintain the performance at higher levels. High variability in some energetical aspects was observed in elite swimmers over 5 consecutive seasons [1].

Methodological issues

This study allowed the tracking of the energetic and performance progression over only one part of the season instead of a full season. For a full-season investigation a baseline and a post-tapering evaluation moment should be added. In this investigation, the swimmers were monitored for at least 10 months.

One problem often found in training studies is the need to use convenience samples. In most cases such interventions have a reduced sample size. Nevertheless, the sample size of this investigation is in accordance with earlier longitudinal designs [10, 16, 24, 33, 35, 40].

Most of the recent studies in aquatic environment used portable apparatus connected to swimming snorkels for the gas exchange measurement. Indeed, the manufactures describe the snorkels as being light, hydrodynamic, ergonomic and comfortable, with waterproof design, high accuracy and reliability. However, several constrictions were determined during front crawl swimming using such apparatus [8]. The main changes in swimming velocity imposed by its use do not occur in the main stroke cycle variables while swimming but in other race phases (i.e. gliding phase and turns). Longitudinal designs require more operative experimental procedures that are easy to apply (i.e., less time-consuming and with a minimal effect on the daily/weekly/monthly training program) than the ones for cross-sectional studies. To avoid such limitations we used the backward extrapolation method, which has already been reported in previous studies [25, 27, 31]. The backward extrapolation method showed an acceptable accuracy ($r = 0.88$) to estimate VO_{2peak} [31]. Furthermore, it allows the swimmer to perform each bout in a much more mimetic manner than during training and competition. However, several limitations are associated with this procedure such as: (i) the inability to obtain the oxygen uptake kinetics during exercise and; (ii) it is not a direct measure but an estimation of the gas exchange collection imposing some slight bias.

Our data shows that some practical variables were stable enough to be used as diagnostic tools for further adaptations in performance and energetic profile. However, the performance was influenced by several factors, and it is not possible to fully understand this without an integrated/holistic perspective of all determinant domains. In addition the classic methods may not be precise enough to evaluate performance improvements in elite athletes. In this context, it is relevant that besides energetics and biomechanics, other factors that influence endurance capacity of performance should be assessed.

Conclusions

In conclusion, a high stability in most selected energetic variables when assessing elite athletes seems to exist. Elite swimmers did not present significant adaptations in the performance and energetic variables after several months of swim training. Each subject seems to demonstrate an individual way of responding to the training load by combining the different energetic confounders to maintain the performance at higher levels. So, coaches should focus their training prescription on an individual's background, rather than on the mean level presented by a swimming team.

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