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Change in young swimmers' anaerobic potential in response to taper

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ABSTRACT

The current study aims to determine the effect of one-week tapering on the anaerobic potential of young swimmers based on a simple and non-invasive test. Twenty competitive young swimmers (12.83 ± 1.08 years) performed an all-out 25 m front crawl sprint coupled to an electromechanical speedometer before and after a week of taper. The variation of the velocity along time [v/(t) curves] was determined for each swimmer. The push-off maximum velocity, push-off velocity decay, maximum and average gliding velocity, maximum and average swimming velocity, fatigue index, swimming velocity decay, velocity variation coefficient, total number of cycles, and total swim time were calculated. An individual anaerobic fatigue threshold was determined by applying a mathematical procedure based on wavelet analysis to the aforementioned v/(t) curves. The number of upper limb cycles performed was registered using video. The blood lactate concentration was measured at rest and after the 25 m sprint. The swim duration time of 25 m (pre-taper: 17.91 ± 1.69; post-taper: 17.90 ± 2.18 s, p= .976) and the post-effort blood lactate (pre-taper: 4.92 ± .85 and post-taper: 4.77 ± 1.80 mmol/l, p= .780) did not change with the taper. The other variables also did not change, except for the velocity decay (-1.19 ± .94 vs. -.52 ± .21 m.s^{-1}, p= .016). The moment of occurrence of the anaerobic fatigue threshold was no different after the taper. The one-week taper did not significantly change young swimmers' anaerobic potential.
KEYWORDS: swimming; taper; anaerobic potential; anaerobic fatigue threshold.

INTRODUCTION

Swimmers' performance is closely dependent on bioenergetic and biomechanical factors (Fernandes et al., 2010; Vilas-Boas et al., 2015), and it is well-accepted that other factors also contribute to improving swimming performance in young athletes (Figueiredo et al., 2016; Silva et al., 2019). Swimming coaches have a fundamental role in the training process (Fernandes et. al., 2012; Zacca et al., 2020), enhancing swimmers performance by optimising physical, technical and psychological skills (Carvalho et al., 2020). To achieve this, they should develop a specific, controlled, and systematised training program (Zacca et al., 2020) that includes several training periods. One of those periods is known as taper and is characterised by a load change several days before a competition, allowing the optimisation of the swimmer's performance (Hellard, Scordia, Avalos, Mujika, & Pyne, 2017; Mujika & Padilla, 2003). The effects of taper over performance, namely an anaerobic potentiation, must be measured to test its efficacy.

The taper is a period of progressive and non-linear training load reduction over time, intending to reduce the physiological (fatigue) and psychological stress of daily training and optimise performance in competition (Hellard et al., 2017; Mujika & Padilla, 2003). The taper content should be adapted to each swimmer's needs since variables such as recovery duration, volume, and intensity of the training tasks will determine the performance gain (Mujika et al., 2002; Trinity et al., 2006). Studies about tapper effects on

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the performance of athletes of different sports, such as runners, swimmers, and cyclists, point to a significant improvement in performance (.7 ± 7.7%) with a fourteen days taper (Costill, et al., 1985; Houmard & Johns, 1994). Other studies report that a gradual reduction of the training volume applied seven to twenty-one days before a major competition could enhance performance by 2% to 4% (Johns et al., 1992). Those reductions do not affect the training-induced adaptations (Le Meur et al., 2012). Studies also indicate that the training load should not be reduced by lowering training intensity and may benefit from its maintenance or rise (Bosquet et al., 2007; Mujika et al., 2002). Curiously, such information is missing for young swimmers.

More or less specific tests such as tethered swimming and crank ergometers (Hooper et al., 1998; Toubekis et al., 2006; Trinity et al., 2006) have been used to study the taper effects on swimmers' physiological performance. General performance tests highlight the need for a more precise evaluation of the anaerobic potential (Gastin, 2001) using simple tests that would help coaches adjust training with efficacy, especially for young swimmers (Fernandes et al., 2008; Silva et al., 2012). In reality, most of the research conducted in recent years with young swimmers has focused on the study of factors that directly or indirectly determine the swimmers performance, like bioenergetics (Denadai et al., 2000; Toubekis et al., 2006), biomechanics (Figueiredo et al., 2016; Morais et al., 2012; Silva et al., 2019) and anthropometrics (Geladas et al., 2005; Nevill et al., 2020), but the anaerobic domain keeps fragile. The little attention directed to evaluating the anaerobic potential was likely due to the difficulty of implementing indirect and less invasive assessment methodologies.

In the last 20 years, a simple 100 m maximum front crawl test was proposed to measure anaerobic power (Vitor & Böhme, 2010), as well as a more straightforward 50m all-out front crawl test to assess an anaerobic fatigue threshold as an indicator of anaerobic potential (Soares et al., 2014). This last test is elementary and, if used before and after the taper, would show a different time occurrence of the anaerobic fatigue threshold due to the improvement of the anaerobic potential (Soares et al., 2014). Such expectations make it practical to use as an evaluation tool during taper. The lack of information on the anaerobic potential of young swimmers and the lack of a simple method for determining it, capable of producing quick results that coaches can use to control training, is the reason behind this study. Therefore, this study intends to determine the effect of a one-week taper on the anaerobic potential of young swimmers based on a simple and non-invasive test supported by a wavelets procedure.

METHODS

Sample

Twenty young competitive swimmers (12.83 ± 1.08 years, 47.95 ± 8.47 kg, and 159.1 ± 10.77 cm), non-injured and with a non-lower to 90% training frequency, participated in the study. Swimmers were evaluated in a 25 m indoor pool, with heated water at 28°C and under regulatory thermo hygrometric conditions. All the swimmers were encouraged to maintain a regular hydration and nutrition status. After a typical warm-up session (Neiva et al., 2012), the swimmers recovered actively for 10 to 20 min until they reached a personal readiness to perform a 25 m all-out front crawl sprint. The test was performed before and after a one-week taper. All swimmers freely volunteered for the study, and parents signed the informed consent. The local ethics committee (CEFADE 27 2022) approved all testing procedures that followed the Helsinki Declaration.

Procedures

Evaluation occurred during the winter season in regular training. Swimmers were tested one week before the national championship (pre-taper) and one day after its end (post-taper). Training before the evaluation was composed of 20 weeks (general and specific periods). In the pre-taper assessment week, swimmers completed 5470 ± 394.84 m per training unit, 40945 ± 3135.61 m·week^{-1} and 7.5 ± .51 training units. Training volume decreased in the taper week to 3820 ± 366.49 m per training unit, 23525 ± 3476.37 m·week^{-1} and 6.15 ± .59 training units.

Swimmers were connected to an electromechanical speedometer [previously described by Lima et al. (2006)] through a fine nylon line to determine the variation of the swimming velocity with the time [v(t) curve] (Soares et al., 2014). Variables defined were maximum push-off velocity (maximum peak velocity reached during the thrust on the forehead wall), decay of the push-off velocity (value of the slope of the linear regression line defined by the maximum and minimum value of the impulsion velocity), maximum and average gliding velocity (average swimmer velocity from leaving the wall to leaving the head), maximum and average swimming velocity, fatigue index, swimming velocity decay, variation coefficient of the velocity, total upper limb cycles and total swim time. The maximal and minimum velocities were used to calculate the fatigue (FI (%) = [(vmax - vmin) / vmax] × 100). The velocity decay during the 25 m was determined by the slope of the regression line defined over the v(t) curve, and the variation coefficient of the velocity was calculated using the expression VC (%) = (sd / vmean) × 100.

A MATLAB routine based on wavelets procedure [described by Machado et al. (2007)] was used to identify anaerobic fatigue thresholds over the v/(t) curves. The wavelets allow to discriminate time regions with markedly different frequency behaviour, as well as to determine the instant of time (anaerobic fatigue threshold) separating those regions. This also means that the swimming pattern until the threshold has different characteristics from the swimming pattern that the swimmer performs after the occurrence of the threshold.

First, the anaerobic fatigue threshold is chosen by visual inspection and then is accepted or rejected based on a periodogram. The MATLAB routine was also prepared to give the total number of upper limbs cycles, stroke frequency, stroke length and stroke index for each time interval. The stroke frequency (cycles.min^{-1}) was calculated by dividing 60 s by the mean time taken with a stopwatch to complete three upper limb cycles. Stroke length (m) was the quotient between mean velocity and stroke frequency and the stroke index ($m^2 \cdot s^{-1}$) was the product of stroke length by the velocity.

The blood lactate concentration [La$^-$] was determined during rest and at the end of the exercise, placing a blood drop collected by ear puncture in a blood lactate analyser (Lactate Pro 2, Arkray, Inc.). To show that swimmers increase the lactate values in very short efforts like the 25 m, sometimes considered alactic, the blood was collected by finger punction at 0, 1, 3, 5 min and every second minute until the maximum value was found. All efforts were video recorded at 50 Hz using a SONY Handycam camera (HDR-CX160E) placed on a trolley and moving on the poolside parallel to the swimmers' movement. A sound starting signal was used to synchronise the velocity record with the video images.

Statistical procedures

Mean and standard deviations were calculated for all the variables. The sample normality was ensured using the Shapiro-Wilk test. Means were compared using a repeated measures t-test, establishing the probability value at 5%. All statistical procedures were performed in the IBM Statistical Package for The Social Sciences (SPSS) (v.24.0, IBM, New York, USA).

RESULTS

In the current study, the variables related to the instantaneous velocity curves corresponding to the total effort time in the pre-taper and post-taper moments were initially analysed. As can be seen in Table 1, only the decline of the push-off velocity (-1.19 ± .94 vs. -.52 ± .21 m.s^{-1}; p= .02) was greater in the post-taper, this being one variable that is not directly related to the anaerobic potential of the swimmers. No changes were observed in the remaining variables at both moments, pre-taper and post-taper. Other important variables studied showed no improvements such as maximum velocity, mean velocity, velocity variation coefficient, lactate and net lactate concentration, between pre-taper and post-taper. Also, the biomechanical variable, number of cycles, revealed an absence of improvements compared to the pre-taper.

Table 1. Mean and standard deviations of variables of instantaneous velocity curves of total effort test in pre-taper and post-taper.

Variables	Pre-taper	Post-taper
Time (s)	17.91 ± 1.69	17.90 ± 2.18
Push-off maximum velocity (m·s^{-1})	2.69 ± .28	2.67 ± .38
Push-off velocity decay (m·s^{-1})	-1.19 ± .94*	-.52 ± .21
Gliding maximum velocity (m·s^{-1})	2.56 ± .21	2.55 ± .33
Gliding mean velocity (m·s^{-1})	1.58 ± .18	1.57 ± .17
Maximum velocity (m·s^{-1})	2.29 ± .37	2.27 ± .30
Mean velocity (m·s^{-1})	1.53 ± .17	1.51 ± .19
Fatigue index (%)	1.08 ± 10.80	4.32 ± 10.04
Swimming velocity decay (m·s^{-1})	-.01 ± .01	-.01 ± .01
Velocity variation coefficient (%)	19.03 ± 4.63	17.39 ± 2.79
Upper limb cycles per 25 m (nº)	13.54 ± 3.31	12.5 ± 1.65
Lactate (mmol·L^{-1})	4.92 ± .85	4.77 ± 1.80
Net lactate (mmol·L^{-1})	2.72 ± .85	2.68 ± .71

*Different from Post-taper ($p \leq .05$).

In a second phase of data processing and using a MatLab routine, we identified the fatigue thresholds and compared the variables in the two-time intervals defined by them (Table 2). In the pre-taper, there were differences between the 1st and 2nd intervals for the upper limb cycles, upper limb cycle duration, swim duration, swim distance, mean velocity and stroke frequency. In the post-taper, there were differences between the 1st and 2nd intervals for the upper limb cycle duration, mean velocity, stroke frequency and velocity variation coefficient. Finally, in a last analysis in which the fatigue thresholds were included (Table 3), we could verify that all the variables studied had a small alteration, showing the absence of differences between pre-taper and post-taper periods.

DISCUSSION

The aim of the study was to determine the effect of seven days taper period on the anaerobic potential of young swimmers using a specific test. The level of performance in swimming is directly related to physiological factors

(Carvalho et al., 2023; Fernandes et al., 2010), such as overcoming fatigue caused by metabolic acidosis (Pla et al., 2019; Toubekis et al., 2008). This taper period seemed insufficient to improve the swimming time performance and reveal any changes in velocity variation. The decay in push-off velocity was the only variable that showed differences between pre-taper and post-taper, but this difference in this isolated variable does not seem to be enough to justify any change in the anaerobic potential of swimmers.

There was no difference between the swimming times before and after seven days of taper. We verified the absence of differences in the variables related to velocity. It seems that the magnitude of changes was not sufficient to improve the performance of swimmers. Previous studies have not evaluated velocity variation before and after a taper, however, unchanged performance during a short duration 15 s test and during competition has been observed following two weeks of taper (Toubekis et al., 2013), while improved performance following a 30 s test observed following a 10 days taper (Papoti et al., 2007). It seems that the duration of the taper and tests used for detecting anaerobic potential changes are confounding factors. The test used in the present study may evaluate velocity variations during free swimming as opposed to tethered swimming used in the abovementioned studies (Papoti et al., 2007; Toubekis et al., 2013). However, despite the test sensitivity to detect velocity variations and locate likely fatigue thresholds, the taper duration may not be enough to allow anaerobic potential improvement.

The analysis of the variables related to the effort developed during the test (fatigue index and velocity decay) also did not show different values in the pre-test and post-test, results that had also been ascertained previously (Soares et al., 2014). It is important to highlight the high standard deviations associated with the fatigue index means, which reveal the existence of great variability between the sample subjects regarding the fatigue generated for the same effort, which reinforces the idea that using individual training records could help determine the ideal taper duration itself (Bosquet et al., 2007; Le Meur et al., 2012). Finally, the analysis of blood lactate concentration, one of the study variables used to analyse the impact of taper on the swimmers' anaerobic potential, revealed no differences between the two testing times, a result indicating the absence of effect of taper on this variable as well, which is not surprising given the maintenance of swimming time.

To evaluate the impact of taper on the anaerobic potential of young swimmers, fatigue thresholds were determined based on the velocity curves (Soares et al., 2014). In the evaluation carried out before the taper, six of the eleven variables analysed revealed differences between the two temporal

Table 2. Mean and standard deviations of variables from the second phase of data processing presenting the comparison between the 1st and 2nd intervals separated by the defined fatigue threshold.

Variables	Pre-taper	Post-taper
Fatigue threshold (s)	9.51 ± 1.02	9.87 ± 1.63
Upper limb cycle 1st int (nº)	4.83 ± 1.33*	5.00 ± 1.59
Upper limb cycle 2nd int (nº)	6.08 ± 1.31	5.33 ± 1.45
Swim duration 1st int (s)	5.25 ± 1.32*	5.77 ± 2.06
Swim duration 2nd int (s)	6.96 ± 1.47	6.28 ± 1.68
Upper limb cycle duration 1st int (s)	1.09 ± .07*	1.14 ± .1*
Upper limb cycle duration 2nd int (s)	1.14 ± .1	1.18 ± .11
Swim distance 1st int (m)	8.19 ± 1.75*	8.79 ± 2.8
Swim distance 2nd int (m)	10.47 ± 1.85	9.14 ± 2.09
Maximum velocity 1st int ($m \cdot s^{-1}$)	2.31 ± .24	2.21 ± .31
Maximum velocity 2nd int ($m \cdot s^{-1}$)	2.26 ± .28	2.21 ± .24
Mean velocity 1st int ($m \cdot s^{-1}$)	1.57 ± .16*	1.54 ± .2*
Mean velocity 2nd int ($m \cdot s^{-1}$)	1.52 ± .18	1.49 ± .19
Minimum velocity 1st int ($m \cdot s^{-1}$)	.81 ± .27	.93 ± .18
Minimum velocity 2nd int ($m \cdot s^{-1}$)	.79 ± .22	.84 ± .23
Stroke frequency 1st int (Hz)	.91 ± .06*	.87 ± .07*
Stroke frequency 2nd int (Hz)	.87 ± .07	.85 ± .07
Stroke length 1st int (m)	1.73 ± .18	1.75 ± .11
Stroke length 2nd int (m)	1.69 ± .24	1.66 ± .28
Stroke index 1st int ($m^2 \cdot s^{-1}$)	2.75 ± .52	2.73 ± .51
Stroke index 2nd int ($m^2 \cdot s^{-1}$)	2.69 ± .56	2.64 ± .55
Velocity variation coefficient 1st int (%)	.16 ± .03	.13 ± .02*
Velocity variation coefficient 2nd int (%)	.17 ± .04	.17 ± .04

*Different from 2nd int. ($p \leq .05$)

Table 3. Mean and standard deviations of final phase of data processing with respective study variables.

Variables	Pre-taper	Post-taper
Upper limb cycles per 25 m (nº)	12.91 ± 2.15	12.25 ± 1.42
Swim duration (s)	13.34 ± 2.09	13.25 ± 2.23
Cycle duration (s)	1.03 ± .08	1.07 ± .09
Swim distance (m)	20.43 ± 1.89	19.87 ± 1.50
Maximum velocity ($m \cdot s^{-1}$)	2.64 ± .25	2.57 ± .23
Mean velocity ($m \cdot s^{-1}$)	1.52 ± .19	1.52 ± .18
Minimum velocity ($m \cdot s^{-1}$)	.67 ± .15	.74 ± .20
Stroke frequency (Hz)	.97 ± .06	.93 ± .08
Stroke length (m)	1.60 ± .14	1.62 ± .1
Stroke index ($m^2 \cdot s^{-1}$)	2.49 ± .45	2.47 ± .44
Velocity variation coefficient (%)	.20 ± .03	0.18 ± .02

intervals (before and after the fatigue threshold) defined by the threshold. The instability of technical patterns differs from swimmer to swimmer; in young swimmers, this seems to be more observable than that displayed in older and elite swimmers (Alberty et al., 2005).

In the post-taper evaluation, only four of the eleven analysed variables showed differences in the two-time intervals, which indicates that the threshold calculated in the post-taper can be less robust. The absence of differences between the fatigue thresholds calculated in pre and post taper reinforces the conclusion that taper had no effect on the anaerobic potential of swimmers. It is likely that a longer tapering period is required to increase anaerobic potential in young swimmers, including a specific training plan appropriate to the individual characteristics of each swimmer (Trinity et al., 2006).

The procedures for the calculation of fatigue thresholds allowed to estimate other variables (namely velocities) that, when compared, reinforce the conviction that the taper performed by the swimmers of the current study was not enough to change the swimming performance. The total swimming time was lower than the chronometric time obtained in the test, and so was the velocity because of the suppression of the influence of the push-off on the swimming velocity. Comparing this time and these velocities, corresponding to the pre-taper and post-taper, we again observed the absence of differences, in biomechanical variables, such as the stroke frequency and the stroke length, as observed in other studies of two weeks of taper (Barbosa et al., 2020).

The velocity variation coefficient was stable before and after taper, revealing the absence of effects of taper on physiological or biomechanical variables. However, a previous study identified that biomechanical variables play an important role in sprint performance, helping young swimmers accomplish a better and more efficient technique (Silva et al., 2019). It should be noted that the duration of the taper decided by the coach was short, as the literature suggests taper periods of two weeks to reverse the fatigue caused by intense training and enable the swimmer to reach maximum performance (Bosquet et al., 2007; Hellard et al., 2017; Houmard & Johns, 1994). Although some studies examining the performance of swimmers have reported improvements after tapers lasting from seven to twenty-one days (Costill et al., 1985; Hellard et al., 2013; Houmard & Johns, 1994; Johns et al., 1992; Shepley et al., 1992), in the current study, carried out on young swimmers and with a taper period of seven days proved to be insufficient.

No differences in performance were found, particularly in anaerobic potential. These results are in line with those found elsewhere (Toubekis et al., 2013), where they reported that a team of young swimmers showed no significant improvement in performance after a moderate reduction in training load with a two-week taper period. Nevertheless, half of the swimmers showed significant improvements in overall performance. Both studies demonstrated that a moderate reduction and a short duration taper period did not reflect improvements in the anaerobic potential of the athletes. Previous research indicates that the power of type IIa fibres, typically anaerobic, increases 2.5-fold after taper (Trappe et al., 2001), increasing the power may also increase the swimming velocity by the direct relationship between power and velocity (Garrido et al., 2010; Morouço et al., 2015). In the present study perhaps because the swimmers were young and not yet so strong, the influence of the taper period on power and velocity has not been evident, the same occurred in adults during a taper period of between 10 days (Bishop & Edge, 2005) and 14 days (Trinity et al., 2008).

The studies assessing the effect of taper on performance are still insufficient and none have yet managed to connect the change in performance with physiological changes in young swimmers. This lack of knowledge may be due to the fact that taper is a very sensitive and critical period in the swimmers' preparation (Mujika et al., 2002; Pyne et al., 2009) and, sometimes, taper does not operate according to expectations (Grivas, 2018) due to psychosocial and physical factors. Therefore, few coaches allow their swimmers to be involved in experimental studies, which may jeopardise their performance in important competitions. Researchers and coaches should focus on a long-term approach to gain a deeper understanding of how the determinants of swimmers' performance, their interactions and their effect on performance change over time (Zacca et al., 2020). Therefore, swimmers should rest as much as necessary to overcompensate muscle strength and anaerobic potential. Given the results discussed above, it is becoming increasingly crucial to test different taper durations for young swimmers, namely using individual training records to help determine the ideal taper duration for each swimmer (Le Meur et al., 2012). For this, more studies are needed to understand the best balance between the load and duration of the taper and its effects.

CONCLUSIONS

The main purpose of this study was to determine the effect of one-week tapering on the anaerobic potential of young swimmers based on a simple and non-invasive test. Although we used a promising test to detect the anaerobic potential and reveal velocity variation in swimmers, it was not possible to see changes in performance. It seems that the one-week taper duration or the overload period before the taper were not adequate to induce appropriate adaptations. The test deserves attention once it is friendly for the coaches, helping them in training planification and providing supported decisions for their swimmers. A long-duration, detailed monitoring of training content is required in young swimmers, helping to suggest the optimal duration of a taper.

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