Detraining Effect on Sprint Swimming Performance and Load-velocity Profile

Journal:	*International Journal of Sports Physiology and Performance*
Manuscript ID	IJSPP.2024-0491.R2 | DOI: 10.1123/ijspp.2024-0491
Manuscript Type:	Original Investigation
Date Submitted by the Author:	31-Dec-2024
Complete List of Authors:	Ruiz-Navarro, Jesús J.; University of Granada, Aquatics Lab, Faculty of Sport Sciences, Department of Physical Education and Sports López-Belmonte, Óscar; Universidad de Granada, Aquatics Lab. Department of Physical Education and Sports. Faculty of Sport Sciences Febles-Castro, Adrián; University of Granada, Aquatics Lab, Faculty of Sport Sciences, Department of Physical Education and Sports GAY, ANA; Universidad de Granada - Campus de Cartuja, EDUCACIÓN FÍSICA Y DEPORTIVA Lopez-Contreras, Gracia; University of Granada, Physical Education and Sports Morales-Ortíz, Esther; University of Granada, Aquatics Lab. Department of physical education and sports Arellano, Raúl; University of Granada, Aquatics Lab, Department of Physical Education and Sports, Faculty of Sport Sciences; Raúl Arellano, Raúl Arellano
Keywords:	biomechanics, sport physiology, exercise performance, strength, training
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Abstract

Purpose: To assess the effect of five-week training cessation period on performance and load-velocity profile related variables. **Methods:** Twenty-four competitive swimmers (15 males and 9 females: 19.2 ± 3.7 and 17.3 ± 2.3y; 50m front-crawl 550 ± 70 and 572 ± 51 World Aquatics points, respectively) performed a 50 m front-crawl all-out swim, a load-velocity profile, and a pull-up tests before and after a five-week off-season period. Kinematic variables, blood lactate concentration ([La⁻]) and rate of perceived exertion were monitored during the load-velocity profile tests. **Results:** Performance was impaired 1.3% for males ($p<0.01$) and 3.8% for females ($p<0.01$). Neither anthropometric changes (males: $r^2 = 0.277$, females: $r^2 = 0.218$, $p>0.05$) nor the physical activity performed during the off-season (males: $r^2 = 0.329$, females: $r^2 = 0.094$, $p>0.05$) attenuated performance impairments. While males counteract the stroke rate decline ($p<0.05$) by increasing stroke length ($p<0.05$) in the majority of the race, females did not, leading to a decline in clean swimming speed ($p<0.05$). The maximum load at zero velocity decreased ($p<0.05$) during the load-velocity profile test. In addition, males showed an increased in [La⁻] ($p<0.05$), while females decreased the maximum velocity at zero load ($p<0.01$) and stroke rate ($p<0.01$). No change in the slope was observed for either sex ($p>0.05$). **Conclusion:** Following a five-week off-season period sprint swimming performance declines (males: 0.34s; females: 1.15s). The load velocity profile and related variables evidenced deterioration, showing changes in [La⁻], maximum load at zero velocity, average velocity during the third trial, and stroke rate.

Keywords: semi-tethered, strength, training cessation, testing, off-season.

Introduction

Sprint swimming performance is a multifactorial phenomenon largely dependent on the muscular force production while stroking[1], swimming technique[2] and anaerobic/aerobic energy production[3]. Due to the aquatic environment, it is not possible to directly measure the whole-body propulsive forces exerted in the water[1]. Over the years, several estimation methods like hand pressure sensors or tethered swimming have emerged to estimate propulsive forces[4,5]. However, each of these methods has its own inherent limitations[5]. Currently, despite these constraints, the technological development has also enabled the reliable and ecologically valid evaluation of velocity and force simultaneously via semi-tethered swimming[6].

In semi-tethered swimming, the swimmer propels forward while being subjected to an external load. The velocity achieved against different external loads follows a linear relationship ($r^2 > 0.98$)[6,7] that allows to create the swimmers' load-velocity profile. Key features of this profile include the maximum velocity at zero load (V_0), maximum load at zero velocity (L_0) and steepness of the regression line (slope), which together provide insights into an athlete's maximum velocity, the ability to produce propulsive forces, and the ability to minimize resistance force[6–9]. These factors reflect both individual velocity and strength capabilities during swimming[6–9]. Indeed, positive associations between these parameters and sprint performance has been observed across the four swimming strokes[7,8,10,11]. Consequently, the load-velocity profile is considered a practical tool for monitoring changes in swimmers' performance over the course of a season. However, most studies to date are cross-sectional and the longitudinal effects of the profile have yet to be demonstrated.

During the off-season, swimmers typically spend four to six weeks out of the pool, depending on the individual coaches and/or national calendars, with no regular swimming training sessions[12,13]. Although this period is necessary for recovery and relief from training stress, it also leads to a partial or complete loss of training adaptations, a process known as detraining[14]. The detraining effect is clearly observed in the cardiorespiratory function, which is characterized by a rapid decline in maximal oxygen uptake and blood volume[14]. This has led to the research in swimming being primarily focused on middle- and long-distance events, due to the importance of physiological changes that occur even after short periods of training cessation[12–14]. With regards to sprint swimming, recent studies have begun to emerge[13,15,16]; however, given the importance of muscular force production, the in-water forces and related aspects require further in-depth investigation in sprint swimming[13,15,16].

Given the utility of the load-velocity profile for assessing individual velocity and strength capabilities, along with the need to better understand the effects of detraining on sprint and in-water forces, this research aimed to evaluate the impact of a five-week training cessation period on performance and load-velocity profile related variables. The physical activity undertaken during the five-week off-season was monitored. A reduction in performance and load-velocity profile related variables was expected after a five-week training cessation period.

Methods

Participants

Twenty-four swimmers, 15 males and 9 females (19.2 ± 3.7 and 17.3 ± 2.3y; 50m front-crawl 550 ± 70 and 572 ± 51 World Aquatics points, level 4[17], respectively) (competing mainly in 50 and 100 m events, volunteered to participate in the current study. All swimmers had more than six years of regional and/or national competitive experience and participated in at least six water and four dryland training sessions per week. The protocol was explained to the swimmers and their parents (swimmers under 18 years) prior to signing an informed written consent form. The study was conducted according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) and the protocol was approved by the University of ANONIMITY ethics committee.

Design

A longitudinal single-cohort study was carried out assessing swimmers before and after a five-week off-season period. During that period, the swimmers did not follow a specific swimming or dryland training program, but were encouraged to stay physically active and participate in any type of physical activity. The first testing (pre) was conducted the week prior to the initiation of the final peak performance of the season, based on the swimmers' coaches' recommendations in relation to the competition calendar and the general training regime. The second testing (post) took place just before the beginning of training for the following competitive season. Both testing sessions were conducted identically. Given the long periods of rest among trials and the swimmers' availability, the tests were conducted on a single day. To enhance the reliability of the measurements, a three-fold approach was implemented: 1) to avoid bias due to circadian variation, pre and post testing were conducted at the same time of the day[18], 2) the tests were performed in the exact same order, with identical rest intervals between them, and 3) swimmers were instructed to refrain from strenuous exercise and maintain similar dietary habits on the day before and the day of the tests. Moreover, during the testing sessions, participants were verbally encouraged to exert their maximum effort.

Swimming tests were carried out in a 25m swimming pool (25-m length × 16.5-m width × 2.07-m depth with 27.6, 28.8°C, and 51% water, air temperature, and humidity in the pre and 28.2, 30.0°C, and 50% water, air temperature, and humidity in the post). Anthropometric measurements and pull-ups were assessed in an adjacent room directly connected to the testing swimming pool.

Methodology

During the season, before the pre testing session, swimmers followed their specific training program. Swimmers belonged to two different swimming clubs (19 and 5 swimmers) with the same competitive calendar and similar training methodologies employing the 5-zone system proposed by Mujika et al.[19]. In the testing session, upon arrival at the facilities, anthropometric variables were measured following standardized techniques adopted by the International Society for the Advancement of Kinanthropometry (ISAK)[20]. Body height and body mass were measured using a stadiometer/scale (Seca 799, Hamburg, Germany) by the same ISAK Level 2 accredited researcher. Body mass index was calculated as body mass [kg]·height [m]$^{-2}$.

Swimmers then completed their standardized dry-land warm-up, which primarily consisted of joint mobility, dynamic stretching, and elastic band exercises. Moreover, as part of the warm-up, swimmers performed 2-3 submaximal pull-ups (i.e., not maximal intended velocity). Once the swimmers confirmed their readiness to exert their maximum effort, five pull-ups with two min of rest in-between were executed. Swimmers were required to start the pull-ups hanging from the bar with pronated grip and with their elbows fully extended; then, at the researcher's signal, they were requested to perform as quickly as possible. Performance was measured using an isoinertial dynamometer (T-Force Dynamic Measurement System, Ergotech, Murcia, Spain) attached to the subjects' hips via a harness. Pull-up movements were monitored by the same researcher to ensure vertical displacement. If any horizontal movement was observed and/or the swimmers' chin did not reach the bar, the pull-up was not considered as correct, an additional trial was performed[21]. The trials with the highest and lowest mean velocity values of the propulsive phase were excluded, and the average of the remaining three was calculated[22]. Average propulsive velocity, force, and power were obtained (PUv_{avg}, PUf_{avg}, and PUp_{avg}, respectively).

The participants then headed to the water and performed an in-water warm-up comprising 200 m (100 m usual breathing and 100 m breathing every five strokes), 2 × 100 m (2 × [25 m flutter + 25 m increased stroke length]) on 1:50 min, 6 × 50 m (2 × 50 m drill; 2 × 50 m building up swimming speed; and 2 × [25 m race pace + 25 m easy]) on 1:00 min, and 100 m easy swim. This warm-up was adapted from previous literature [23], aligning with the coaches' requirements for their swimmers' in-water warm-up routine before competitions.

The swimmers rested for 10 min and performed a load-velocity profile test, which consisted of three 20 m front-crawl semi-tethered swims from a push-off start with maximal effort, without undulatory underwater swimming and 6 min of total recovery between each sprint[6,24]. The loads used in the three trials were 1, 5, and 7 kg for males, and 1, 3, and 5 kg for females. Initially, the loads were selected based on previous research (males: 1, 5, and 9 kg; females: 1, 3, and 5)[6]. However, during a pilot study, two males struggled with the 9 kg load. Besides, since measurements were to be taken also after a five-week off-season period, the 9 kg load was replaced by a 7 kg load to ensure that swimmers could handle the same loads in both the pre and post testing sessions. This adjustment has been also performed in this kind of testing[9] and prevented potential protocol changes in the post session, which would have resulted in different testing conditions. The external load was applied using the 1080 Sprint 2, a robotic resistance device (1080 Motion, Lidingö, Sweden) which measured the swimming velocity and the force simultaneously with a recording frequency of 200 Hz. The device was positioned and secured on the wall at 0.63 m between the water surface and the origin of the cord in the device. The cord was attached to the back of the swimmers' waists using the manufacturer's belt to prevent the wire from interfering with their kicking motion.

From the 1080 motion web app (https://webapp.1080motion.com), data was downloaded for further analysis within a customized script in Python (V3.11.5). First, given the fact that the device was placed at 0.63 m above the water level, the following correction was applied to obtain the horizontal component of the velocity[8]:

(1)
$$V_H = V \times \cos\left[\sin^{-1}\left(\frac{0.63}{L_C}\right)\right]$$

Where V and V_H represent the average velocities before and after correction, respectively. The value 0.63 refers to the height (m) of the device (i.e., the cord's origin) above the water level, while L_C is the length (m) of the cord extending from the device to the swimmer. Data analysis was restricted to the 10-15m section and the average velocity (SLVP) of the three strokes performed in this section was used. This area was chosen to ensure that all the swimmers were analyzed in the same section during the pre and post measurements, thus controlling for the effect of the push-off, fatigue or stroke adjustments[25].

The calculated average V_H was plotted as functions of the corresponding external load and a linear regression line was established for each load-velocity plot [6–8,25]. The theoretical maximal values of V_H (V_0) and load (L_0) were calculated using the intercept of the regression line with the vertical and horizontal axes, respectively and where V_0 represents the theoretical maximal velocity and L_0 represents the theoretical maximal load the swimmer can pull (without being towed backward). The slope is the steepness of the linear regression line for the load-velocity relationship and was computed as Slope = $-V_0/L_0$ [6–8,25]. The coefficient of determination (r^2) was also calculated individually with a mean value of 0.99. Moreover, given the inherent changes that may occur during the load-velocity tests, the swimming kinematics (stroke rate, length, and index [SR, SL, and SI, respectively]) may also be influenced during each trial, and thus were also included in this study[13].

During the load-velocity profile test, blood lactate concentration [La^-] was analyzed. Capillary blood samples (25 µL) were collected from the same fingertip 1 min before the first semi-tethered trial, immediately after each effort, and at minute 1, and every 2 min until the peak was reached after the third trial ($[La^-]_{peak}$). The samples were analyzed using Lactate Pro 2 analyzer (Arkray, Inc., Kyoto, Japan). Rate of perceived exertion (RPE) was asked immediately after each semi-tethered trial using the 0 – 10 scale with which the swimmers were already familiar[26]. Moreover, all the trials were recorded with a Sony FDR-AX53 (Sony Electronics Inc., Tokio, Japan) at 100 Hz sampling rate.

Finally, swimmers rested for 10 min and perform 50 m front-crawl all-out with in-water start with restricted underwater duration (i.e., swimmers were asked to avoid performing undulatory underwater swimming). The time taken to complete the given distance was considered as T50 and SR, SL, SI and clean swimming speed were also obtained [13]. All the videos were analyzed by one expert evaluator on an in-house customized software for race analysis in competitive swimming[27] with an intraclass correlation coefficient ≥ 0.975. The variables were collected as previously explained in the literature[13].

During the five-week off-season period, swimmers were instructed to self-assess their weekly physical activity by the International Physical Activity Questionnaire (IPAQ) [12,13,28] and complete the corresponding online formulary. The information was summarized according to the registered physical activities (i.e., low, moderate, and vigorous activities). The swimmers' questionnaires results were transformed into units of metabolic equivalent of task following the IPAQ specifications[12,13,28]. In addition, swimmers were asked to provide the specific type of activity conducted (e.g., basketball, running, cycling, etc.).

Statistical analysis

The normality of all distributions was assessed using the Shapiro–Wilk test. Napierian logarithms were calculated for analytical purposes. All analyses were stratified by sex[29]. To examine the impact of growth on performance changes, a multiple regression analysis was performed. The change in performance (i.e., relative change) served as the dependent variable, while the relative change for height and body mass were included as predictor variables. The same procedure was applied using off-season physical activity data to assess the effects of non-swimming-specific physical activities. Paired sample t test was used to compare differences between pre and post off-season for each variable. Effect sizes (d) of the obtained differences were calculated and categorized as follow: small if $0 \le |d| \le 0.5$, medium if $0.5 < |d| \le 0.8$, and large if $|d| > 0.8$[30]. Pearson correlation was used to quantify the degree of association between deltas (Δ, i.e., post−pre values) for each variable and the change in T50. Statistical procedures were conducted with the Jamovi software package version 2.3.28.0 (Jamovi Project 2022, retrieved from https://www.jamovi.org) with the level of statistical significance set at 0.05.

Results

The mean volume and training load per week over the las 15 weeks immediately before the off-season were 27 ± 5 $km \cdot wk^{-1}$ and 55 ± 11 $T.U. \cdot week^{-1}$. While females increased their height ($p < 0.05$), no other anthropometric change was observed in males or females after the five-week training cessation (Table 1). In this regard, neither anthropometric variations (males: $r^2 = 0.277$, $p > 0.05$; females: $r^2 = 0.218$, $p > 0.05$) nor off-season physical activity (males: $r^2 = 0.329$, $p > 0.05$; females: $r^2 = 0.094$, $p > 0.05$) influenced the total variance in performance change. The swimming performance of both male and female was found to be impaired by 1.3% and 3.8%, respectively, after the off-season. Furthermore, the clean swimming velocity was markedly slower at the end of the race at the post condition ($p < 0.01$), evoked by a reduction in the SR in both sexes ($p < 0.05$) (Table 2). Following each semi-tethered trial, males exhibited an increase in [La^-], while this increase was only evident in the third trial for females ($p < 0.05$). Additionally, both sexes demonstrated a decline in L_0, with females displaying a deterioration in V_0 and no alterations in the Slope in any of the sexes (Figure 1; Table 3). The third semi-tethered trial exhibited the most pronounced impact of the training cessation period, manifesting a discernible decline in velocity, SR, and SI ($p < 0.05$) (Table 3). The specific effects of the five-week off-season on swimmers' anthropometrics, physical activity, upper-body strength, kinematics, and load-velocity profile related variables are presented in Tables 1-3.

[please insert Figure 1 and Tables 1-3 near here]

Discussion

Our study aimed to assess the effect of five-week training cessation period on performance and load-velocity profile related variables. As hypothesized, the results showed an impairment in both males (1.3%) and females (3.8%) sprint swimming performance, with neither anthropometric changes nor physical activity accounting for the differences in performance decline. A deterioration in the load-velocity profile was evidenced in both sexes ([La^-] especially in males, L_0, $SLVP_{3T}$, SR), with females showing a particularly strong negative association between changes in V_0 and 50 m sprint performance.

After the training cessation period, swimmers evidenced a clear decline in overall sprint performance. This impairment was associated with declines in both 25-m splits, turn (males only) and finish phases (females only), findings consistent with previous research[13], confirming the negative consequences of detraining in sprint swimming events. Furthermore, after the off-season, SR decreased in both sexes, which has been previously suggested as a consequence of anaerobic energetic impairments[13,31]. Indeed, to counteract the decline in SR, swimmers exhibited higher SL during the clean swimming phase of the first and second split (not in the finish). This augmented SL in males prevented a reduction in clean swimming speed during the first split, and even increased it during the second half of the race. Based on the evident impairment in the finish, this higher clean swimming speed seems to be the consequence of a race strategy in which the swimmers boosted all their energy after the turn, without being able to maintaining it to the end. Indeed, these results are supported by the SI behavior, which dramatically dropped at the end of the race, likely as result of higher fatigue[32]. On the contrary, females' increase in SL was not enough to counteract the SR decline and, thus, clean swimming speed impaired throughout the race. The impairment during the first half and end of the race presented association with overall performance, which is in agreement with previous research[13]. Finally, it is important to note that given the established relationship between SR and SL, it is reasonable to expect that declines in SR would result in increases of SL, as a consequence of longer stroke duration[33]; nevertheless, these increases must be sufficiently substantial to prevent a reduction in swimming speed.

After the off-season, L_0 was reduced in both sexes. Considering that L_0 corresponds to a fully tethered swimming condition[8], these results are in line with those previously presented for mean fully tethered swimming[13] and indicate a decline in swimmers in-water maximum strength. While the reduction in SLVP in females was evident in all three loads (Table 3), the greatest decline was observed at the heaviest load, which was significantly reduced in males. On the other hand, the slope, which is a strong indicator of active drag[9], was unaffected in both sexes. Thus, based on the changes in velocity across the different loads and the lack of variation in the slope (Table 3), swimmers manifested a reduction in the applied force in the water[34], especially at high loads, with no apparent change in hydrodynamic resistance. Furthermore, the pull-up results seem to support the aforementioned statement. In this case, the changes in pull-up performance among the male participants were not significant. Since the pull-up is a bodyweight exercise[22], it is possible that a reduction in maximal strength (defined as the maximal load lifted for one repetition) occurred, which may have affected swimming velocity at higher loads. Indeed, maximal upper-body dry-land strength has been suggested as the main predictor of in-water forces[35]. In contrast, the female participants exhibited a significant decline in pull-up performance (in particular, two females were unable to complete the pull-up in the post test), and this decay was accompanied by a significant reduction in swimming velocity across all load conditions. Overall, despite the lack of association between deltas, the results suggest that the decline in performance of the swimmers may be partly attributed to neuromuscular impairments likely including a reduction in maximal strength and altered muscle activation patterns, which would have affected force production[35], especially at higher loads.

From the performance perspective, the V_0 could be considered the most important parameter, as it represents the maximum velocity a swimmer can achieve without any load (i.e., free swimming). In this respect, no changes were observed in males' V_0, as well as their clean swimming speed remained unchanged. In fact, the highest clean swimming speed in males corresponded to V_0 (1.79 vs. 1.79 $m \cdot s^{-1}$, respectively), thus, given that no changes were observed in one, a lack of change in the other would be expected[8]. On the other hand, the opposite behavior was observed in females, who showed a significant reduction in V_0 associated with the T50 impairment, i.e., the higher the reduction in V_0, the higher the increase in T50. These results confirm that this method is useful for monitoring changes in swimmers' performance over time.

To gain a clearer understanding of the changes in the load-velocity profile, it is interesting to consider the intrinsic variations that occur during the test [36]. There was an evident reduction in SR after the off-season in every semi-tethered trial (Table 3). This SR reduction has been previously associated with impairments in the anaerobic capacity[13,31], which was more pronounced in female swimmers. On the other hand, males' swimmers counteracted the SR reduction by increasing their SL during the first semi-tethered trial. This specific increase in SL led to a higher SI, suggesting that the swimmers, in an attempt to reach greater speeds, adopted a SR during the pre testing session (i.e., before the off-season) that exceeded the optimal[33]. This not only fails to translate into higher speeds, but also diminishes propulsive efficiency, ultimately leading to greater energy expenditure for the same swimming speed[37,38]. On the contrary, females were not able to counteract the SR decline by increasing their SL. To better understand this offsetting effect, it is important to recognize that SR and SL present a negative association (i.e., an acute increase in SR results in an immediate decrease in SL)[33], but also that SL has been associated with strength levels[21]. Hence, despite the decrease in SR, which should have resulted in a greater SL, females' strength impairment led to the similar SL after the off-season. This may be a consequence of the low level of vigorous activity performed during the off-season, as discussed below. Moreover, the SL invariance was translated into a decline in SI, which, as discussed in males, reduced their propulsive efficiency and likely increased the energy expenditure.

The males' [La⁻] during the load-velocity profile test increased following the training cessation period (Table 3). However, this does not necessarily indicate an improvement in anaerobic capacity, as it reflects the balance between lactate production and removal[39]. In fact, given the changes in SR, the physical activity reported during this period, and based on previous studies that have found impairments of cardiac and aerobic capacity functions in swimmers[12,13,40,41], it is likely that the males managed to mitigate their impairment of anaerobic function to a greater extent compared to the aerobic function, leading to higher [La⁻] after the off-season. Unfortunately, no aerobic indicators were measured to corroborate this. On the other hand, females' [La⁻] remained unaltered (except after the third trial), which aligns with previous findings[13]. In this case, the amount of physical activity conducted during the off-season was considerably lower than males, especially, the vigorous activity was almost a third (Table 1) which is likely to induce an impairment in both aerobic and anaerobic functions[39]. Furthermore, the changes in energy production might have influenced also the L_0, given the relationship between the pure capacity to produce power at a higher rate and higher capacity to apply force to the water[3].

Finally, the amount of physical activity did not seem to have a linear effect on the change in performance. However, it is clear that females who were less physically active, especially in terms of vigorous activities, had greater impairments than males. Moreover, it is important to note the reported activities in males were mainly resistance training, basketball, football, or racket sports, whereas for females it was running, or cycling. Given the nature of these activities, it is important to consider their different effects on neuromuscular adaptations Moreover, this difference in training modalities may have contributed to the higher RPE reported by females compared to males in all three trials (Table 3). This raises the question of whether the chosen activities were appropriate for maintaining the specific demands of sprint swimming, particularly in terms of neuromuscular conditioning.

Practical applications

The off-season is an essential part of the training process, providing recovery and relief from training stresses to support the athlete's long-term development and prevent burnout. However, after five-week of training cessation, sprint performance is clearly impaired. Given the time needed to regain these capacities, such impairments could potentially compromise performance in the upcoming competitive season. The use of the load-velocity profile allows to assess the maximum velocity, the ability to produce propulsive forces, and the ability to minimize resistance force in a single test, providing valuable insights into the causes of performance changes. This deeper understanding is essential for guiding the training program at the beginning of the following competitive season, potentially reducing the time to reach the peak performance. Finally, coaches and future research should explore strategies during the detraining period to minimize these declines. Based on the evidence and observed sex differences, it may be beneficial to implement more tailored activities. In particular, the inclusion of vigorous, high-intensity exercise (e.g., resistance training or team sports) may help to maintain strength and neuromuscular capacities, especially in female sprinter swimmers.

Conclusion

After a five-week off-season period both males (1.3%) and females (3.8%) sprint swimming performance declined, primarily compromised by a reduction in SR. The load-velocity profile and related variables evidenced deterioration, showing both sexes changes in [La⁻], L_0, $SLVP_{3T}$, and SR. Notably, females displayed a negative association between changes in V_0 and 50 m sprint performance.

Disclosure statement

Authors have no conflicts of interest to report.

Acknowledgments

The authors are grateful to the swimmers and coaches for their cooperation and involvement in this research project. This study was supported by the Grant PID2022.142147NB.100 (SWIM III) funded by MICIU/AEI/10.13039/501100011033/ and by ERDF, EU. AFC has an FPI fellowship, PID2022-142147NB-I00, which is part of the aforementioned grant and OLB was supported by the grant FPU19/02477 funded by MICIU/AEI/10.13039/501100011033.

References

1. Ruiz-Navarro JJ, Morouço PG, Arellano R. Relationship between tethered swimming in a flume and swimming performance. *Int J Sports Physiol Perform*. 2020;15(8):1087-1094. doi:https://doi.org/10.1123/ijspp.2019-0466
2. Barbosa TM, Bragada JA, Reis VM, Marinho DA, Carvalho C, Silva AJ. Energetics and biomechanics as determining factors of swimming performance: Updating the state of the art. *J Sci Med Sport*. 2010;13(2):262-269. doi:10.1016/j.jsams.2009.01.003
3. Sengoku Y, Shinno A, Kim J, et al. The relationship between maximal lactate accumulation rate and sprint performance parameters in male competitive swimmers. *Front Sports Act Living*. 2024;(October). doi:10.3389/fspor.2024.1483659
4. Morais JE, Barbosa TM, Bragada JA, Ramirez-Campillo R, Marinho DA. Interaction of Kinematic, Kinetic, and Energetic Predictors of Young Swimmers Speed. *Int J Sports Physiol Perform*. 2023;18(8):833-839. doi:10.1123/ijspp.2022-0430

5. Santos CC, Marinho DA, Neiva HP, Costa MJ. Propulsive forces in human competitive swimming: a systematic review on direct assessment methods. *Sports Biomech*. 2021;00(00):1-21. doi:10.1080/14763141.2021.1953574
6. Olstad BH, Gonjo T, Njøs N, Abächerli K, Eriksrud O. Reliability of Load-Velocity Profiling in Front Crawl Swimming. *Front Physiol*. 2020;11(September):1-8. doi:10.3389/fphys.2020.574306
7. Gonjo T, Eriksrud O, Papoutsis F, Olstad BH. Relationships between a Load-velocity Profile and Sprint Performance in Butterfly Swimming. *Int J Sports Med*. 2020;41(7):461-467. doi:10.1055/a-1103-2114
8. Gonjo T, Njøs N, Eriksrud O, Olstad BH. The Relationship Between Selected Load-Velocity Profile Parameters and 50 m Front Crawl Swimming Performance. *Front Physiol*. 2021;12. doi:10.3389/fphys.2021.625411
9. Gonjo T, Vitazka M, Ljødal I, Olstad BH. The load-velocity slope is an indicator of the active drag in all competitive swimming strokes. *Med Sci Sports Exerc*. 2024;(August). doi:10.1249/MSS.0000000000003551
10. Olstad BH, Hunger L, Ljødal I, Ringhof S, Gonjo T. The relationship between load-velocity profiles and 50 m breaststroke performance in national-level male swimmers. *J Sports Sci*. 2024;42(16):1512-1518. doi:10.1080/02640414.2024.2397234
11. Olstad BH, Ljødal I, Karlsson R. The relationship between backstroke swimming sprint performance and load-velocity profiles. In: *40th International Society of Biomechanics in Sports Conference*. ; 2022:531-534. https://commons.nmu.edu/isbs/vol40/iss1/128
12. Zacca R, Toubekis A, Freitas L, et al. Effects of detraining in age-group swimmers performance, energetics and kinematics. *J Sports Sci*. 2019;00(00):1-9. doi:10.1080/02640414.2019.1572434
13. Ruiz-Navarro JJ, Gay A, Zacca R, et al. Biophysical impact of five-weeks training cessation on sprint swimming performance. *Int J Sports Physiol Perform*. 2022;17(10):1463-1472.
14. Mujika I, Padilla S. Detraining: Loss of Training-Induced Physiological and Performance Adaptations. Part I short term insufficiente training stimulus. *Sports Medicine*. 2000;30(2):79-87.
15. Santos CC, Costa MJ, Marinho DA. The effects of 6-week training cessation on anthropometrics, in-water force, performance, and kinematics of young competitive swimmers: A maturity development approach. *Int J Sports Physiol Perform*. 2023;18(6):643-652.
16. Morais JE, Lopes VP, Barbosa TM, Moriyama SI, Marinho DA. How does 11-week detraining affect 11-12 years old swimmers’ biomechanical determinants and its relationship with 100 m freestyle performance? *Sports Biomech*. 2020;00(00):1-15. doi:10.1080/14763141.2020.1726998
17. Ruiz-Navarro JJ, López-Belmonte Ó, Gay A, Cuenca-Fernández F, Arellano R. A new model of performance classification to standardize the research results in swimming. *Eur J Sport Sci*. 2023;23(4):478-488.
18. Atkinson G, Reilly T. Circadian variation in sports performance. *Sports Medicine*. 1996;21(4):292-312. doi:10.2165/00007256-199621040-00005

19. Mujika I, Busso T, Lacoste L, Barale F, Geyssant A, Chatard JC. Modeled responses to training and taper in competitive swimmers. *Med Sci Sports Exerc*. 1996;28(2):251-258.
20. Ross W, Marfell-Jones MJ. Kinanthropometry. In: Mac Dougall J, ed. *Physiological Testing of the High Performance Athlete*. Human Kinetics; 1991:223-307.
21. Ruiz-Navarro JJ, Gay A, Cuenca-Fernández F, et al. The relationship between tethered swimming, anaerobic critical velocity, dry-land strength, and swimming performance. *Int J Perform Anal Sport*. 2022;22(3):407-421. doi:10.1080/24748668.2022.2072561
22. Perez-Olea JI, Valenzuela PL, Aponte C, Izquierdo M. Relationship between dryland strength and swimming performance: pull-up mechanics as a predictor of swimming speed. *J Strength Cond Res*. 2018;32(6):1637-1642.
23. Neiva HP, Marques MC, Barbosa TM, et al. The effects of different warm-up volumes on the 100-m swimming performance: A randomized crossover study. *J Strength Cond Res*. 2015;29(11):3026-3036. doi:10.1519/JSC.0000000000001141
24. Hancock AP, Sparks KE, Kullman EL. Postactivation potentiation enhances swim performance in collegiate swimmers. *J Strength Cond Res*. 2015;29:912-917.
25. Dominguez-Castells R, Izquierdo M, Arellano R. An updated protocol to assess arm swimming power in front crawl. *Int J Sports Med*. 2013;34(4). doi:10.1055/s-0032-1323721
26. Borg GA. Psychophysical bases of perceived exertion. *Med sci sports exerc*. 1982;14(5):377-381. doi:10.1249/00005768-198205000-00012
27. Arellano R, Ruiz-Navarro JJ, Barbosa TM, et al. Are the 50 m Race Segments Changed From Heats to Finals at the 2021 European Swimming Championships? *Front Physiol*. 2022;13. doi:10.3389/fphys.2022.797367
28. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-Country reliability and validity. *Med Sci Sports Exerc*. 2003;35(8):1381-1395. doi:10.1249/01.MSS.0000078924.61453.FB
29. Shapiro JR, Klein SL, Morgan R. Stop controlling for sex and gender in global health research. *BMJ Glob Health*. 2021;6(4):6-8. doi:10.1136/bmjgh-2021-005714
30. Cohen J. Statistical power analysis for the behavioural sciences. In: Lawrence Erlbaum Associates; 1988:20-27.
31. Wakayoshi K, D'Acquisto LJ, Cappaert JM, Troup JP. Relationship between oxygen uptake, stroke rate and swimming velocity in competitive swimming. *Int J Sports Med*. 1995;16(1):19-23. doi:10.1055/s-2007-972957
32. Costill D, Kovalevski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. *Int J Sports Med*. 1985;6(05):266-270.
33. Morais JE, Barbosa TM, Nevill AM, Cobley S, Marinho DA. Understanding the Role of Propulsion in the Prediction of Front-Crawl Swimming Velocity and in the Relationship Between Stroke Frequency and Stroke Length. *Front Physiol*. 2022;13. doi:10.3389/fphys.2022.876838

34. Morouço P, Marinho DA, Keskinen KL, Badillo JJ, Marques MC. Tethered swimming can be used to evaluated force contribution for short-distance swimming performance. *J Strength Cond Res*. 2014;28(11):3093-3099.
35. Morais JE, Marques MC, Rodríguez-Rosell D, Barbosa TM, Marinho DA. Relationship between thrust, anthropometrics, and dry-land strength in a national junior swimming team. *Physician and Sportsmedicine*. 2019;00(00):1-8. doi:10.1080/00913847.2019.1693240
36. Cuenca-Fernández F, Gay A, Ruiz-Navarro JJ, Arellano R. The effect of different loads on semi-tethered swimming and its relationship with dry-land performance variables. *Int J Perform Anal Sport*. 2020;20(1):90-106. doi:10.1080/24748668.2020.1714413
37. Barbosa TM, Lima F, Portela A, et al. Relationships between energy cost, swimming velocity and speed fluctuation in competitive swimming strokes. *Portuguese Journal of Sport Sciences*. 2006;6(2):192-194.
38. Barbosa AC, Barroso R, Gonjo T, et al. 50 m freestyle in 21, 22 and 23 s: What differentiates the speed curve of world-class and elite male swimmers? *Int J Perform Anal Sport*. 2021;21(6):1055-1065. doi:10.1080/24748668.2021.1971509
39. Di Prampero PE, Ferretti G. The energetics of anaerobic muscle metabolism: A reappraisal of older and recent concepts. *Respir Physiol*. 1999;118(2-3):103-115. doi:10.1016/S0034-5687(99)00083-3
40. Ruiz-Navarro JJ, Plaza-florido A, Alcantara JMA, Gay A, Arellano R. Detraining effect on cardiac autonomic response to an all-out sprint exercise in trained adolescent swimmers. *Int J Sports Physiol Perform*. Published online 2023:1-6.
41. Granata C, Oliveira RSF, Little JP, Renner K, Bishop DJ. Mitochondrial adaptations to high-volume exercise training are rapidly reversed after a reduction in training volume in human skeletal muscle. *FASEB Journal*. 2016;30(10):3413-3423. doi:10.1096/fj.201500100R

TABLES CAPTIONS

Figure 1. Individual and average load-velocity profiles obtained during pre and post testing for male (left panel) and female (right panel) swimmers.

Table 1. Effects of five-week off-season on swimmers' anthropometrics, physical activity, and upper-body strength. The pre and post mean ± standard deviation values are presented, along with corresponding *p*-values, mean differences, 95% confidence intervals (CI), relative changes (Δ%), effect sizes, and correlations between deltas and delta performance (Δ).

Table 2. Effects of a five-week off-season on swimmers' race kinematics. The pre and post mean ± standard deviation values are presented, along with their corresponding *p*-

values, mean differences, 95% confidence intervals (CI), relative changes (%Δ), effect sizes, and correlations between changes in kinematics (Δ) and changes in performance (Δ).

Table 3. Effects of five-week off-season on swimmers' load-velocity profile related variables. The pre and post mean ± standard deviation values are presented, along with the corresponding p-values, mean differences, 95% confidence intervals (CI), relative changes (%Δ), effect sizes, and correlations between changes in the load-velocity profile (Δ) and changes in performance (Δ).

Table 1. Effects of five-week off-season on swimmers' anthropometrics, physical activity, and upper-body strength. The pre and post mean ± standard deviation values are presented, along with corresponding *p*-values, mean differences, 95% confidence intervals (CI), relative changes (Δ%), effect sizes, and correlations between deltas and delta performance (Δ).

	Variable	Pre	Post	Difference [95%CI]; Δ%	*p*-value	Effect size (*d*)	ΔvsΔT50
MALES (n = 15)	Height (cm)	175.4 ± 7.0	175.8 ± 6.7	0.4 (0 to 0.9); 0.3%	0.075	0.50, small	0.106
	Body mass (kg)	71.7 ± 6.9	72 ± 7.5	0.3 (-0.6 to 1.1); 0.3%	0.489	0.18, small	0.155
	BMI (kg·m^{-2})	23.3 ± 1.3	23.3 ± 1.5	0 (-0.4 to 0.3); -0.2%	0.846	0.05, small	0.081
	Low intensity (MET-min·wk^{-1})	-	927 ± 604	-	-	-	-0.519*
	Moderate intensity (MET-min·wk^{-1})	-	506 ± 487	-	-	-	-0.346
	Vigorous intensity (MET-min·wk^{-1})	-	1553 ± 1310	-	-	-	0.146
	Total physical activity (MET-min·wk^{-1})	-	2986 ± 1757	-	-	-	-0.165
	PUv_{avg} (m·s^{-1})^{a}	0.89 ± 0.19	0.92 ± 0.2	0.02 (-0.05 to 0.1); 3.5%	0.587	0.14, small	-0.271
	PUf_{avg} (N)	725.02 ± 74.75	728.4 ± 72.86	3.38 (-7.46 to 14.21); 0.5%	0.515	0.17, small	-0.403
	PUp_{avg} (W)^{a}	634.18 ± 151	647.82 ± 151.04	13.64 (-39.59 to 66.88); 3.4%	0.619	0.13, small	-0.348
FEMALES (n = 9)	Height (cm)	167.8 ± 6.8	168.4 ± 7	0.6 (0 to 1.2); 0.4%	0.038#	0.83, large	-0.388
	Body mass (kg)	58.7 ± 5.6	59.4 ± 6.2	0.7 (-0.5 to 1.8); 1.1%	0.202	0.46, medium	-0.420
	BMI (kg·m^{-2})	20.8 ± 1.1	20.9 ± 1.4	0.1 (-0.3 to 0.4); 0.4%	0.560	0.20, small	-0.314
	Low intensity (MET-min·wk^{-1})	-	1206 ± 855	-	-	-	-0.234
	Moderate intensity (MET-min·wk^{-1})	-	314 ± 324	-	-	-	-0.209
	Vigorous intensity (MET-min·wk^{-1})	-	640 ± 567	-	-	-	0.034
	Total physical activity (MET-min·wk^{-1})	-	2160 ± 1265	-	-	-	-0.197
	PUv_{avg} (m·s^{-1})$^{a\$}$	0.52 ± 0.21	0.50 ± 0.12	-0.09 (-0.16 to -0.02); -14.4%	0.002#	1.94, large	0.441
	PUf_{avg} (N)$^{a\$}$	627.92 ± 147.97	558.95 ± 42.41	-59.23 (-209.54 to 91.09); -5.8%	0.379	0.36, small	-0.148
	PUp_{avg} (W)$^{a\$}$	331.72 ± 222	276.75 ± 62.56	-101.3 (-265.68 to 63.08); -18.2%	0.064	0.86, large	0.078

T50: time taken to complete 50-m; BMI: body mass index; MET: metabolic equivalent of task; PUv_{avg}: average propulsive velocity; PUf_{avg}: average propulsive force; PUp_{avg}: average propulsive power; [a:] Raw data is presented, but Napierian logarithm transformed data was used in the analysis; $: n=7, two swimmers were unable to complete the pull-up in the post test; #significant difference; *significant correlation.

Table 2. Effects of a five-week off-season on swimmers' race kinematics. The pre and post mean ± standard deviation values are presented, along with their corresponding *p*-values, mean differences, 95% confidence intervals (CI), relative changes (%Δ), effect sizes, and correlations between changes in kinematics (Δ) and changes in performance (Δ).

	Variable	Pre	Post	Difference [95%CI]; Δ%	*p*-value	Effect size (*d*)	ΔvsΔT50
MALES (n = 15)	T50 (s)	27.13 ± 1.33	27.47 ± 1.20	0.34 (0.15 to 0.53); 1.3%	0.002#	0.98, large	-
	T25 (s)	13.34 ± 1.00	13.48 ± 0.59	0.15 (0.04 to 0.25); 1.1%	0.009#	0.78, medium	0.826*
	T25-50 (s)	13.79 ± 0.68	13.98 ± 0.64	0.19 (0.07 to 0.31); 1.4%	0.004#	0.88, large	0.870*
	$Turn_{(20-30)}$ (s)	8.12 ± 0.41	8.39 ± 0.42	0.27 (0.17 to 0.37); 3.3%	< 0.001#	1.50, large	0.728*
	$Finish_{(45-50)}$ (s)	2.75 ± 0.15	2.87 ± 0.15	0.12 (0.05 to 0.18); 4.3%	0.002#	1.00, large	0.304
	SR_{0-25} ($Cyc·min^{-1}$)	54.65 ± 2.66	52.68 ± 3.94	-1.97 (-3.49 to -0.46); -3.6%	0.014#	0.72, medium	-0.126
	SR_{25-50} ($Cyc·min^{-1}$)	51.19 ± 2.80	49.13 ± 3.55	-2.06 (-3.18 to -0.94); -4.0%	0.001#	1.02, large	-0.431
	SR_{Fin} ($Cyc·min^{-1}$)	50.17 ± 2.88	48.96 ± 3.27	-1.21 (-2.3 to -0.11); -2.4%	0.033#	0.61, medium	-0.300
	SL_{0-25} (m)	1.97 ± 0.15	2.05 ± 0.14	0.08 (0.02 to 0.15); 4.4%	0.019#	0.69, medium	-0.132
	SL_{25-50} (m)[a]	1.95 ± 0.14	2.07 ± 0.16	0.11 (0.06 to 0.17); 5.9%	< 0.001#	1.21, large	0.164
	SL_{Fin} (m)	1.97 ± 0.14	1.94 ± 0.19	-0.03 (-0.09 to 0.04); -1.5%	0.374	0.24, small	0.011
	SI_{0-25} ($m^2·s^{-1}$)	3.53 ± 0.42	3.68 ± 0.33	0.15 (0 to 0.3); 4.8%	0.047#	0.56, medium	-0.294
	SI_{25-50} ($m^2·s^{-1}$)	3.25 ± 0.39	3.49 ± 0.37	0.23 (0.13 to 0.34); 7.5%	< 0.001#	1.20, large	-0.035
	SI_{Fin} ($m^2·s^{-1}$)	3.23 ± 0.36	3.06 ± 0.44	-0.17 (-0.34 to -0.01); -5.3%	0.042#	0.58, medium	-0.120
	Clean swimming $speed_{0-25}$ ($m·s^{-1}$)	1.79 ± 0.09	1.79 ± 0.08	0.01 (-0.02 to 0.03); 0.4%	0.681	0.11, small	-0.543*
	Clean swimming $speed_{25-50}$ ($m·s^{-1}$)	1.66 ± 0.10	1.69 ± 0.08	0.02 (0 to 0.04); 1.5%	0.037#	0.60, medium	-0.462
	Clean swimming $speed_{Fin}$ ($m·s^{-1}$)	1.64 ± 0.09	1.57 ± 0.08	-0.07 (-0.1 to -0.03); -4.0%	0.002#	0.99, large	-0.303
FEMALES (n = 9)	T50 (s)	30.39 ± 1.10	31.55 ± 1.23	1.15 (0.8 to 1.51); 3.8%	< 0.001#	2.48, large	-
	T25 (s)	14.89 ± 1.00	15.34 ± 0.50	0.45 (0.28 to 0.61); 3.0%	< 0.001#	2.09, large	0.557
	T25-50 (s)	15.50 ± 0.62	16.21 ± 0.79	0.71 (0.41 to 1.01); 4.5%	< 0.001#	1.81, large	0.892*
	$Turn_{(20-30)}$ (s)	9.14 ± 0.32	9.59 ± 0.30	0.45 (0.35 to 0.55); 4.9%	< 0.001#	3.45, large	0.499
	$Finish_{(45-50)}$ (s)	3.11 ± 0.17	3.34 ± 0.19	0.23 (0.13 to 0.33); 7.5%	< 0.001#	1.71, large	0.776*
	SR_{0-25} ($Cyc·min^{-1}$)	53.37 ± 2.50	49.23 ± 2.90	-4.15 (-5.83 to -2.47); -7.7%	< 0.001#	1.90, large	-0.330
	SR_{25-50} ($Cyc·min^{-1}$)	48.82 ± 2.45	45.74 ± 2.57	-3.08 (-4.63 to -1.52); -6.3%	0.002#	1.52, large	-0.471
	SR_{Fin} ($Cyc·min^{-1}$)	47.64 ± 2.84	43.96 ± 2.69	-3.68 (-5.95 to -1.41); -7.6%	0.006#	1.25, large	-0.618
	SL_{0-25} (m)	1.81 ± 0.13	1.92 ± 0.11	0.11 (0.04 to 0.17); 5.9%	0.005#	1.29, large	0.033
	SL_{25-50} (m)	1.84 ± 0.12	1.90 ± 0.12	0.06 (0.03 to 0.1); 3.5%	0.005#	1.26, large	-0.078
	SL_{Fin} (m)	1.83 ± 0.15	1.85 ± 0.09	0.01 (-0.07 to 0.09); 1.0%	0.706	0.13, small	0.096
	SI_{0-25} ($m^2·s^{-1}$)	2.93 ± 0.29	3.02 ± 0.22	0.09 (-0.02 to 0.2); 3.5%	0.096	0.63, medium	-0.248
	SI_{25-50} ($m^2·s^{-1}$)	2.75 ± 0.27	2.76 ± 0.30	0.01 (-0.08 to 0.11); 0.4%	0.771	0.10, small	-0.540
	SI_{Fin} ($m^2·s^{-1}$)	2.67 ± 0.31	2.50 ± 0.21	-0.17 (-0.33 to -0.01); -5.8%	0.045#	0.79, medium	-0.355
	Clean swimming $speed_{0-25}$ ($m·s^{-1}$)	1.61 ± 0.06	1.57 ± 0.06	-0.04 (-0.06 to -0.02); -2.4%	0.003#	1.44, large	-0.762*
	Clean swimming $speed_{25-50}$ ($m·s^{-1}$)	1.49 ± 0.07	1.45 ± 0.09	-0.04 (-0.08 to -0.01); -3.0%	0.025#	0.92, large	-0.639
	Clean swimming $speed_{Fin}$ ($m·s^{-1}$)	1.45 ± 0.07	1.35 ± 0.07	-0.10 (-0.15 to -0.05); -6.8%	0.001#	1.67, large	-0.784*

T: time taken to complete the given distance; SR, SL and SI: stroke rate, length and index; FIN: last five meter section. [a:]Raw data is presented, but Napierian logarithm transformed data was used in the analysis; *significant correlation; #significant difference.

Table 3. Effects of five-week off-season on swimmers' load-velocity profile related variables. The pre and post mean ± standard deviation values are presented, along with the corresponding *p*-values, mean differences, 95% confidence intervals (CI), relative changes (%Δ), effect sizes, and correlations between changes in the load-velocity profile (Δ) and changes in performance (Δ).

	Variable	Pre	Post	Difference [95%CI]; Δ%	*p*-value	Effect size (*d*)	ΔvsΔT50
MALES (n = 15)	$[La^-]_{basal}$ (mmol·L^{-1})	2.3 ± 0.7	3.2 ± 1.3	0.9 (0.3 to 1.7); 49.7%	0.011#	0.76, medium	0.193
	$[La^-]_{1T}$ (mmol·L^{-1})	2.3 ± 0.8	3.3 ± 1.3	1.0 (0.3 to 1.7); 54.8%	0.010#	0.77, medium	-0.191
	$[La^-]_{2T}$ (mmol·L^{-1})	4.1 ± 0.9	5.5 ± 2	1.4 (0.2 to 2.6); 42.5%	0.025#	0.65, medium	-0.307
	$[La^-]_{3T}$ (mmol·L^{-1})	5.7 ± 1.5	7.7 ± 2.8	2.0 (0.8 to 3.2); 36.5%	0.003#	0.93, large	-0.307
	$[La^-]_{peak}$ (mmol·L^{-1})	10.7 ± 4.1	11.9 ± 3.7	1.2 (0.3 to 2.2); 14.6%	0.014#	0.72, medium	-0.653*
	$[La^-]_{net}$ (mmol·L^{-1})	8.5 ± 4.1	8.7 ± 3.2	0.2 (-1.1 to 1.6); 11.4%	0.674	0.11, small	-0.568*
	RPE_{1T}[a]	4 ± 2	5 ± 2	0 (-1 to 1); 21.8%	0.539	0.16, small	-0.185
	RPE_{2T}	7 ± 1	7 ± 1	0 (-1 to 0); -1.5%	0.486	0.18, small	-0.100
	RPE_{3T}[a]	9 ± 1	9 ± 1	0 (0 to 1); 2.5%	0.467	0.19, small	-0.366
	V_0 (m·s^{-1})	1.79 ± 0.12	1.79 ± 0.09	0.00 (-0.05 to 0.05); 0.0%	0.896	0.03, small	0.055
	L_0 (kg)	18.43 ± 3.29	16.48 ± 2.38	-1.95 (-3.56 to -0.34); -8.9%	0.021#	0.67, medium	0.006
	Slope	-0.10 ± 0.02	-0.11 ± 0.02	-0.01 (-0.02 to 0); 13.6%	0.328	0.44, small	0.105
	$SLVP_{1T}$ (m·s^{-1})	1.68 ± 0.11	1.66 ± 0.09	-0.02 (-0.06 to 0.01); -1.4%	0.164	0.38, small	0.054
	$SLVP_{2T}$ (m·s^{-1})	1.30 ± 0.13	1.29 ± 0.12	-0.01 (-0.06 to 0.03); -0.8%	0.526	0.17, small	-0.071
	$SLVP_{3T}$ (m·s^{-1})	1.07 ± 0.15	0.98 ± 0.15	-0.10 (-0.15 to -0.05); -8.7%	0.001#	1.05, large	-0.008
	SR_{1T} (Cyc·min^{-1})	57.48 ± 4.30	56.52 ± 4.63	-0.96 (-2 to 0.08); -1.7%	0.067	0.51, medium	0.399
	SR_{2T} (Cyc·min^{-1})	56.45 ± 4.63	55.81 ± 4.87	-0.64 (-1.73 to 0.45); -1.1%	0.228	0.33, small	0.349
	SR_{3T} (Cyc·min^{-1})	55.94 ± 5.37	54.87 ± 4.33	-1.08 (-2.02 to -0.14); -1.8%	0.028#	0.63, medium	-0.459
	SL_{1T} (m)[a]	1.75 ± 0.16	1.84 ± 0.15	0.09 (0.02 to 0.15); 5.2%	0.009#	0.78, medium	-0.239
	SL_{2T} (m)	1.41 ± 0.15	1.45 ± 0.15	0.04 (-0.05 to 0.12); 3.2%	0.223	0.25, small	-0.032
	SL_{3T} (m)	1.18 ± 0.16	1.14 ± 0.19	-0.05 (-0.1 to 0); -3.9%	0.068	0.51, medium	0.179
	SI_{1T} (m·s^{-1})[a]	2.95 ± 0.44	3.18 ± 0.36	0.23 (0.01 to 0.45); 9.3%	0.038#	0.59, medium	-0.119
	SI_{2T} (m·s^{-1})	1.88 ± 0.35	1.95 ± 0.35	0.07 (-0.14 to 0.28); 6.3%	0.478	0.19, small	0.015
	SI_{3T} (m·s^{-1})	1.32 ± 0.29	1.20 ± 0.34	-0.12 (-0.22 to -0.02); -8.4%	0.025#	0.65, medium	0.107
FEMALES (n = 9)	$[La^-]_{basal}$ (mmol·L^{-1})	2.2 ± 0.4	2.5 ± 0.8	0.3 (-0.6 to 1.2); 24.2%	0.420	0.28, small	0.244
	$[La^-]_{1T}$ (mmol·L^{-1})	2.4 ± 0.2	2.3 ± 0.6	-0.1 (-0.6 to 0.5); -1.3%	0.776	0.10, small	0.121
	$[La^-]_{2T}$ (mmol·L^{-1})	4.1 ± 0.7	4.3 ± 1.1	0.2 (-0.9 to 1.3); 10.9%	0.622	0.17, small	-0.274
	$[La^-]_{3T}$ (mmol·L^{-1})	5.0 ± 1.5	5.8 ± 1.6	0.9 (0 to 1.7); 23.5%	0.046#	0.79, medium	-0.180
	$[La^-]_{peak}$ (mmol·L^{-1})	9.7 ± 2.5	9.4 ± 2.3	-0.3 (-2 to 1.5); -3.0%	0.739	0.12, small	0.026
	$[La^-]_{net}$ (mmol·L^{-1})	7.5 ± 2.3	6.9 ± 2.5	-0.6 (-2.1 to 0.9); -6.0%	0.387	0.31, small	0.105
	RPE_{1T}	4 ± 1	5 ± 2	1 (0 to 2); 35.7%	0.035#	0.84, large	-0.398
	RPE_{2T}	6 ± 1	7 ± 1	1 (0 to 2); 17.3%	0.028#	0.89, large	-0.182
	RPE_{3T}[a]	9 ± 1	9 ± 1	0 (0 to 1); 4.9%	0.035#	0.84, large	0.041
	V_0 (m·s^{-1})	1.64 ± 0.09	1.56 ± 0.09	-0.08 (-0.12 to -0.03); -4.7%	0.004#	1.31, large	-0.791*
	L_0 (kg)	11.12 ± 1.03	10.17 ± 0.98	-0.95 (-1.68 to -0.22); -8.3%	0.017#	1.00, large	0.337
	Slope[a]	-0.15 ± 0.02	-0.15 ± 0.02	-0.01 (-0.02 to 0.01); 0.9%	0.328	0.35, small	-0.531
	$SLVP_{1T}$ (m·s^{-1})	1.49 ± 0.08	1.4 ± 0.08	-0.09 (-0.12 to -0.05); -5.7%	< 0.001#	2.13, large	-0.814*
	$SLVP_{2T}$ (m·s^{-1})	1.21 ± 0.09	1.13 ± 0.08	-0.09 (-0.14 to -0.05); -7.7%	0.002#	1.69, large	-0.504
	$SLVP_{3T}$ (m·s^{-1})	0.89 ± 0.08	0.78 ± 0.09	-0.11 (-0.15 to -0.07); -12.5%	< 0.001#	2.18, large	0.089
	SR_{1T} (Cyc·min^{-1})	52.78 ± 3.01	49.19 ± 2.48	-3.59 (-5.89 to -1.29); -6.6%	0.007#	1.20, large	-0.253
	SR_{2T} (Cyc·min^{-1})	52.84 ± 2.93	49.39 ± 3.02	-3.45 (-5.19 to -1.7); -6.5%	0.002#	1.52, large	-0.180
	SR_{3T} (Cyc·min^{-1})	51.78 ± 2.72	48.89 ± 3.3	-2.89 (-4.53 to -1.25); -5.6%	0.004#	1.35, large	0.113
	SL_{1T} (m)[a]	1.69 ± 0.17	1.75 ± 0.11	0.06 (-0.05 to 0.16); -20.8%	0.223	0.44, small	0.298
	SL_{2T} (m)	1.42 ± 0.14	1.41 ± 0.15	-0.01 (-0.04 to 0.04); -0.2%	0.848	0.07, small	0.135
	SL_{3T} (m)	1.07 ± 0.10	1.03 ± 0.14	-0.04 (-0.1 to 0.02); -3.7%	0.159	0.52, medium	-0.033
	SI_{1T} (m·s^{-1})	2.53 ± 0.43	2.52 ± 0.26	-0.02 (-0.28 to 0.24); -4.0%	0.881	0.05, small	-0.311
	SI_{2T} (m·s^{-1})	1.77 ± 0.29	1.65 ± 0.29	-0.12 (-0.21 to -0.04); -6.9%	0.011#	1.10, large	0.040
	SI_{3T} (m·s^{-1})	0.99 ± 0.18	0.87 ± 0.20	-0.12 (-0.2 to -0.04); -12.3%	0.008#	1.17, large	-0.013

T50: time taken to complete 50-m; $[La^-]$: blood lactate concentration; basal: basal blood lactate concentration; peak: peak blood lactate concentration; net: blood lactate concentration difference between the $[La^-]$ peak and basal values; RPE: rate of perceived exertion; V_0: maximum velocity at zero load; L_0:

maximum load at zero velocity; Slope: steepness of the linear regression line for the load-velocity relationship; SLVP: speed during load-velocity profile trials ; SR, SL, SI: stroke rate, length and index, respectively; 1T, 2T, 3T: first, second, and third semi-tethered trial, respectively; [a:] Raw data is presented, but Napierian logarithm transformed data was used in the analysis; *significant correlation; #significant difference.

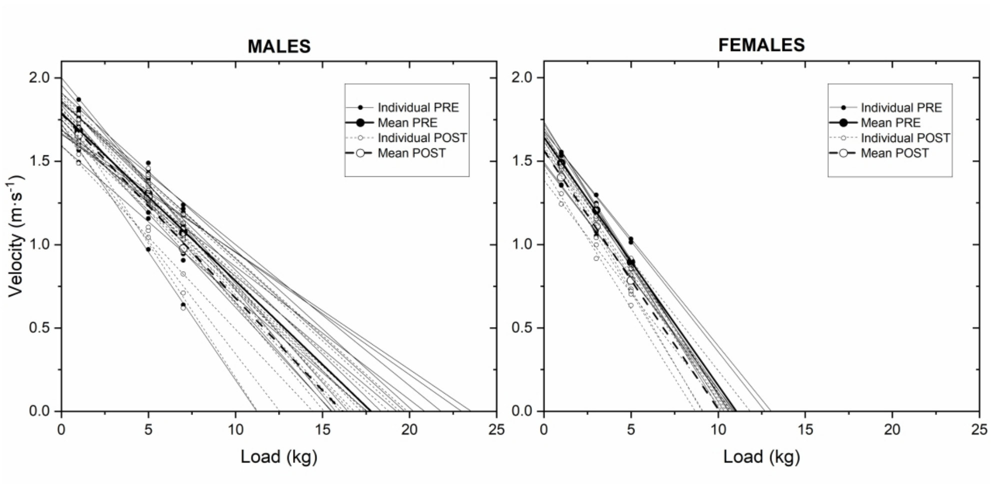

Figure 1. Individual and average load-velocity profiles obtained during pre and post testing for male (left panel) and female (right panel) swimmers.

1693x952mm (120 x 120 DPI)