# Biophysical impact of five-weeks training cessation on sprint swimming performance.

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| Complete List of Authors: | Ruíz-Navarro, Jesús J.; University of Granada, Aquatics Lab., Department of Physical Education and Sports, Faculty of Sport Sciences<br>GAY, ANA; Universidad de Granada - Campus de Cartuja, Aquatics Lab, Department of Physical Education and Sports, Faculty of Sport Sciences<br>Zacca, Rodrigo; University of Porto, Research Center in Physical Activity, Health and Leisure (CIAFEL), Faculty of Sports; University of Porto, Research Center in Physical Activity, Health and Leisure (CIAFEL), Faculty of Sports; University of Porto, Laboratory for Integrative and Translational Research in Population Health (ITR),<br>Cuenca-Fernandez, Francisco; University of Granada, Aquatics Lab, Physical Education and Sports, Faculty of Sport Sciences<br>López-Belmonte, Óscar; Universidad de Granada, Aquatics Lab. Department of Physical Education and Sports. Faculty of Sport Sciences<br>Morales-Ortíz, Esther; University of Granada, Aquatics Lab. Department of physical education and sports<br>Lopez-Contreras, Gracia; University of Granada, Aquatics Lab. Department of Physical Education and Sports. Faculty of Sport Sciences<br>Arellano, Raúl; University of Granada, Aquatics Lab. Department of Physical Education and Sports. Faculty of Sport Sciences |
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## Abstract

**Purpose:** To assess changes in swimming performance, anthropometrics, kinematics, energetics, and strength after five-weeks training cessation. **Methods:** 21 trained and highly-trained swimmers (13 males: 17.4±3.1-years; 50-m front crawl 463±77 FINA points; 8 females 16.7±1.7-years; 50-m front crawl 535±48 FINA points) performed a 50-m front crawl all-out swim test, dry-land and pool-based strength tests, and 10-,15-,20-, and 25-m front crawl all-out efforts for anaerobic critical velocity assessment before and after five-weeks training cessation. Heart rate (HR) and oxygen uptake ($\dot{V}O_2$) were continuously measured before and after the 50-m swim test (off-kinetics). **Results:** Performance impaired 1.9% (0.54-s) for males ($p=0.007$,$d=0.91$) and 2.9% (0.89-s) for females ($p=0.033$;$d=0.93$). Neither the anthropometrical changes (males: $r^2=0.516$, $p=0.077$; females: $r^2=0.096$, $p=0.930$) nor the physical activities that each participant performed during off-season (males: $r^2=0.060$, $p=0.900$; females: $r^2=0.250$, $p=0.734$) attenuated performance impairments. Stroke rate and clean swimming speed decreased ($p<0.05$) despite similar stroke length and stroke index ($p>0.05$). Blood lactate concentrations values remained similar ($p>0.05$), but the $\dot{V}O_2$ peak decreased in females ($p=0.04$,$d=0.85$). Both sexes showed higher HR before and after the 50-m swim test after five-weeks($p<0.05$). Anaerobic metabolic power deterioration was only observed in males ($p=0.035$,$d=0.65$). Lower in-water force during tethered-swimming at zero speed was observed in males ($p=0.033$,$d=0.69$). Regarding dry-land strength, lower body impairments were observed for males, while females showed upper body impairments ($p<0.05$). **Conclusions:** Five-weeks training cessation period yielded higher HR in the 50-m front crawl, anaerobic pathways and dry-land strength impairments. Coaches should find alternatives to minimize detraining effects during the off-season.

**Keywords:** Exercise Physiology; Oxygen Uptake Kinetics; Energetics; Biomechanics; Detraining.

## Introduction

Partial or complete loss of training-induced anatomical, physiological and functional adaptations is termed detraining.[1] During a training season, it generally occurs as a result of illnesses or injuries,[1] but swimmers typically recover for several weeks in the off-season.[1,2] Its duration, usually 4–6 weeks, may differ according to the requirements of individual coaches and/or the calendar of each national swimming federation.[2] This swimming performance impairment has been mainly studied in middle and long distance events with scarce knowledge about sprint swimming events.[1,2] Conclusive evidence concerning cause-and-effect relationships between sprint swimming determinant variables and performance during training and off-season phases is still required.

Swimming performance can be broken down into start, turn, and clean swimming phases.[3] The clean swimming phase is highly determined by the swimming technique[4,5] which, during a race, is assessed through clean swimming speed, stroke length (SL), and stroke rate (SR).[5,6] Indeed, the combination of clean swimming speed and SL is known as stroke index (SI), an indirect estimation of swimming efficiency and strongly associated with lower values of energy cost of swimming.[5,7] These kinematic parameters are usually assessed to understand changes in performance during swimming events.[8] Therefore, to aid coaches in planning the next season's training, it is crucial to identify which kinematic changes might be related to performance impairment during a training cessation period.

Swimming performance is also highly determined by energetics, [5,9] in which the metabolic power, *i.e.*, the energy expended per the unit of time ($\dot{E}$), is converted into mechanical power through a given metabolic efficiency.[5,9] The total energy expenditure ($E_{tot}$) is obtained through the sum of aerobic and anaerobic energy systems.[5,9] Although both energy pathways work in an integrated way, there is an important contribution of the aerobic energy supply during longer swimming events,[10] which relies on exercise duration and intensity, as well as swimmers' training status.[9] However, in sprint swimming events (e.g. 50-m front crawl) the majority of the energy is obtained via anaerobic pathways, alactic (AnAL), and lactic (AnL) energy systems (~70%).[10] In fact, at extreme exercise intensities, not accounting for the anaerobic contribution might underestimate $E_{tot}$.[9,11]

Moreover, short-term cardiorespiratory detraining causes an immediate reduction in blood and plasma volumes. These reductions impair the oxygen uptake ($\dot{V}O_2$),[1,2] meaning that the oxygen supply and utilization is reduced[11] and as a consequence, an increase in maximal and submaximal heart rate (HR).[1] The detraining effects on energetics have been observed in middle distance swimming events, such as 400-m,[2] but there is scarce information on sprint swimming events, particularly the 50-m front crawl. In addition, there is no information about training cessation effects on specific tools used during training to evaluate and control the anaerobic fitness, such as the anaerobic critical velocity (AnCV).[12]

Sprint swimming performance is also influenced by muscle strength and power, thus the ability to apply force in the water is a key factor for sprint swimmers.[13,14] In fact, lower and upper limbs strength are associated with starts, turns,[15] and overall swimming performance.[13] Moreover, swimmers anthropometric characteristics are swimming performance determinants due to their relationship with drag and propulsion.[2,6] Thus, the aim of this study was to assess performance, anthropometrics, kinematics, energetics and strength after five-weeks training cessation. Non-swimming specific physical activities performed during this period of swimming training cessation were quantified. We expected that five-weeks of training cessation (i.e., off-season) would yield impairments in performance, anthropometrics, kinematics, energetics, and strength, partially offset by a swimmer's non-specific physical activities during the transition period.

## Methods

### *Participants*

Twenty-one trained and highly-trained swimmers,[16] 13 males (17.4 ± 3.1 years, 50-m front crawl FINA points: 463 ± 77, Level 4)[17] and 8 females (16.7 ± 1.7 years, 50-m front crawl FINA points: 550 ± 29, Level 4)[17] volunteered to participate in the current study. Swimmers had over five years of competitive experience and trained six swimming and four dry-land sessions per week in the same squad and under the direction of the same coach. The protocol was fully explained to the participants and their parents (under 18) before providing written consent to participate. 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 ethics committee (project code: ANONIMITY).

### *Design*

A longitudinal single cohort study was conducted in two different moments, before and after five-weeks off-season period. During this period, swimmers were advised by their coach to keep actively enrolled in any sort of physical activity they wished to, but they did not follow any specific swimming training program. The first testing (PRE) was conducted at the end of the week before the last peak-performance of the season. The second testing (POST) was performed right before the beginning of the next competitive season. Swimmers were assessed on two days to eliminate any residual fatigue effect and they were familiarized with the tests and flume prior testing to avoid the learning effect. To improve the reliability of the measurements, participants were asked to refrain from intense exercise and to abstain from alcohol, or any stimulant drink the day prior to and on the test days. Tests were conducted at the same time of the day (during PRE and POST) to avoid systematic bias due to circadian variation.[18] Swimmers were verbally encouraged during all the tests and in-water tests were preceded by a 1200-m standardized warm-up *(Supplementary material 1).*

Swimming performance was tested in a 25-m swimming pool (25-m length × 16.5-m width with 27.3ºC, 29.4ºC and 52% of water, air temperature and humidity in the PRE, and 27.4ºC, 28.9ºC and 54% of water and air temperature and humidity in the POST). Tethered forces were tested in a swimming flume (Endless Pool Elite Techno Jet Swim 7.5; HP, Aston PA, with 4.7-m length × 2.4-m width with 27.5ºC, 30.4%, and 47% of water and air temperature and humidity in the PRE, and 26.2ºC, 29.1ºC, and 46% of water and air temperature and humidity in the POST) with predefined speed range and with flow speed being measured at 0.30-m depth using an FP101 flow probe (Global Water, Gold River, CA20).[14]

*Methodology*

Swimmers followed the training program set by their coach before the beginning of the study. Using standard methodologies swimming training load during the last macrocycle prior PRE was computed and categorized with a five-zone system (Figure 1)(*Supplementary Material 2*).[19]

[Please insert Figure 1 near here]

On day one anthropometric measurements were performed. A stadiometer/scale (Seca 799, Hamburg, Germany) was used to measure height, body mass, and the sitting height of participants. A flexible meter was used to measure arm span. Body mass index was calculated as [body mass (kg)·height (m)$^2$]$^{-1}$. The data was measured by the same researcher. Moreover, biological maturation was evaluated using the age of peak height velocity (PHV).[20]

Swimmers then completed a standardized warm-up based on jogging, joint mobility, dynamic stretching, and three sub-maximal countermovement jumps (CMJ). Five min after the end of the warm-up swimmers performed five maximal CMJ on a force plate (1000 Hz, Dinascan/IBV, Biomechanics Institute of Valencia, Spain) with 1-min of rest between repetitions. If the execution was not adequately performed an extra trial was conducted. The highest and the lowest jumps were removed, and the mean CMJ height ($CMJ_{JH}$) of the other three was calculated.[21]

Subsequently, swimmers rest 10-min and performed five pull-ups with 1-min of rest in-between. Performance was recorded through an isoinertial dynamometer (T-Force Dynamic Measurement System, Ergotech, Murcia, Spain) attached to the subjects' hips through a harness. The pull-ups were inspected by the same researcher to assure that the swimmers displaced vertically. If a horizontal movement was observed an extra trial was conducted. The pull-ups which obtained the greatest and the lowest mean velocity values were excluded, and the mean of the remaining three was calculated.[21] Average propulsive velocity, force, and power were obtained ($PUv_{avg}$, $PUf_{avg}$, and $PUP_{avg}$, respectively).

Then, after the in-water warm-up swimmers rest 10-min prior to performing the 50-m front crawl all out (time trial with dive start). The race was recorded with a Sony FDR-AX53 (Sony electronics Inc., Tokyo, Japan) at 50 Hz sampling rate. The videos were analyzed by one expert evaluator, on an in-house customized software for race analysis in competitive swimming. Table 1 shows the description of variables and respective calculation approaches. The Intra-class Correlation Coefficient (ICC) was computed to verify the absolute agreement between repeated measures for each trial. A very-high agreement was obtained (ICC: 0.979 to 0.999).

[Please insert Table 1 near here]

In an attempt to explore the effects of detraining in an ecological environment, reliable swimming recovery-based methods were applied to estimate oxygen uptake kinetics related variables, $\dot{V}O_{2peak}$ and AnAL before and after a five-weeks training cessation.[2,22–24] The $\dot{V}O_2$ was continuously measured (breath-by-breath) before (baseline) and after 50-m test (recovery period, *i.e.,* off-kinetics). Respiratory gas exchange was measured breath-by-breath during recovery period using a portable gas analyzer (Cosmed K4b$^2$, Cosmed, Rome, Italy), which was calibrated with 16% $O_2$ and 5% $CO_2$ concentration gases and a 3 L syringe before each testing session. To reduce the noise in the signal, $\dot{V}O_2$ values included only those between mean $\dot{V}O_2$ ± 4 standard deviation (SD).[22] The off-kinetics response was modelled with $\dot{V}O_2$FITTING, a free and open-Source software (*https://shiny.cespu.pt/vo2_news/).*[25] Raw data was used in all the cases. Bootstrapping with 1000 samples was used to estimate $\dot{V}O_2$ kinetics parameters.[25] Breath-by-breath data obtained during 5-min of recovery were adjusted as a function of time using a bi-exponential model:[22,23]

$$\dot{V}O_2(t) = EE\dot{V}O_2 - H\,(t - TD_p)\,A_P\left(1 - e^{-(t - \mathrm{TD}_p)/\tau_p}\right) - H\,(t - TD_{SC})\,A_{SC}\left(1 - e^{-(t - \mathrm{TD}_{SC})/\tau_{SC}}\right) \tag{1}$$

where $EE\dot{V}O_2$is the $\dot{V}O_2$ at the end of exercise (50-m swim test), H represents the Heaviside step function, $A_p$ and $A_{sc}$, $\tau_p$ and $\tau_{sc}$, and $TD_p$ and $TD_{sc}$ are the amplitudes, time constants, and time delays of the $\dot{V}O_2(t)$ curve fast and slow components, respectively.[25] AnAL energy was assumed as the fast component of excess post-oxygen consumption,[22] *i.e.*, the product between $A_p$ and $\tau_p$ of the fast component was assumed as AnAL.[22,25] The AnL energy was calculated using the following equation:

$$\mathrm{AnL} = [\mathrm{La}^-]_{net} \cdot \beta \cdot \mathrm{M} \tag{2}$$

where $[\mathrm{La}^-]_{net}$ is the difference between the blood lactate concentration ($[\mathrm{La}^-]$) before and after exercise ($[\mathrm{La}^-]_{peak}$), $\beta$ is the constant for $O_2$ equivalent of $[\mathrm{La}^-]_{net}$ (2.7 $ml \cdot kg^{-1} \cdot mM^{-1}$)[26] and M is the body mass of the swimmer.

Both energy systems were then expressed in kJ assuming an energy equivalent of 20.9 $kJ \cdot L^{-1}$.[27] The sum of the AnAL and AnL was considered as the anaerobic energy expenditure ($E_{ana}$) and the anaerobic metabolic power ($\dot{E}_{ana}$) was estimated as the ratio between $E_{ana}$ and performance (s). The $\dot{V}O_{2peak}$ was estimated by backward extrapolation at zero recovery time using linear regressions applied to the first 20-s of recovery.[24] HR was recorded using a POLAR RS800CX (Polar Electro Oy Inc., Kempele, Finland). Gas exchanges and HR were measured in sitting position for 10-min at rest prior to and after the 50-m all out trial.[28] For $[\mathrm{La}^-]$ analysis, capillary blood samples (25 µL) were collected from the same fingertip at min five during the resting period before the 50-m and immediately after the effort, at min one, and every 2-min until the peak was reached, using Lactate Pro 2 analyzer (Arkray, Inc., Kyoto, Japan).

Thirty min after completion of the 50-m, swimmers performed 30-s tethered swimming in two conditions: at zero speed and at 1.124 $m \cdot s^{-1}$ water flow speed in a flume with 30-min of active rest between each trial. This speed was chosen after checking that this was the maximum speed that allowed registering all the forces of this group of swimmers. The start and end of the 30-s effort were determined through an auditory signal. Before that, the participants swam for 5-s at low intensity, to avoid inertial effect.[14] A snorkel was used for tethered swimming to avoid interferences in force parameters caused by breathing. A steel cable was attached to the swimmer through a floating trapezoidal structure (which allows them to kick) and fixed to a load cell (RSCC S-Type; HBM, Darmstadt, Germany) leading to an angle of 10º with the water surface, recording at 1500Hz. Analog data were converted (celula 1.4; Remberg, Force Isoflex, Spain), registered, and exported (NIUSB600; National Instruments, Austin, TX) to a specific software (myoRESEARCH, Noraxon, USA). The force-time curves were processed, using a fourth-order Butterworth low-pass digital filter (4.5 Hz cut-off frequency), and the average force (Favg), maximum force (Fmax), average impulse (Iavg), and maximum impulse (Imax) were computed.[14]

On the second day of data collection, after the in-water warm-up swimmers performed 10-, 15-, 20-, and 25-m all out front crawl with in-water starts and 30-min passive rest in-between. The distances were recorded and analyzed using the same methodology as for the 50-m all out. The AnCV was calculated from the slope of the distance-time relationship.[12]

During the five-weeks of training cessation, swimmers were instructed to self-assess their weekly physical activity by the International Physical Activity Questionnaire (IPAQ),[2,29] which was summarised according to the registered physical activities (low, moderate, and vigorous activities). The swimmers' questionnaires results were displayed into units of metabolic equivalent of task (METs) following the IPAQ specifications.[2,29] The IPAQ is test-retest reliable with a mean correlation of ~0.80 (ranging from "fair" 0.46 to "excellent" 0.96).[29]

### *Statistical analysis*

Normality of all distributions was verified using Shapiro–Wilk. Napierian logarithm was calculated for analytical purposes. All analyses were conducted differentially by sex. 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 $0 \leq |d| \leq 0.5$, medium if $0.5 < |d| \leq 0.8$, and large if $|d| > 0.8$).[30] To test the growth effects over performance changes, multiple regression analysis was conducted with the change in performance (*i.e.*, POST-PRE) as the dependent variable and the change score values of height, body mass, and arm span as predictors. The same procedure was conducted using the total physical activity during off-season to test the effects of non-swimming specific physical activities. Pearson's 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 performed using SPSS 24.0 (IBM, Chicago, IL, USA) with the level of statistical significance set at 0.05.

## Results

The mean volume and training load per week over the last 15-weeks immediately before the off-season were 28 ± 6 $\text{km}\cdot\text{week}^{-1}$ and 45 ± 12 $\text{T.U.}\cdot\text{week}^{-1}$, respectively (Figure 1). The effects of the five-weeks off-season on swimmers' anthropometrics, kinematics, energetics, and strength are presented in Tables 2, 3, 4, and 5, respectively. The total variance in performance change was not influenced by neither anthropometric changes (males: $r^2$=0.516, $p$ = 0.077; females: $r^2$=0.096, $p$ = 0.930) nor physical activity during off-season (males: $r^2$= 0.060, $p$ = 0.900; females: $r^2$=0.250, $p$ = 0.734). All swimmers had reached their PHV (male maturity offset: 2.90 ± 2.86 years; female maturity offset: 3.41 ± 0.86 years ago).

[Please insert table 2, 3, 4, and 5 near here]

## Discussion

The main finding of this study was that 50-m swimming performance was impaired after a five-weeks training cessation in both male (1.9%, 0.54-s) and female (2.9%, 0.89-s) swimmers. Neither anthropometric changes nor physical activity during off-season significantly accounted for variance in performance decrements. The decrease in performance was mainly associated with kinematics' changes, physiological, and strength's impairments.

After the off-season males showed a SR reduction in the latter half of the 50-m, while females' SR reduction was evidenced in the whole 50-m., suggesting biomechanical and energetic impairments[31](Table 4). This reduction together with the fact that SL did not increase, likely provoked the clean swimming speed decline. This behavior was also observed on T400 in young swimmers after a four-weeks of training cessation,[2] and could be explained by the association between muscular power and energetic capabilities with the capacity to maintain a high SR until the end of a race.[31] Hence, the strength and energetic impairments might have provoked that swimmers were not able to reach and sustain such high SR[32,33](Table 4 and 5). Moreover, in the current study, the SR reduction was only correlated with females' 50-m performance impairment. This difference might lie in the interaction between SR and SL, suggesting that males relied more on their SL than on their SR. Therefore, the SR reduction showed a bigger impact on females' performance. Differences in energy cost of swimming between males and females are mainly related to differences in hydrodynamic resistance, which could explain at least in part these results. Unfortunately, swimming speed was not controlled for practical purposes (which would make it difficult to compare energy cost and related variables).[32,33] On the other hand, the performance deficiencies in both sexes were especially related to the reduction of the clean swim speed in the second half of the 50-m. A similar association between performance and SI during the latter half of the 50-m was observed, which suggests that a higher fatigue evoked a loss of swimming efficiency and therefore the reduction of clean swimming speed.[7] Although the turn ($Turn_{20-30}$) evidenced an impairment, this was not related to 50-m performance changes. By contrast, swimming start time did not decrease significantly after the training cessation period, but the changes were related to performance deterioration in males. In swimming, unlike other sports, movements cannot be fully replicated out of the water since the hydrodynamic reaction stimulus can only be experienced in the water.[34] As a result, loss of "feeling for the water" during training cessation might explain, at least in part, the kinematic changes. In addtition, due to the turn influence, it is possible that the impact of five-weeks training cessation on sprint swimming performance might differ between long and short courses.

Regarding cardiorespiratory responses, female swimmers evidenced lower $\dot{V}O_{2peak}$ after the training cessation period. Hence, it is possible that the same effort produced higher fatigue due to the lower blood and plasma volumes.[1,2] It is important to be aware that high aerobic power (e.g., $\dot{V}O_{2peak}$), *i.e.*, elevated rate of adenosine triphosphate production by the aerobic system, is determinant even for such a short effort (PRE: 31.09 ± 2.53-s *vs*. POST: 31.99 ± 2.24-s). Thus, oxygen supply and utilization should be taken into account by coaches for maximal efforts of short duration[11], seeking for different strategies to mitigate such losses. Similar $\tau_p$ and $A_p$ were observed for both males and females, *i.e.*, not sensitive enough to a five-weeks training cessation period, perhaps as a consequence of not controlling the swimming speed.[5] The energetics determinants of swimming performance decay when the training process is interrupted evoking performance impairment.[1] Although it was observed only a significant decrease in AnAL energy contribution in males, both male and female swimmers presented the same energetics trend. Neither the $E_{Ana}$, nor the AnL decreased significantly, possibly due to the short duration of the effort and/or not controlling swimming speed.[5] Nevertheless, the $\dot{E}_{Ana}$ was significantly reduced in males, and females presented similar trend (same effect size), which shows a lower anaerobic energy contribution after the five-weeks training cessation period, likely, due to the reduction or absence of high-intensity training during that period.[35] Nevertheless, none of the changes in energetics variables were correlated with the change in performance. Moreover, despite the aerobic pathways were not measured (which contribution to $E_{tot}$ is ~27%[10]) a decline was reported in four weeks detraining period,[2] which might suggest that aerobic pathways and therefore $E_{tot}$ could have been impaired in this study, negatively affecting performance. The data obtained provide relevant information for swimmers and coaches about the behavior of the energetic contributions during the shortest competitive event in swimming.

The $[La^{-}]$ remained the same after five-weeks (Table 4), which does not necessarily mean that the anaerobic capacity was not reduced, since is the balance between production and removal and therefore, it is possible that both processes were impaired (*i.e.*, similar $[La^{-}]$ values).[27] From a practical perspective, male swimmers did not evidence a change in AnCV, but presented a negative correlation between ΔAnCV and ΔT50. On the contrary, female swimmers showed a significant decrease in AnCV without correlation with performance worsening. As a non-invasive method,[12] the difference between sexes might be influenced by other factors, such as the SR, which might interfere with the energy sources and with the neuromuscular power.[31]

Both sexes exhibited greater mean HR before and after the 50-m (*i.e.*, $HR_{basal}$ and $HR_{50m}$, respectively), yet only the $HR_{net}$ was higher in the POST in males. These increases might be due to the reduction in blood volume and were negatively correlated with performance impairment (Table 4)(*i.e.*, the less the $HR_{net}$ increased the more the T50 increased).[1] Hence, those that were not able to counterbalance the blood volume reduction by increasing the HR, showed worse performance. Regarding maximum HR, there was not a sex-induced difference, but the increase was only significant in males. Moreover, female swimmers showed a positive correlation between the change in performance and maximum basal heart rate, suggesting that those swimmers for whom the warm-up was more stressful after the detraining period, were the ones who obtained greater T50 worsening.

The inconsistency of results regarding muscle strength changes after a training cessation period, previously discussed by Marques et al.,[36] was also observed in our results. Female swimmers showed a significant decline in $CMJ_{JH}$ of 5%. However, males did not exhibit changes in $CMJ_{JH}$, indeed, some swimmers reached higher heights after the off-season than before that period. The difference may lay in the activities conducted during the training cessation period. For instance, hypothetically, if swimmer A and B reached the same amount of physical activity, but swimmer A rode a bike and swimmer B played basketball, the adaptations would be different.[36] Regarding upper limbs, only males exhibited a deterioration in pull-up performance. With the exception of $Favg_0$, these muscle strength impairments were not translated into lower in-water force, probably because the ability to apply force in the water remained unaltered.[14] Yet, the fact that $Favg_0$ was reduced in males, might be more related to energy contributions than to neuromuscular impairments.[4,13] Finally, among all the pool-based strength tests, only the females change in $Iavg_{1.124}$ was negatively associated with the performance changes (*i.e.,* the higher the reduction in $Iavg_{1.124}$, the higher the T50 increments).

Contrary to our hypothesis, the amount of physical activity performed in the transition period did not attenuate the performance impairment as previously observed in 400-m front crawl.[2] Hence, despite the amount of activity was quantified there is no record of the type of activity performed, which might have different effects on swimming performance. Therefore, future research should try to control not only the amount of activity but also the specific activity carried out. We are aware that when swimmers start a new season we do not expect them to swim a 50-m effort as fast as at the end of the previous season. However, a considerable part of the following season is lost just to return to previous performance levels. Minimising impairments in swimming performance during the transition to the following competitive season is important for technical continuity. Thus, identifying which changes might account for performance impairment in trained-highly trained sprint swimmers can guide coaches in planning the next season's training program.[2,37]

We acknowledge some shortcomings and potential limitations in our study. For instance, although all swimmers were evaluated at a maximum relative intensity during PRE and POST, swimming speed was not controlled for practical purposes.[38] Likewise, since we tried to explore detraining effects in an ecological environment, the on-kinetics $\dot{V}O_2$ response (*i.e.,* breath-by-breath analysis during the 50-m front crawl test) was not measured. Moreover, the biophysical impact of five-weeks training cessation on sprint swimming performance might differ between long and short courses or between performance level. Hence future studies should address this issue on long course and/or with international level swimmers.

## Practical applications

Our results showed the negative effects of an off-season period on sprint performance. Although swimmers need rest time to recover physiologically and/or mentally, such impairments could compromise the performance of the following competitive season. This is an important aspect, as otherwise, the first part of the season would consist of catching up rather than enhancing sprint swimming performance. Coaches should seek different strategies to minimize such performance deteriorations, either reducing the number of sessions per week instead of a complete break or establishing specific activities oriented to preserve sprint performance. Moreover, the sex-induced effects should be considered when planning these strategies (*e.g.*, the effect of SR impairment).

## Conclusion

Five-weeks training cessation impaired sprint swimming performance in 1.9 (0.54-s) and 2.9% (0.89-s) in male and female swimmers (respectively), which was mainly compromised by a reduction in SR and therefore clean swimming speed. Five-weeks training cessation impaired HR for the same distance and intensity, anaerobic pathways and dry-land strength. These impairments had a sex-induced effect on performance.

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## Figure and Tables captions

**Figure 1.** Training volume and units (T.U.) of the monitored last macrocycle prior the off-season. PRE: assessment conducted right at the end of the macrocycle; POST: assessment conducted right before the beginning of the next season, after the training cessation period.

**Table 1.** Description of the variables analyzed in the 50-m front crawl test.

**Table 2**. Effects of five-weeks off-season on swimmers' anthropometrics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, relative changes (%Δ), effect sizes, and correlations between deltas and delta performance (Δ).

**Table 3.** Effects of five-weeks off-season on swimmers' race kinematics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, relative changes (%Δ), effect sizes, and correlations between deltas and delta performance (Δ).

**Table 4.** Effects of five-weeks off-season on swimmers' energetics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, relative changes (%Δ), effect sizes, and correlations between deltas and delta performance (Δ).

**Table 5.** Effects of five-weeks off-season on swimmers' strength. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, relative changes (%Δ), effect sizes, and correlations between deltas and delta performance (Δ).

**Supplementary Material 1.** Description of the standardized warm-up performed.

**Supplementary Material 2.** Description of the method use for the calculations of five-zone training system.

**Table 1.** Description of the variables analyzed in the 50-m front crawl test.

| Variable | Definition |
|---|---|
| T50 (s) | Time lag between the starting signal and the hand touches the 50-m wall. |
| T15 (s) | Time lag between the starting signal and the head reaches 15-m point. |
| T25 (s) | Time lag between the starting signal and the feet touches the 25-m wall. |
| $Turn_{(20\text{-}30)}$ (s) | Time lag between the head reaches 20- and 30-m point. |
| $Finish_{(45\text{-}50)}$ (s) | Time lag between the head reaches 45-m point and the hand touches the wall. |
| $SR_{0\text{-}25}$ (Hz) | Collected from 15-m point onwards, using a frequency measuring function for each three arm strokes and divided by the time elapsed during this action. |
| $SR_{25\text{-}50}$ (Hz) | Collected from 35-m point onwards, using a frequency measuring function for each three arm strokes and divided by the time elapsed during this action. |
| $SR_{Fin}$ (Hz) | Using a frequency measuring function for each the last two arm strokes and divided by the time elapsed during this action. |
| $SL_{0\text{-}25}$ (m) | Collected from 15-m point onwards, from the ratio between Clean swimming $speed_{0\text{-}25}$ and $SR_{0\text{-}25}$. |
| $SL_{25\text{-}50}$ (m) | Collected from 35-m point onwards, from the ratio between Clean swimming $speed_{25\text{-}50}$ and corresponding $SR_{25\text{-}50}$. |
| $SL_{Fin}$ (m) | Collected from 45-m point onwards, from the ratio between Clean swimming $speed_{Fin}$ and corresponding $SR_{Fin}$. |
| $SI_{0\text{-}25}$ ($m^2 \cdot s^{-1}$) | Product of the corresponding Clean swimming $speed_{0\text{-}25}$ and $SL_{0\text{-}25}$. |
| $SI_{25\text{-}50}$ ($m^2 \cdot s^{-1}$) | Product of the corresponding Clean swimming $speed_{25\text{-}50}$ and $SL_{25\text{-}50}$. |
| $SI_{Fin}$ ($m^2 \cdot s^{-1}$) | Product of the corresponding Clean swimming $speed_{Fin}$ and $SL_{Fin}$. |
| Clean swimming $speed_{0\text{-}25}$ ($m \cdot s^{-1}$) | Collected as the ratio between 5-m and the time lag between the 15- and 20-m mark. |
| Clean swimming $speed_{25\text{-}50}$ ($m \cdot s^{-1}$) | Collected as the ratio between 5-m and the time lag between the 40- and 45-m mark. |
| Clean swimming $speed_{Fin}$ ($m \cdot s^{-1}$) | Collected as the ratio between 5-m and the time lag between the 45- and 50-m mark. |

SR, SL and SI: Stroke rate, length and index.

**Table 2.** Effects of five-weeks off-season on swimmers' anthropometrics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, 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 = 13) | Height (cm) | 175.8 ± 7.9 | 176.0 ± 7.7 | 0.2 [-0.1, 0.4]; 0.9% | 0.117 | 0.46, Small | 0.500 |
| | Arm span (cm) | 181.2 ± 9.9 | 181.6 ± 9.9 | 0.4 [0.1, 0.7]; 0.2% | 0.007# | 0.89, Large | 0.247 |
| | Body mass (kg) | 66.1 ± 9.1 | 67.2 ± 8.9 | 1.1 [0.2, 1.9]; 1.6% | 0.021# | 0.73, Medium | -0.254 |
| | BMI (kg·m$^2$) | 21.3 ± 2.3 | 21.6 ± 2.4 | 0.3 [0.01, 0.6]; 1.5% | 0.030# | 0.68, Medium | -0.353 |
| | Low intensity (MET-min·wk$^{-1}$) | - | 1116 ± 922 | - | - | - | -0.091 |
| | Moderate intensity (MET-min·wk$^{-1}$) | - | 1088 ± 1526 | - | - | - | 0.098 |
| | Vigorous intensity (MET-min·wk$^{-1}$) | - | 1426 ± 1399 | - | - | - | -0.228 |
| | Total physical activity (MET-min·wk$^{-1}$) | - | 3630 ± 1634 | - | - | - | -0.155 |
| FEMALES (n = 8) | Height (cm)[a] | 165.5 ± 3.3 | 166.0 ± 3.5 | 0.0 [0.0, 0.1]; 0.2% | 0.012# | 1.18, Large | -0.308 |
| | Arm span (cm)[a] | 169.9 ± 4.5 | 170.2 ± 4.3 | 0.0 [-0.1, 0.1]; 0.2% | 0.158 | 0.56, Medium | -0.132 |
| | Body mass (kg) | 58.1 ± 6.2 | 59.1 ± 5.4 | 1.0 [-0.1, 2.2]; 1.8% | 0.065 | 0.77, Medium | 0.089 |
| | BMI (kg·m$^2$) | 21.2 ± 2.4 | 21.5 ± 2.2 | 0.3 [-0.2, 0.7]; 1.3% | 0.204 | 0.49, Small | 0.113 |
| | Low intensity (MET-min·wk$^{-1}$) | - | 817±165 | - | - | - | 0.062 |
| | Moderate intensity (MET-min·wk$^{-1}$) | - | 322±233 | - | - | - | -0.398 |
| | Vigorous intensity (MET-min·wk$^{-1}$) | - | 213±281 | - | - | - | -0.038 |
| | Total physical activity (MET-min·wk$^{-1}$) | - | 1352±515 | - | - | - | -0.182 |

BMI: body mass index, MET: metabolic equivalent of task, [a]Raw data is presented, but Napierian logarithm transformed data was used in the analysis. #significant difference.

**Table 3.** Effects of five-weeks off-season on swimmers' race kinematics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, 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 = 13) | T50 (s) | 27.78 ± 1.71 | 28.32 ± 2.07 | 0.54 [0.18, 0.89]; 1.9% | 0.007# | 0.91, Large | - |
| | T15 (s) | 7.35 ± 0.53 | 7.43 ± 0.71 | 0.08 [-0.09, 0.25]; 1.1% | 0.322 | 0.28, Small | 0.978* |
| | T25 (s) | 13.48 ± 0.86 | 13.68 ± 1.10 | 0.20 [-0.02, 0.42]; 1.5% | 0.076 | 0.53, Medium | 0.980* |
| | Turn$_{(20-30)}$ (s) | 5.49 ± 0.33 | 5.59 ± 0.32 | 0.10 [0.03, 0.17]; 1.9% | 0.009# | 0.85, Large | 0.472 |
| | Finish$_{(45-50)}$ (s) | 2.91 ± 0.17 | 2.97 ± 0.18 | 0.05 [0.02, 0.08]; 1.9% | 0.001# | 1.21, Large | 0.088 |
| | SR$_{0-25}$ (Hz)$^{a}$ | 0.94 ± 0.08 | 0.92 ± 0.08 | -0.02 [-0.05, 0.01];-2.1% | 0.164 | 0.41, Small | 0.196 |
| | SR$_{25-50}$ (Hz) | 0.89 ± 0.09 | 0.87 ± 0.10 | -0.02 [-0.03, -0.01];-2.2% | 0.012# | 0.82, Large | -0.235 |
| | SR$_{Fin}$ (Hz) | 0.89 ± 0.01 | 0.87 ± 0.01 | -0.02 [-0.04, -0.01];-2.4% | 0.041# | 0.63, Medium | -0.166 |
| | SL$_{0-25}$ (m)$^{a}$ | 1.83 ± 0.13 | 1.84 ± 0.12 | 0.01 [-0.03, 0.03]; 0.3% | 0.792 | 0.07, Small | -0.287 |
| | SL$_{25-50}$ (m) | 1.85 ± 0.14 | 1.86 ± 0.15 | 0.01 [-0.01, 0.02]; 0.6% | 0.188 | 0.39, Small | -0.363 |
| | SL$_{Fin}$ (m) | 1.93 ± 0.22 | 1.94 ± 0.19 | 0.01 [-0.04, 0.05]; 0.2% | 0.819 | 0.06, Small | 0.180 |
| | SI$_{0-25}$ (m$^{2}$·s$^{-1}$) | 3.18 ± 0.29 | 3.13 ± 0.31 | -0.04 [-0.17, 0.07];-1.5% | 0.409 | 0.23, Small | -0.329 |
| | SI$_{25-50}$ (m$^{2}$·s$^{-1}$) | 3.05 ± 0.32 | 3.00 ± 0.34 | -0.04 [-0.08, 0.01];-1.3% | 0.084 | 0.52, Medium | -0.529* |
| | SI$_{Fin}$ (m$^{2}$·s$^{-1}$) | 3.34 ± 0.55 | 3.28 ± 0.48 | -0.05 [-0.16, 0.04];-1.7% | 0.255 | 0.33, Small | 0.153 |
| | Clean swimming speed$_{0-25}$ (m·s$^{-1}$) | 1.73 ± 0.09 | 1.69 ± 0.10 | -0.03 [-0.05, -0.01];-1.8% | 0.005# | 0.94, Large | -0.272 |
| | Clean swimming speed$_{25-50}$ (m·s$^{-1}$) | 1.64 ± 0.11 | 1.61 ± 0.12 | -0.03 [-0.05, -0.01];-1.8% | 0.014# | 0.79, Medium | -0.478* |
| | Clean swimming speed$_{Fin}$ (m·s$^{-1}$) | 1.71 ± 0.10 | 1.68 ± 0.10 | -0.03 [-0.04, -0,01];-1.9 | 0.010# | 1.20, Large | -0.026 |
| | AnCV (m·s$^{-1}$) | 1.67 ± 0.08 | 1.67 ± 0.10 | -0.00 [-0.02, 0.02]; -0.1% | 0.885 | 0.04, Small | -0.647* |
| FEMALES (n = 8) | T50 (s) | 31.09 ± 2.53 | 31.99 ± 2.24 | 0.89 [0.09, 1.69]; 2.9% | 0.033# | 0.93, Large | - |
| | T15 (s) | 8.07 ± 0.88 | 8.22 ± 0.54 | 0.15 [-0.19, 0.49]; 1.9% | 0.335 | 0.36, Small | 0.574 |
| | T25 (s) | 14.84 ± 1.31 | 15.16 ± 0.91 | 0.32 [-0.16, 0.80]; 2.2% | 0.163 | 0.55, Medium | 0.860* |
| | Turn$_{(20-30)}$ (s) | 6.06 ± 0.43 | 6.21 ± 0.53 | 0.15 [-0.03, 0.34]; 2.6% | 0.094 | 0.68, Medium | 0.530 |
| | Finish$_{(45-50)}$ (s) | 3.36 ± 0.22 | 3.45 ± 0.25 | 0.09 [0.03, 0.14]; 2.7% | 0.005# | 1.40, Large | -0.292 |
| | SR$_{0-25}$ (Hz) | 0.86 ± 0.12 | 0.82 ± 0.12 | -0.04 [-0.07, -0.01];-4.7% | 0.011# | 1.21, Large | -0.892* |
| | SR$_{25-50}$ (Hz) | 0.79 ± 0.10 | 0.74 ± 0.10 | -0.04 [-0.07, -0.02];-5.9% | 0.002# | 1.65, Large | -0.672* |
| | SR$_{Fin}$ (Hz) | 0.79 ± 0.09 | 0.73 ± 0.09 | -0.05 [-0.09, -0.01];-6.6% | 0.015# | 1.13, Large | -0.638* |
| | SL$_{0-25}$ (m) | 1.82 ± 0.21 | 1.84 ± 0.22 | 0.02 [-0.02, 0.07]; 1.2% | 0.322 | 0.37, Small | 0.157 |
| | SL$_{25-50}$ (m) | 1.83 ± 0.17 | 1.86 ± 0.18 | 0.03 [-0.04, 0.10]; 1.4% | 0.437 | 0.29, Small | -0.863* |
| | SL$_{Fin}$ (m)$^{a}$ | 1.90 ± 0.18 | 1.98 ± 0.20 | 0.04 [-0.01, 0.10]; 4.6% | 0.120 | 0.62, Medium | 0.626* |
| | SI$_{0-25}$ (m$^{2}$·s$^{-1}$)$^{a}$ | 2.85 ± 0.40 | 2.78 ± 0.31 | -0.02 [-0.07, 0.03];-2.5% | 0.333 | 0.37, Small | -0.442 |
| | SI$_{25-50}$ (m$^{2}$·s$^{-1}$) | 2.64 ± 0.27 | 2.57 ± 0.34 | -0.06 [-0.32, 0.18];-2.6% | 0.550 | 0.22, Small | -0.864* |
| | SI$_{Fin}$ (m$^{2}$·s$^{-1}$) | 2.83 ± 0.32 | 2.89 ± 0.35 | 0.05 [-0.15, 0.27]; 1.9% | 0.554 | 0.21, Small | 0.605 |
| | Clean swimming speed$_{0-25}$ (m·s$^{-1}$) | 1.56 ± 0.11 | 1.50 ± 0.06 | -0.05 [-0.11, -0.01];-3.6% | 0.042# | 0.87, Large | -0.754* |
| | Clean swimming speed$_{25-50}$ (m·s$^{-1}$) | 1.44 ± 0.09 | 1.38 ± 0.11 | -0.06 [-0.14, 0.02];-4.2% | 0.146 | 0.57, Medium | -0.841* |
| | Clean swimming speed$_{Fin}$ (m·s$^{-1}$)$^{a}$ | 1.49 ± 0.09 | 1.45 ± 0.09 | -0.02 [-0.03, -0.01];-2.2% | 0.009# | 1.27, Large | 0.259 |
| | AnCV (m·s$^{-1}$) | 1.55 ± 0.09 | 1.49 ± 0.07 | -0.06 [-0.11, -0.01]; -3.8% | 0.025# | 1.00, Large | -0.138 |

T: time taken to complete the given distance; SR, SL and SI: stroke rate, length and index; AnCV: anaerobic critical velocity. $^{a}$Raw data is presented, but Napierian logarithm transformed data was used in the analysis, *significant correlation, #significant difference.

**Table 4.** Effects of five-weeks off-season on swimmers' energetics. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, 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 |
|---|---|---|---|---|---|---|
| $\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) | 61.3 ± 15.5 | 55.5 ± 12.6 | -5.8 [-14.3, 2.6]; -9.5% | 0.162 | 0.41, Small | 0.288 |
| $A_p$ ($mL \cdot kg^{-1} \cdot min^{-1}$) | 42.6 ± 13.7 | 38.7 ± 12.4 | -4.2 [-12.4, 3.8]; -10.0% | 0.276 | 0.31, Small | 0.314 |
| τp (s) | 48.5 ± 30.0 | 36.5 ± 17.8 | -11.9 [-27.2, 3.3]; -24.6% | 0.114 | 0.47, Small | 0.331 |
| $[La^-]_{basal}$ ($mmol \cdot L^{-1}$) | 4.4 ± 1.6 | 4.3 ± 1.6 | -0.1 [-1.4, 1.1]; -2.4% | 0.857 | 0.05, Small | 0.107 |
| $[La^-]_{peak}$ ($mmol \cdot L^{-1}$) | 11.5 ± 2.3 | 12.6 ± 2.9 | 1.1 [-0.9, 3.1]; 9.3% | 0.262 | 0.32, Small | -0.182 |
| $[La^-]_{net}$ ($mmol \cdot L^{-1}$) | 7.1 ± 2.8 | 8.3 ± 2.6 | 1.2 [-1.0, 3.4]; 16.6% | 0.275 | 0.31, Small | -0.221 |
| $HR_{basal}$ (bpm) | 102 ± 17 | 108 ± 15 | 6 [0, 12]; 6.2% | 0.041# | 0.63, Medium | -0.268 |
| $HR_{50m}$ (bpm) | 113 ± 16 | 126 ± 13 | 13 [7, 19]; 12.0% | 0.001# | 1.30, Large | -0.622* |
| $HR_{net}$ (bpm) | 10 ± 5 | 18 ± 9 | 7 [3, 11]; 66.9% | 0.003# | 1.03, Large | -0.545* |
| $HR_{maxB}$ (bpm) | 115 ± 18 | 121 ± 17 | 6 [-1, 12]; 5.0% | 0.081 | 0.52, Medium | -0.331 |
| $HR_{max50m}$ (bpm) | 146 ± 19 | 168 ± 15 | 22 [12, 32];14.9% | <0.001# | 1.33, Large | -0.192 |
| $HR_{maxnet}$ (bpm) | 30 ± 13 | 47 ± 14 | 16 [10, 21]; 52.1% | <0.001# | 1.76, Large | 0.049 |
| AnL (kJ) | 27.05 ± 12.75 | 31.29 ± 10.45 | 4.24 [-3.73, 12.22]; 15.6% | 0.269 | 0.32, Small | -0.240 |
| AnAL (kJ)$^a$ | 46.75 ± 29.28 | 31.94 ± 17.32 | -0.35 [-0.69, -0.01]; -31.6% | 0.045# | 0.62, Medium | 0.451 |
| $E_{Ana}$ (kJ)$^a$ | 73.80 ± 26.62 | 63.24 ± 23.02 | -0.15 [-0.32, 0.01]; -14.3% | 0.061 | 0.57, Medium | 0.403 |
| $\dot{E}_{Ana}$ (kW)$^a$ | 2.68 ± 1.05 | 2.25 ± 0.88 | -0.17 [-0.33,-0.01] -16.0% | 0.035# | 0.65, Medium | 0.358 |
| $\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)$^a$ | 54.5 ± 14.6 | 45.1 ± 11.9 | -0.2 [-0.3, -0.01]; -17.1% | 0.047# | 0.85, Large | 0.227 |
| $A_p$ ($mL \cdot kg^{-1} \cdot min^{-1}$) | 40.5 ± 12.8 | 34.1 ± 9.8 | -6.4 [-15.7, 2.9]; -15.8% | 0.148 | 0.57, Medium | 0.403 |
| τp (s) | 43.4 ± 9.1 | 41.3 ± 11.6 | -2.1 [-12.5, 8.2]; -4.9% | 0.639 | 0.17, Small | 0.437 |
| $[La^-]_{basal}$ ($mmol \cdot L^{-1}$) | 2.6 ± 0.8 | 2.5 ± 0.5 | -0.1 [-0.7, 0.6]; -0.9% | 0.934 | 0.03, Small | 0.099 |
| $[La^-]_{peak}$ ($mmol \cdot L^{-1}$) | 10.0 ± 2.7 | 10.0 ± 3.1 | 0.00 [-1.45, 1.50]; 0.2% | 0.969 | 0.01, Small | -0.385 |
| $[La^-]_{net}$ ($mmol \cdot L^{-1}$) | 7.3 ± 2.1 | 7.4 ± 2.7 | 0.1 [-1.0, 1.2]; 0.6% | 0.919 | 0.03, Small | -0.567 |
| $HR_{basal}$ (bpm) | 94 ± 7 | 102 ± 7 | 8 [3,13]; 8.8% | 0.008# | 1.46, Large | 0.808* |
| $HR_{50m}$ (bpm) | 109 ± 10 | 122 ± 7 | 13 [6, 19]; 11.7% | 0.003# | 1.87, Large | -0.493 |
| $HR_{net}$ (bpm) | 15 ± 7 | 20 ± 8 | 4 [-3, 12]; 29.9% | 0.224 | 0.51, Medium | -0.915* |
| $HR_{maxB}$ (bpm) | 111 ± 7 | 117 ± 8 | 6 [-2, 14]; 5.5% | 0.117 | 0.69, Medium | 0.671* |
| $HR_{max50m}$ (bpm)$^a$ | 147 ± 21 | 163 ± 13 | 0.11 [-0.04, 0.26]; 10.9% | 0.122 | 0.67, Medium | -0.488 |
| $HR_{maxnet}$ (bpm) | 36 ± 20 | 46 ± 15 | 10 [-14, 34]; 28.0% | 0.348 | 0.38, Small | -0.644 |
| AnL (kJ) | 23.85 ± 6.20 | 24.43 ± 8.22 | 0.57 [-3.41, 4.56]; 2.4% | 0.742 | 0.12, Small | -0.495 |
| AnAL (kJ) | 34.96 ± 11.35 | 29.24 ± 12.74 | -5.71 [-15.01, 3.58]; -16.3% | 0.189 | 0.51, Medium | 0.572 |
| $E_{Ana}$ (kJ) | 58.82 ± 14.30 | 53.68 ± 11.72 | -5.14 [13.24, 2.95]; -8.7% | 0.177 | 0.53, Medium | 0.413 |
| $\dot{E}_{Ana}$ (kW) | 1.90 ± 0.50 | 1.69 ± 0.41 | -0.21 [-0.46, 0.04]; -11.9% | 0.090 | 0.69, Medium | 0.276 |

$\dot{V}O_{2peak}$: highest exercise oxygen uptake; $A_p$, τp: amplitude and time constant of the fast $\dot{V}O_2$ component; $[La^-]_{basal}$: basal lactate; $[La^-]_{peak}$: peak blood lactate concentration; $[La^-]_{net}$: blood lactate concentration difference between the $[La^-]$ before and after exercise; $HR_{basal}$: mean basal heart rate; $HR_{50m}$: mean heart rate after exercise; $HR_{net}$: difference between the mean heart rate before and after exercise; $HR_{maxB}$: maximum basal heart rate; $HR_{max50m}$: maximum heart rate after exercise; $HR_{maxnet}$: difference between the maximum heart rate before and after exercise; AnL: anaerobic lactic contribution; AnAL: anaerobic alactic contribution; $E_{Ana}$: anaerobic energy expenditure; $\dot{E}_{Ana}$: anaerobic metabolic power. $^a$Raw data is presented, but Napierian logarithm transformed data was used in the analysis, *significant correlation, #significant difference.

**Table 5.** Effects of five-weeks off-season on swimmers' strength. There are displayed the PRE and POST mean ± SD values with respective level of probabilities (*p*), mean differences, 95% confidence intervals, 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 = 13) | $CMJ_{JH}$ (cm) | 0.33 ± 0.06 | 0.33 ± 0.06 | -0.00 [-0.01, 0.08]; -0.4% | 0.746 | 0.09, Small | 0.501* |
| | $PUv_{avg}$ $(m \cdot s^{-1})^{a}$ | 0.68 ± 0.18 | 0.64 ± 0.18 | -0.06 [-0.10, -0.03]; -6.2% | 0.001# | 1.44, Large | 0.033 |
| | $PUf_{avg}$ (N) | 620 ± 115 | 625 ± 105 | 4.98 [-6.74, 16.71]; 0.8% | 0.362 | 0.30, Small | -0.033 |
| | $PUP_{avg}$ $(W)^{a}$ | 432 ± 158 | 408 ± 144 | -0.05 [-0.08, -0.02]; -5.4% | 0.004# | 1.20, Large | -0.004 |
| | $Favg_0$ $(N)^{a}$ | 103 ± 20 | 92 ± 21 | -0.11 [-0.22, -0.01]; -10.3% | 0.033# | 0.69, Medium | 0.357 |
| | $Fmax_0$ (N) | 236 ± 42 | 227 ± 38 | -9 [-23, 3];-4.1% | 0.136 | 0.44, Small | -0.121 |
| | $Iavg_0$ $(N \cdot s)^{a}$ | 64 ± 14 | 63 ± 13 | -0.87 [-6.78, 5.04]; -1.3% | 0.754 | 0.08, Small | 0.118 |
| | $Imax_0$ $(N \cdot s)^{a}$ | 89 ± 15 | 88 ± 20 | -0.02 [-0.15, 0.09]; -1.5% | 0.597 | 0.15, Small | -0.019 |
| | $Favg_{1.124}$ (N) | 43 ± 11 | 40 ± 11 | -3 [-9, 2]; -7.5% | 0.240 | 0.34, Small | 0.115 |
| | $Fmax_{1.124}$ (N) | 124 ± 34 | 119 ± 34 | -5 [-18, 7]; -4.3% | 0.383 | 0.25, Small | 0.192 |
| | $Iavg_{1.124}$ (N·s) | 29 ± 9 | 25 ± 6 | -3 [-7, 0]; -11.5% | 0.094 | 0.50, Small | 0.215 |
| | $Imax_{1.124}$ (N·s) | 51 ± 15 | 49 ± 19 | -2 [-9, 5]; -0.8% | 0.564 | 0.16, Small | -0.053 |
| FEMALES (n = 8) | $CMJ_{JH}$ (cm) | 0.25 ± 0.04 | 0.24 ± 0.04 | -0.01 [-0.02, -0.01]; -4.9% | 0.038# | 0.90, Large | -0.295 |
| | $PUv_{avg}$ $(m \cdot s^{-1})$ | 0.64 ± 0.21 | 0.59 ± 0.25 | -0.05 [-0.11, 0.01]; -8.1% | 0.072 | 0.82, Large | 0.524 |
| | $PUf_{avg}$ (N) | 609 ± 71 | 631 ± 71 | 21 [5, 38]; 3.5% | 0.018# | 1.22, Large | -0.297 |
| | $PUp_{avg}$ (W) | 399 ± 147 | 377 ± 167 | -21 [-55, 12]; -5.3% | 0.172 | 0.58, Medium | 0.559 |
| | $Favg_0$ (N) | 70 ± 8 | 65 ± 4 | -5 [-11, 1]; -6.9% | 0.087 | 0.70, Medium | -0.081 |
| | $Fmax_0$ $(N)^{a}$ | 164 ± 24 | 158 ± 16 | -0.02 [-0.06, 0.01]; -3.2% | 0.126 | 0.61, Medium | 0.074 |
| | $Iavg_0$ (N·s) | 47 ± 5 | 47 ± 5 | 0 [-1, 3]; 1.4% | 0.516 | 0.24, Small | -0.547 |
| | $Imax_0$ (N·s) | 69 ± 10 | 63 ± 7 | -6 [-16, 5]; -8.1% | 0.274 | 0.41, Small | 0.447 |
| | $Favg_{1.124}$ (N) | 19 ± 5 | 17 ± 5 | -2 [-5, 1]; -10.6% | 0.176 | 0.53, Medium | -0.256 |
| | $Fmax_{1.124}$ (N) | 57 ± 15 | 53 ± 13 | -4 [-17, 10]; -6.3% | 0.566 | 0.21, Small | -0.075 |
| | $Iavg_{1.124}$ (N·s) | 15 ± 10 | 14 ± 7 | 1 [-4, 2]; -7.3% | 0.495 | 0.25, Small | -0.683* |
| | $Imax_{1.124}$ (N·s) | 24 ± 6 | 21 ± 5 | -3 [-10, 4]; -13.0% | 0.352 | 0.35, Small | 0.223 |

$CMJ_{JH:}$ countermovement jump height; $PUv_{avg}$: average propulsive velocity; $PUf_{avg}$: average propulsive force; $PUp_{avg}$: average propulsive power; Favg: average force; Fmax: maximum force; Iavg: average impulse; Imax: maximum impulse. [a]Raw data is presented, but Napierian logarithm transformed data was used in the analysis, *significant correlation, #significant difference.

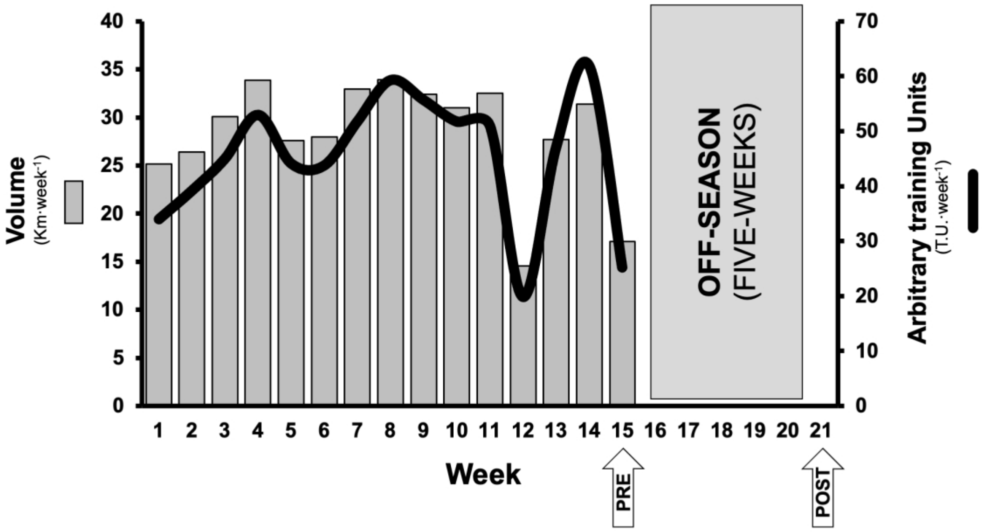

Figure 1. Training volume and units (T.U.) of the monitored last macrocycle prior the off-season. PRE: assessment conducted right at the end of the macrocycle; POST: assessment conducted right before the beginning of the next season, after the training cessation period.

338x190mm (144 x 144 DPI)

# Supplementary Material 1: Description of the standardized warm-up performed.

Standardized warm-up:

i. *300 m (100 m usual breathing, 100 m breathing every five strokes, 100 m usual breathing);*
ii. *4 × 100 m (2 × [25 m flutter kick + 25 m increased SL]) on 1:50;*
iii. *8 × 50 m (2 × 50 m drill; 2 × 50 m building up swimming speed; and 4 × [25 m race pace + 25 m easy]) on 1:00;*
iv. *100 m easy.*

## Supplementary Material 2: Description of the method use for the calculations of five-zone training system.

Swimming training load was calculated for each week and expressed in the total volume completed (km) and arbitrary training units (T.U.), which was quantified as:

$$T.U. = \left(km_{z1} \cdot if_{z1}\right) + \left(km_{z2} \cdot if_{z2}\right) + \left(km_{z3} \cdot if_{z3}\right) + \left(km_{z4} \cdot if_{z4}\right) + \left(km_{z5} \cdot if_{z5}\right)$$

where *km* represents the sum of the total volume swum in kilometres in the respective zone (*z1* = zone 1, *z2* = zone 2, *z3*= zone 3, *z4* = zone 4, and *z5*= zone 5) and *if* was the respective intensity factor for each zone: $if_{z1} = 1$, $if_{z2} =2$, $if_{z3} = 3$, $if_{z4} = 5$, and $if_{z5} = 8$.