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Effects of two types of activation protocols based on postactivation potentiation on 50-meter freestyle performance

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Abstract:	Postactivation potentiation (PAP) is a phenomenon which improves muscle contractility, strength and speed in sporting performances through previously applied maximal or submaximal loads on the muscle system. This study aimed to assess the effects of two types of activation protocols based on PAP, on sprint swimming performance. A repeated-measures design was used to compare three different scenarios prior to a 50-m race. First, all of the participants performed a standard warm-up (SWU), consisting of a 400-m swim followed by dynamic stretching. This protocol acted as the control. Subsequently, the swimmers were randomly assigned into two groups: the swimmers in the first group performed the SWU followed by a PAP one-repetition warm-up (RMWU), consisting of three "lunge" and three "arm stroke" repetitions, both at 85% of the one-repetition maximum. The swimmers in the second group performed the SWU followed by a PAP eccentric flywheel warm-up (EWU), consisting of one set of four repetitions of exercises of both the lower and upper limbs on an adapted eccentric flywheel at the maximal voluntary contraction. The time required for the swimmers to swim 5 and 10 m was shorter with the PAP protocols. The swimming velocity of the swimmers who underwent the EWU and RMWU protocols were faster at 5 and 10 m. The best total swimming time was not influenced by any of the protocols. When isolating swimming (excluding start performance and turn), best time was achieved with the SWU and RMWU compared with EWU (SWU: 20.86 ± 0.95 s; EWU: 21.25 ± 1.12 s; RMWU: 20.97 ± 1.22 s). In conclusion, a warm up based on PAP protocols might exert an influence on performance in the first meters of a 50-m race. Nevertheless, other factors, such as fatigue, could modify swimming patterns and yield results contradictory to those of the desired task.

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ABSTRACT

Postactivation potentiation (PAP) is a phenomenon which improves muscle contractility, strength and speed in sporting performances through previously applied maximal or submaximal loads on the muscle system. This study aimed to assess the effects of two types of activation protocols based on PAP, on sprint swimming performance. A repeated-measures design was used to compare three different scenarios prior to a 50-m race. First, all of the participants performed a standard warm-up (SWU), consisting of a 400-m swim followed by dynamic stretching. This protocol acted as the control. Subsequently, the swimmers were randomly assigned into two groups: the swimmers in the first group performed the SWU followed by a PAP one-repetition warm-up (RMWU), consisting of three "lunge" and three "arm stroke" repetitions, both at 85% of the one-repetition maximum. The swimmers in the second group performed the SWU followed by a PAP eccentric flywheel warm-up (EWU), consisting of one set of four repetitions of exercises of both the lower and upper limbs on an adapted eccentric flywheel at the maximal voluntary contraction.

The time required for the swimmers to swim 5 and 10 m was shorter with the PAP protocols. The swimming velocity of the swimmers who underwent the EWU and RMWU protocols were faster at 5 and 10 m. The best total swimming time was not influenced by any of the protocols. When isolating swimming (excluding start performance and turn), best time was achieved with the SWU and RMWU compared with EWU (SWU: 20.86 ± 0.95 s; EWU: 21.25 ± 1.12 s; RMWU: 20.97 ± 1.22 s). In conclusion, a warm up based on PAP protocols might exert an influence on

performance in the first meters of a 50-m race. Nevertheless, other factors, such as fatigue, could modify swimming patterns and yield results contradictory to those of the desired task.

KEYWORDS: Flywheel, Warm-up, PAP, OSB11 Block, Sprint Swimming.

INTRODUCTION

In sprint swimming events every instant is critical (1). In the last Olympics in Rio 2016, only one hundredth of a second (0.01 s) determined the difference between the first (A.E., USA: 21.40 s) and the second qualified (F. M., FRA: 21.41 s) swimmer on the 50-m male freestyle (www.fina.org). At this level of performance, small variations in speed resulting from the start performance, underwater swimming or stroke patterns are definitively essentials points to success (2). One key aspect in the preparation of the swimmers might involve the physical warm-up and all possible activities that are particularly designed to produce an optimal cortical activation for the desired task (3). A combination of dry land-based activation exercises followed by pool-based warm-up routines appears to be the preferred approach taken by elite swimming coaches preparing their athletes for competition (4). Some of these methods are based on postactivation potentiation (PAP), a phenomenon which improves muscle contractility, strength and speed in sporting performances through previously applied maximal or submaximal loads on the muscle system (5, 6).

Following maximal muscular contraction, the muscles are in a potentiated, as well as fatigued state. However, although fatigue is more dominant in the early stages of contractile history, it seems to dissipate faster than potentiation, creating a window of opportunity for possible performance enhancement (6, 7). Therefore, if fatigue and potentiation co-exist as responses following muscle and motor unit activation, PAP benefits might be more effective if an optimal recovery time is given after the conditioning activity (6). Thus the performance enhancement depends on the prevalence of potentiation over fatigue (8-11).

Any increase in swimming velocity requires a proportional increase in the applied muscle force and the development of power, capacity and efficiency in the energy delivery systems to sustain a higher swimming velocity (12). Muscles provide work and power to effect movement through contractions, which are characterized by the production of force and changes in length over a discrete time interval, suggesting the existence of strong logical relationships between strength abilities and performance in swimmers (13). One of the principles of PAP is to provide a conditioning exercise that is as similar as possible to the real action (5). Therefore, if the movement of the body is the outcome of a carefully sequenced activation of motor units to provide the force and displacement required for limb articulation (14, 15), identification of an approach to stimulate the motor units is needed.

Two studies that aimed to determine the relationships among resistance exercise and swim performance inspired the warm-up protocols applied in the present study (16, 17).

In both studies, arm stroke exercises replicating the front crawl underwater phase were tested through adapted devices. The subjects laid in prone position on a 45º inclined bench, extended their arms horizontally to the front, and pulled two handles connected to ropes, which were fully extended and tensed into the device, replicating the biomechanical gestures of swimming. Dominguez-Castells showed that maximum power on the arm stroke exercise was relatively similar to maximum swim power (r = 0.91), and both of these powers were related to swim velocity (r = 0.85, r = 0.72) (16). Interestingly, arm stroke tests were monitored and loads were specifically applied to every subject. Fact of interest for this study, as it might produce a conditioning stimulus in accordance with the level of conditioning of every subject. On the other hand, Naczk et al., showed improvements in 100- (-1.83%) and 50-m (- 0.76%) performance after four weeks of inertial training of the muscles involved in the upsweep phase of the arm stroke in front crawl swimming (17). These gains were related to increases in muscle strength (12.8%) and muscle power (14.2%) in the elbow flexors. Authors concluded that greater increases in muscle power could result from greater muscle stimulation during eccentric vs traditional weight training and claimed for additional research testing like of protocols on swimming performance. Both studies provided us specific procedures to apply loaded conditioning protocols on upper limbs.

Hence, if the performance of a dry land test is related to swimming velocity and power, which can be elicited through isotonic load lifting exercises (free-weight and eccentric-resistance exercises), a competition warm-up that includes some of the above-mentioned methods could yield interesting improvements in swimming performance. Previous results reported by Cuenca-Fernández et al., showed improvements in a swimming start after the application of conditioning exercises imitating the leg placement of the swimmer on the block start (15). Routines included free-weight and eccentric-resistance lunges to activate the hip and knee extensor muscles of the front leg, causing the main impulse in track starts (18). Therefore, both routines for lower body were also adopted for the current study's protocol. This study aimed to assess the effects of two types of activation protocols based on PAP, upon sprint swimming performance. Both protocols consisted of exercises for lower and upper limbs by replicating the impulse from the block-start and the arms strokes pulling movements. One of the protocols was based on maximal load repetitions performed on an adapted Smith machine, and the other consisted of maximal repetitions of exercises performed on an adapted eccentric flywheel. Our hypothesis is that protocols based on PAP could generate better results for 50-m swimming performance by taking advantage of performance improvements in the first 15 m.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

A repeated-measures counterbalanced design was utilized to determine differences between standard swimming warm up and two PAP-based warm up protocols on 50-m performance. The swimmers visited the laboratory three days. On first day, all of the participants performed a standard warm-up (SWU), which consisted of a 400-m swimming warm-up followed by dynamic lower and upper limb stretching and it was considered the control. On the second day, the swimmers were randomly assigned into two groups according to the best and worst 50-m time they achieved during the SWU trial: the swimmers in the first group completed the SWU followed by a PAP one-repetition warm-up (RMWU), consisting of one set of three “lunge” and three “arm stroke” repetitions, both at 85% of the one-repetition maximum. The swimmers in the second group performed the SWU followed by a PAP eccentric flywheel warm-up (EWU), consisting of one set of four repetitions of exercises of both the lower and upper limbs on an adapted eccentric flywheel at the maximal voluntary contraction. After six minutes of rest, swimmers were tested on a 50-m race. Finally, on a third day, the group order was reversed to avoid the “fatigue/learning” effect and tests were repeated. In the study of Hancock et al., 30 collegiate swimmers were allowed to rest for six min between a PAP based warm-up and a 100-m swim race, and it was concluded adequate to enhance swim performance (19). Therefore, six minutes of rest were given on the present study between PAP warm-up and a 50-m race.

SUBJECTS

Seventeen competitive male swimmers (age, 18.42 ± 1.39; body mass, 73.65 ± 8.99 kg; and height, 1.81 ± 0.02 m) provided written informed consent and volunteered to participate in this study. Swimmers under age of 18 were asked to provide parental consent. All of the recruited swimmers (representing a performance level of 74.26% of the world record), were federated swimmers with at least 5 years of participation in regional-and national-level competitions. The swimmers usually underwent a complex training protocol involving at least five training sessions per week, which allows the development of power and speed while decreasing the volume of aerobic training (20).

Prior to the study, the participants visited the laboratory to become familiar with the testing methods and to determine the load required to perform a 1RM according the guidelines of the American College of Sports Medicine (21). The arm stroke 1RM was 38.82 ± 5.29 kg, and the lunge 1RM was 93.35 ± 12.51 kg. None of the swimmers reported use of the following: drugs, medication, or dietary supplements known to influence physical performance. The tests were scheduled to occur before their daily training regimen, and the subjects were instructed to avoid any physical exertion prior to testing. All of the procedures were performed in accordance to the Declaration of Helsinki with respect to human research, and the study was approved by the ethics committee of the university.

PROCEDURES

The experimental setting was a 25-m indoor pool (with water and air temperatures of 28.1 and 29.0ºC, respectively). Every swimmer performed individually three warm-up protocols in three separate days (1 protocol per day). Upon arrival, reference points were marked (in black) on the joints of the hip, knee, ankle and hand, in order to be tracked and analyzed later through a specific software. Subsequently, the swimmers were accurately informed about the testing protocol, which involved a rest period of six min prior to a 50-m race performed at maximum intensity. Each test was only performed once to simulate the conditions of competition (FINA rules). Throughout the session, a collaborator controlled the rest time for each subject. An auditory stimulus, similar to the one used in competition was used as starting signal. In each trial, the subject was asked to mount the block, and once in position, the subject was given the verbal command “take your mark” shortly before the starting signal was sounded.

During the first visit, all of the swimmers performed the standard warm-up (SWU) protocol. This protocol was based on the standard warm-up used in the study of Cuenca-Fernández et al., (15). It consisted of 400-m standardized warm-up consisting of 2 x 100-m easy freestyle swim with 2 starts from the wall; 2 x 50 m front crawl swim (12’5 fast/12’5 smooth) and 100 m front crawl at a normal pace. The participants then began their dynamic stretching protocol, which consisted of forward leg/arm swings, ankle dorsi-and plantar-flexion, arm circles, side leg swings, arm crossovers, high knees, heel flicks, hands up, squats and lunges. Each exercise was performed ten times, and the entire series was repeated twice (one series per min). Throughout the stretching set, a collaborator ensured that the stretching protocol was performed properly and at the right pace over 4 min, and after 6 min of rest, the swimmers performed a 50-m race.

Upon return for the second session, the swimmers were randomly assigned into two groups, according to the best and worst 50-m time achieved during the SWU trial. The first group performed the heavy load warm-up (RMWU), which consisted of warm-up and stretching exercises as in the SWU protocol supplemented with the PAP stimulus through arm stroke and lunge exercises on an adapted “Smith-Machine” (Jim Sports Technology S.L., Lugo, Spain; Figure 1). The second group performed the eccentric flywheel warm-up (EWU), which consisted of warm-up and stretching exercises as in the SWU protocol supplemented with the PAP stimulus through five-maximum repetitions on the nHANCE™ Squat Ultimate device (YoYo™ Technology AB, Stockholm, Sweden; Figure 2). The order was reversed for the third, and last, testing sessions: the second group performed the RMWU protocol, and the first group performed the EWU protocol. A certified personal trainer (NSCA-CPT®) controlled the initial position and the specific loads provided to the swimmer's device harnesses.

STRENGTH TESTS AND CONDITIONING EXERCISES

Arm Stroke and Lunge Strength Test

A "Smith machine" (Jim Sports Technology S.L., Lugo, Spain) was adapted to perform both conditioning exercises. The incremental strength test consisted of completing two repetitions with each load, with loads that were increasing every two minutes (21). The increments of the load were 10 kg at the beginning of the test and 5 kg later. The participants were asked to perform the complete movement at maximal velocity, return to the starting position in a controlled manner, maintain the position for 0.5 s and perform a second repetition. The test finished when they were unable to do a complete repetition. The last load they could lift completely was their repetition maximum (1RM).

Arm strokes were replicated according to Dominguez-Castells on the above mentioned Smith machine (16). An own made pulley system (Barton Marine Equipment Limited, Whitstable, England), was adapted to the bar to allow development of pulling actions away from the system (Figure 1). All of the targeted loads were adapted and previously confirmed with an electronic dynamometer (WeiHeng®, Guangzhou WeiHeng Electronics Co., Ltd. China). The swimmers started the exercise in prone position on an inclined bench (45º from vertical) and then extended their arms horizontally to the front, with each hand holding one handle. The machine exerted some tension such that the arms were relaxed. The swimmers were instructed to perform a shoulder extension similar to the movements in the front/crawl or butterfly underwater phase. One repetition finished when the arms reached the trunk line, i.e., 135º shoulder extension.

FIGURE 1 NEAR HERE

The lunge exercise was replicated as described by Cuenca-Fernández et al., on the above mentioned Smith machine (15). The swimmers first placed their rear knee on a lifted surface at a height of 5 cm from the ground such that the leg and thigh formed a 90º angle; similarly, the entire surface of the foot of the front leg was placed on the ground such that the leg and thigh also formed a 90º angle. After the swimmers attained this initial position, they started extending the limbs. For this exercise, the swimmers were asked to place their lower limbs in the same position as that used to perform swimming starts to control which leg was placed in front or behind.

Eccentric flywheel protocols

Eccentric flywheel protocols were applied using a nHANCE^{TM} Squat Ultimate device (YoYo™ Technology AB, Stockholm, Sweden) (Figure 2). The arm strokes were replicated according to Naczk et al., (17). The participants laid in prone position on the stationary bench in front of the inertial device, and their legs were held by an assistant. The participants maintained their arms along their body and flexed approximately 90º at the elbow joint. The swimmers held the handles connected to the ropes, which were fully extended and tensed into the device (hands in pronation; Figure 2). During the 10-s maximal trial, the participants attempted to imitate the pulling movements of the arm swim strokes, with instructions to perform the exercise as rapidly as possible. During testing, the elbow extensor and back muscles worked concentrically during the elbow extension movement (the flywheel was accelerated during this phase) and eccentrically during elbow flexion (the swimmers attempted to extend their elbow throughout the exercise, and elbow joint flexion was forced by the mass of inertia of the flywheel). The range of motion of the elbow joint was approximately 90º.

FIGURE 2 NEAR HERE

Lower limb extension was replicated according to Cuenca-Fernández et al., (15). The initial position was the same as that performed by swimmers on the block, with the same front/behind placement of the lower limbs. Once the belt was attached, the swimmers performed five maximum-intensity repetitions.

KINEMATIC MEASUREMENTS

Data collection for the 50-m Race

Each trial was recorded with five digital video cameras. One of these was mounted on a tripod focused to the block (Casio HS Camera 60 Hz; Computer CO., LTD. Tokyo, Japan), operated at a sampling rate of 60 Hz and used to record the kinematic variables associated to the swimming start (Block time, dive distance & velocity, angles of take-off & entry). The block camera was focused on the starting system to spot the light emitted by the starting signal. The starting system (Signal Frame, Sportsmetrics, Cincinnati, OH, USA) simultaneously emitted an audible signal and a strobe flash to allow synchronization of the starting signal with the video image. The four other digital video cameras (Sony Video Camera, 50 Hz; Sony Electronics Inc., Tokyo, Japan) were installed on four underwater portholes along the pool. One of them recorded the block underwater phase to 7.5 m, the second recorded from 7.5 to 12.5 m, the third from 12.5 to 17.5 m and the last one from 17.5 to 25 m, including turn. The four sequences were overlapped in space and time by a video switcher (Digital Video Switcher SE-900, Taiwan, Republic of China). These cameras recorded the swimming *time* and *velocity* variables from 5 to 50 m, including the Stroke rate and Stroke length. The shutter speed was adjusted using a modality (Sport Mode) that maximized the shutter speed within the limits of the cameras being used (1/4,000 seconds), consequently minimizing any distortion in the movement of the swimmers. All video files registered were analysed by two different researchers using Kinovea® software (version 0.7.10, France), which allowed an accurate analysis of the reference points drawn on swimmers.

Kinematic variables

Block time (BT). The time from flashlight-up to the moment at which the swimmer separates from the block (s).

Dive distance (DD). The distance from the swimming pool wall under the starting block to the place where the swimmer's fingers first contact the water (cm).

Dive velocity (DV). The distance from the place where the feet last contact the starting block to the place where the swimmer's fingers first contact the water divided by the time elapsed during this action (m/s)

Angle of take-off (AT). The angle between the horizontal line and the line that connects the hip with the referential point on the foot at the moment of last contact between the foot and the starting block (º).

Angle of entry (AE). The angle between the horizontal line and the line that connects the hip with the referential point on the hand at the moment of first contact between the fingers and the water (º).

Underwater undulatory swimming after swim start (UUSss): The distance from the swimming pool wall under the starting block to the place of emersion above the water (m).

Underwater undulatory swimming after turn (UUS_{TU}): The distance from the swimming pool wall where the turn is performed to the place of emersion above the water (m).

Time to 5-50 m (T5M-T50M). The time from flashlight-out to the time at which the swimmer's head touches the baseline at 5-50 m (s).

Time to 25 m (T25M). The time from flashlight-out to the time at which the swimmer's feet touch the wall in which the turn is performed (s).

Split time to every 5 m. The time elapsed at every distance of 5 m along the race (5-50 m) (s).

Velocity over 5-50 m (V5-V50M). The distance of 5 m divided by the time elapsed during this action (m/s).

Isolated swimming phase (ISP)*:* Total swimming time extracting start performance time and the time to five meters after turn. (From 10 to 25-m and 30 to 50-m) (s).

Stroke rate (SR): These values were collected at the 15-, 20-, 35- and 45-m marks and determined using a video camera with a frequency measuring function for each three arm strokes and divided by the time elapsed during this action (to obtain the rate in Hertz) (Hz).

Stroke length (SL): These values were collected at the 15-, 20-, 35- and 45-m marks and was obtained by diving the mean velocity by the mean SR (Hz) and multiplying by 60 (m).

STATISTICAL ANALYSES

Descriptive statistics data are expressed as the means ± SDs and confidence intervals (95%). After Saphiro-Wilk testing for normality distribution, analysis using repeated-measures one-way ANOVA was applied concerning the three protocols to determine differences on the kinematic variables within and between subjects. To detect differences between the protocols, significance was accepted at the *alpha* < 0.05 level, and paired comparisons were used in conjunction with Holm's Bonferroni method for controlling type 1 errors. All the test were carried out by using SPSS Version 21.0 (IBM, Chicago, IL, USA).

The test-retest reliability (intraclass correlation [ICC]) within and between observers was analyzed for all of the variables. Six trials (three were digitized by the researcher, and the other three were digitized by an investigator with experience in digitization management with Kinovea® software) were quantified using intra-class correlation coefficients (ICC) to assess the reliability of the digitizing process (intra, inter-observer). These correlations were calculated separately for the repeated measures of the values for all of the variables for six randomly selected subjects. The intra-observer ICC ranged from 0.96 (95% confidence interval [CI] 0.94-0.97) to 0.99 (95% CI 0.98-

0.99), and the inter-observer ICC ranged from 0.97 (95% CI 0.96-0.98) to 0.99 (95% CI 0.99-0.99). These results showed high correlation and reliability.

RESULTS

The means, standard deviations and confidence intervals of all the variables for the protocols studied are shown in Tables (1 and 2) and Figure 3.

Swimming Start:

The data obtained for the block time, dive distance and diving time did not express differences (Table 1). For the diving velocity, the analysis revealed changes only with the EWU protocol ($F_{2,32}$ = 3.020, p = 0.048), which yielded faster values (3.40 ± 0.49 m/s) compared with those obtained with the SWU (3.26 ± 0.33 m/s) and RMWU protocols (3.31 ± 0.47 m/s). The analysis of the angles at take-off revealed differences between the SWU compared with the experimental protocols ($F_{2,15}$ = 4.028, p = 0.040). Specifically, higher angles at take-off were found with the EWU (31.17 ± 6.40º) and RMWU protocols (32.17 ± 7.11º) than with the SWU (27.76 ± 6.14º). The analysis of the angles at entry did not reveal any differences (Table 1). The total distance during underwater undulatory swimming was similar between the three protocols studied, both after the swimming start and after the turn (Table 1).

TABLE 1 NEAR HERE

Swimming Time and Swimming Velocity:

The analyses revealed differences in split times at 5 and 20 m (Split_5: $F_{2,15} = 4.936$, $p = 0.013$; Split_20: $F_{2,15} = 5.765$, $p = 0.014$) and in velocity at 5 and 10 m (V5: $F_{2,15} = 5.242$; $p = 0.011$; V10: $F_{2,15} = 3.406$; $p = 0.050$). A shorter time and a higher velocity were obtained with both experimental protocols compared with the SWU protocol (Table 2). No differences in time and velocity were found at any point between 15 to 50 m between the three protocols applied (Table 2). Isolated clean swimming time was slower in EWU compared with the rest of the protocols ($F_{2,15} = 3.727$, $p = 0.049$) (SWU: 20.86 ± 0.95 s; EWU: 21.25 ± 1.12 s; RMWU: 20.97 ± 1.22 s).

TABLE 2 NEAR HERE

Swimming Patterns:

The swimmers showed similar values for stroke rate at the 15-, 20- and 45-m marks (Figure 3). At the 35-m mark, some differences were detected for the stroke rate between the protocols ($F_{2,15} = 3.259$, $p = 0.049$). The value obtained with the SWU protocol was higher from that obtained with the EWU and RWMU protocol (SWU: 0.97 ± 0.11 Hz; EWU: 0.92 ± 0.09 Hz; RMWU: 0.93 ± 0.10 Hz)

The statistical analysis only revealed differences in stroke length at 15-m mark ($F_{2,15}$ = 4.215, p = 0.042). The values obtained with the experimental protocols were higher than with the SWU protocol (Figure 3). No other differences between the protocols were identified in stroke length at 20-, 35- and 45-m marks.

FIGURE 3 NEAR HERE

DISCUSSION

The purpose of this study was to assess the effects of two types of activation protocols based on PAP, on sprint swimming performance (50-m). One of these methods was based on maximal load repetitions of exercises for the lower and upper limbs performed in an adapted Smith Machine, and the other consisted of maximal repetitions of exercises for the lower and upper limbs performed on an adapted eccentric flywheel. The results obtained suggested that protocols based on PAP could generate improvements in the first 15 m. However, due to either fatigue or a modification in the swimming patterns, the final performance obtained with the experimental protocols was not better than that obtained with the SWU.

A deterioration of performance in *time* and *velocity* was obtained after the experimental protocols along the 50 m race, particularly after EWU. Nevertheless, better results were recorded in mentioned protocols at the beginning of the race (Table 2). Analyses of the diving velocity and take-off angle yielded superior values, i.e., faster and higher values, with the experimental protocols, specifically after EWU (Table 1). At this point, it is not possible to discern if improvements at start came because swimmers changed the take off angle or because lower limbs muscles were potentiated. Future studies testing kinetic variables collected on the block should clarify this matter. Nonetheless, some gains on performance as a consequence of the PAP warm-ups were registered on the block. For instance, the improvement on diving velocity after EWU showed that swimmer's flight was longer and faster (Table 1). In addition, this improved performance was transferred to the swimming time and velocity at the beginning of the race (5 and 10-m marks), where the swimmers have just entered the water and have not executed actions other than gliding or underwater swimming (22). Therefore, these aspects would confirm that improvements possibly would arise from gains in impulse at swim start obtained specifically on lower limbs with the experimental warm-up protocols (15). Supporting the influence of PAP on swimming start (15).

The best total swimming time (50 m), was not statistically influenced by any of the PAP protocols. The differences at this point were slight (~ 0.13 s), very similar to what experienced by the eight finalists on 50-m freestyle at the Olympics in Rio 2016 (~ 0.14 s) (www.fina.org). At this point, dealing with such incongruence is inevitable. If a hundredth of a second may decide between winning or losing a race, the differences in performance obtained after PAP would lead swimmers to a more disadvantageous scenario. According to Stewart and Hopkins (2), a strategy intended to change an athlete's performance must suppose an equivalent to at least ~ 0.5 % of the coefficient of variation to be considered effective. The changes on the coefficient of variation in performance collected in this study showed lower values (~ 0.4%). Thus, the null hypothesis may not be rejected. This lack of differences was obtained even though an improvement on swim start performance was obtained after the PAP protocols. In that case, it may suggest that the improved performance registered at the start was countered by a negative influence of PAP on the swimming phase. When the time corresponding to start performance and turn was extracted from the total swimming time, the results showed that the strategy used concretely in the EWU deteriorated the swimming phase considerably. Specifically, the intra-individual variability raised to ~ 0.25 s compared with SWU and it meant a worsening of ~ 1.05 % on the coefficient of variation. Therefore, it is possible to conclude that the PAP warm-up made on the eccentric flywheel yielded positive results at the beginning of the race, but it may affect the swimming phase adversely.

One of the limitations of our study was that the influence of the warm-up protocols in upper limbs could be countered by the action of the lower limbs, because lower and upper limbs acted simultaneously during the task (1, 13). Therefore, we cannot accurately detect the positive or negative influence of the warm-up protocols by analyzing the overall race. Furthermore, when the time specifically developed by lower limbs was extracted from the total swimming time, it gave us an idea of how PAP affected the action of the upper limbs. However, we could not extract the influence of the leg kicking during the whole task. Therefore, such limitation when analyzing the swimming patterns, was also assumed. A greater stroke length was indeed obtained at 15-m with the PAP warm-up protocols in comparison with the SWU (EWU ~ 7%; RMWU ~ 6%). However, those values showed deterioration from this point onwards, predominantly in EWU, (Figure 3). Furthermore, stroke rating was lower after PAP warm-ups, specially remarkable at 35 m in comparison with SWU (Figure 3).

Therefore, the downward trend obtained in the swimming velocity after PAP warm-ups between 35 to 50 m may be linked to these factors. The progressive decline on the stroke length & rate values along with the progressive decrease experienced in the swimming velocity, seemed to be the result of fatigue caused by the PAP warm-ups upon the upper limbs.

In light of this, even though PAP was seen on lower limbs immediately, fatigue on upper limbs was observed soon after the start of the race. Considering the results of the present study, possibly the volume of the conditioning activity applied on lower limbs was appropriated, but exaggerated for upper limbs, concretely after eccentric warm-up (EWU). Another possible limitation of our study may reside in the time of rest given after upper limbs stimulation. According PAP basics, individualized responses are often obtained regarding the subjects level of physical conditioning (6). As fatigue and potentiation co-exists as responses of PAP, the extent of those responses is also related with the time of rest given after the conditioning activity (7). In this study, the time of rest was the same for all the subjects in both PAP warm-up protocols (6 min), and it possibly affected adversely the adaptations in some of the swimmers. Nevertheless, the results obtained after PAP based on repetition maximum (RMWU), seemed not to be as influenced by fatigue as obtained after EWU. Possibly, since the loads applied to the swimmers were in accordance with the strength test previously made on them, this contributed in keeping a balance between fatigue and potentiation. Conversely, if the swimmers were unable of maintaining a high performance after EWU at the end of the race, it is reasonable to state that this protocol possibly induced higher fatigue than potentiation, given the high requirements of power and strength occasioned by the eccentric overload (7, 23).

In conclusion, a PAP-based warm-up protocol might influence sprint swimming performance (50-m). The results suggest that performance in the first meters of a trial could be improved by a warm-up that includes swimming and PAP through eccentric or heavy conditioning exercise for lower limbs. However, other factors, such as fatigue, might impair performance, exerting an influence on swimming technique which could yield results that are contrary to those of the desired task. On the other hand, PAP through heavy conditioning exercises for both the upper and lower limbs seemed to maintain performance as in standard conditions. Future research should identify if suitable conditioning activity, testing different loads and rest times may induce greater adaptations on upper limbs than identified on the present study.

PRACTICAL APPLICATIONS

It is common to see how swimmers prepare for racing by activating themselves in many different ways, through ballistic stretches, by increasing their breathing and heart rate, or by strongly clapping their chest or limbs. Whether those methods really have an influence or not, is not part of this study. However, it cannot be rejected the fact that sprint swimmers need to create an extra activation on their system in order to race at the best of their capacities. The relevance of our study is that swimmers could find benefits from loaded stimulation protocols before a sprint race, at least on the first metres of the race. Considering the given outcomes, coaches could have the opportunity to adapt these basics to competitive constraints or individual characteristics on each case. Three aspects of interest emerged from this study; the first resides on the fact that swimmers could benefit from strength/resistance training in swimming as long as they keep the ability to transfer it into the water propulsion within appropriate swimming patterns. Meaning that stronger swimmers could benefit from a technique of swimming based on long distances per stroke; the second resides on monitoring the strength parameters of the athletes by performing a strength test biomechanically similar to the real action, as swimming coaches should make more emphasis on the control and strength development of their swimmers; the third, including a familiarization PAP training in the habitual warm-up protocol also could induce favourable adaptations on the swimmers.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

The results of the present study are presented without fabrication, falsification or inappropriate data manipulation and do not constitute endorsement by NSCA. Authors have no conflict of interest into report.

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FIGURE AND TABLE LEGENDS

Figure 1. PAP Induction for Upper Limbs through the Arm Stroke conditioning exercise on an adapted "Smith Machine".

Figure 2. PAP Induction for Upper Limbs through the Arm Stroke conditioning exercise on an adapted nHANCE ULTIMATE®.

Figure 3, Stroke rate (SR) and stroke length (SL) on four different point marks (15, 20, 35 and 45 m) for the three protocols studied (n=17). * Differences in performance ($P < 0.05$)

Table 1. Means, SDs and confident intervals for the variables associated with swimming start performance; underwater undulatory swimming (after the swim start

and after turn); and isolated swimming phase, and best total swimming time (T50m), after the three warm-up protocols studied (n = 17).

Table 2. Means and SDs for the swimming split times (each 5 m) and swimming velocities (each 5 m), collected from a 50-m race after the three warm- up protocols studied (n = 17).

Effects of two types of activation protocols based on postactivation potentiation on 50-meter freestyle performance

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Brief running head: PAP on 50-meters freestyle.

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Dear Editorial Office at Journal of Strength and Conditioning Research,

On behalf of all co-authors, I would like to submit our original manuscript entitled "Effects of two types of activation protocols based on postactivation performance enhancement on 50-metre freestyle performance" for review and consideration as an original paper. Our study challenges the adaptability on performance on a sprint swimming race after applying an activation dryland protocol based on post-activation performance enhancement. Specifically, we tested if maximal or submaximal load repetitions applied on lower and upper limbs through an adapted Smith Machine or an Eccentric Flywheel, were able of provoking different results than classical swimming warm up. We tested different trials and outcomes of performance were obtained from the competition analysis. Approvals for the use of human subjects were obtained from local's university committee on consideration of WMA Declaration of Helsinki.

While the results of this study showed that final performance after classical swimming warm-up obtained better results than after experimental protocols, we saw indicators that alterations on performance occurred after these latter ones. Improvements on the first stages of a swimming race were observed as time and velocity at 5, 10 and 15 metres were better after post-activation performance enhancement. Nevertheless, other factors, such as fatigue, could modify the swimming patterns, and these factors could cause contrary results to the aimed task. The repetition maximum protocol seemed to be not affected as the eccentrick flywheel protocol. A possible reason might be that loads applied were in accordance with a previous strength test made on the swimmers. This fact possibly contributed to obtaine a better balance between fatigue and potentiation.

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Thank you for considering our manuscript, and we await your editorial decision.

Kind regards,

Francisco Cuenca-Fernández on behalf of all co-authors.

Figure

Figure

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Figure

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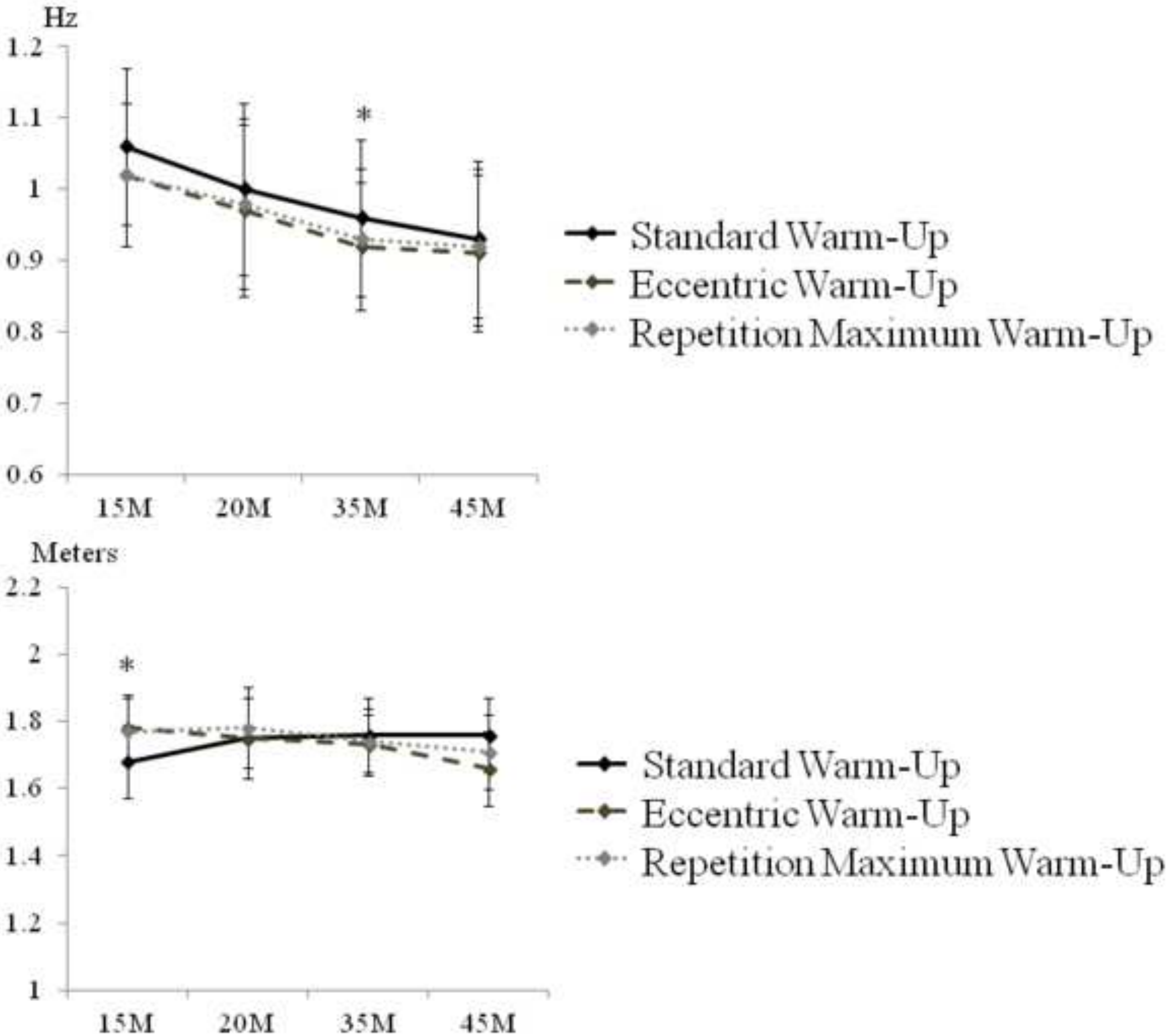

Table

Table 1. Means, SDs and confident intervals for the variables associated with swimming start performance; underwater undulatory swimming (after the swim start and after turn); isolated swimming phase and best total swimming time (T50m), after the three warm-up protocols studied (n = 17).

	Standard Warm-Up		Eccentric Warm-Up		Repetition Maximum Warm-Up	
	Mean ± SD	**CI (95%)**	**Mean ± SD**	**CI (95%)**	**Mean ± SD**	**CI (95%)**
BT (s)	0.658 ± 0.09	0.609 – 0.707	0.657 ± 0.079	0.616 – 0.698	0.653 ± 0.08	0.608 – 0.699
DT (s)	0.931 ± 0.09	0.881 – 0.981	0.935 ± 0.10	0.880 – 0.991	0.944 ± 0.13	0.878 – 1.012
DD (m)	3.11 ± 0.26	2.98 – 3.25	3.20 ± 0.32	3.04 – 3.37	3.14 ± 0.29	2.99 – 3.30
DV (m/s)	3.26 ± 0.33	2.97 – 3.33	3.40 ± 0.49*	3.02 – 3.39	3.31 ± 0.47	2.99 – 3.34
AT (º)	27.76 ± 6.14§	24.60 – 30.92	31.17 ± 6.40	27.88 – 34.47	32.17 ± 7.11	28.51 – 35.83
AE (º)	39.11 ± 4.37	37.16 – 41.66	40.41 ± 3.75	38.47 – 42.34	40.35 ± 4.28	38.14 – 42.55
UUSss (m)	10.09 ± 1.72	9.20 – 10.97	9.96 ± 1.71	9.07 – 10.84	10.00 ± 1.75	9.09 – 10.90
UUS_{TU} (m)	5.97 ± 1.17	5.36 – 6.57	5.58 ± 2.06	4.52 – 6.64	5.50 ± 2.05	4.44 – 6.55
ISP (s)	20.86 ± 0.95	20.37 – 21.36	21.25 ± 1.12§	20.66 – 21.83	20.97 ± 1.22	20.34 – 21.60
T50m (s)	27.28 ± 1.42	26.73 – 28.70	27.51 ± 1.43	26.96 – 28.82	27.31 ± 1.45	26.88 – 28.74

* Differences ($p < 0.05$) in performance compared with the SWU.

§ Differences ($p < 0.05$) in performance in the comparison of all of the studied protocols.

Table

Table 2. Means and SDs for the split times (each 5 m) and swimming velocities (each 5 m), collected from a 50-m race after the three warm-up protocols studied (n = 17).

	Standard Warm-Up		**Eccentric Warm-Up**		**Repetition Maximum Warm-Up**	
	Split time (s)	**Velocity (m/s)**	**Split time (s)**	**Velocity (m/s)**	**Split time (s)**	**Velocity (m/s)**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
5 m	1.57 ± 0.11	3.12 ± 0.28	1.52 ± 0.13*	3.28 ± 0.27*	1.52 ± 0.13*	3.27 ± 0.29*
10 m	2.78 ± 0.26	1.79 ± 0.17	2.73 ± 0.26	1.83 ± 0.15*	2.72 ± 0.28	1.84 ± 0.16*
15 m	2.84 ± 0.17	1.74 ± 0.11	2.80 ± 0.27	1.80 ± 0.21	2.80 ± 0.16	1.79 ± 0.10
20 m	2.85 ± 0.12	1.75 ± 0.02	2.96 ± 0.28*	1.74 ± 0.04	2.97 ± 0.17*	1.72 ± 0.02
25 m	3.28 ± 0.24	1.53 ± 0.10	3.33 ± 0.30	1.51 ± 0.12	3.29 ± 0.29	1.53 ± 0.13
30 m	2.06 ± 0.19	2.44 ± 0.21	2.02 ± 0.09	2.47 ± 0.11	2.02 ± 0.10	2.47 ± 0.12
35 m	3.06 ± 0.19	1.63 ± 0.10	3.09 ± 0.17	1.62 ± 0.08	3.06 ± 0.18	1.63 ± 0.09
40 m	2.98 ± 0.13	1.68 ± 0.07	3.03 ± 0.19	1.65 ± 0.10	3.03 ± 0.20	1.65 ± 0.10
45 m	3.06 ± 0.13	1.63 ± 0.07	3.10 ± 0.15	1.60 ± 0.07	3.07 ± 0.15	1.63 ± 0.08
50 m	2.80 ± 0.14	1.61 ± 0.08	2.85 ± 0.25	1.58 ± 0.14	2.78 ± 0.32	1.58 ± 0.14

* Differences ($p < 0.05$) in performance compared with the SWU

§ Differences ($p < 0.05$) in performance in the comparison of all of the studied protocols.