SciMedCentral

Annals of Sports Medicine and Research

Research Article

Can Short, Intense Exercise Before Sprinting Improve Times?

Gabriela da Cunha Brandão Reis[1,2], Mostafa A. Hegazy[1], Martin R. Wahle[3], and Jeffrey W. Bell[4]

[1]*Department of Science, Southwest Minnesota State University, USA*

[2]*Université Paris-Saclay – UFR STAPS, Bures-sur-Yvette, France*

[3]*Department of Education, Southwest Minnesota State University, USA*

[4]*College of Individual and Community Health, Bemidji State University, USA*

***Corresponding author**

Gabriela da Cunha Brandão Reis, Department of Science, Southwest Minnesota State University. Minnesota, United States, Université Paris-Saclay – UFR STAPS, 335 Rue Pierre de Coubertin, 91440 Bures-sur-Yvette, France, Tel: +33 0749149561

Submitted: 26 September 2023

Accepted: 30 October 2023

Published: 31 October 2023

ISSN: 2379-0571

Keywords

- Post-activation performance-enhancement
- Swimming
- Performance
- Warm-up
- Sprint

Abstract

Introduction: Skeletal muscle contractile response is partially determined by recent contractile history. Post-activation performance-enhancement (PAPE) is a phenomenon that increases muscle force beyond previous contractions. Pre-load exercise potentiates short-term effects on explosive exercises, which may benefit sprint swimming.

Aim: The purpose of this study was to determine if short, high-intensity pre-load exercises before sprinting improves 25-yard sprint times. Methods: Eleven female DII swimmers with different years of experience (age 19.09 ± 1.58, height 169 ± 5.92 cm, mass 64.65 ± 9.56 kg) completed a baseline sprint followed by three sprints under two conditions, with and without PAPE conducted 48 hours apart, in a randomized crossover design.

Results: Although there was a tendency for PAPE to improve time on sprint 1, there was no statistical difference ($p > 0.5$).

Conclusion: There was no significant difference after PAPE, however, no detrimental effects were observed. Athletes may choose to use PAPE as a warm-up or part of a pre-race routine.

ABBREVIATIONS

PAPE: Post-Activation Performance Enhancement

INTRODUCTION

The contractile response of skeletal muscle is partially determined by its contractile history. The enhancement of voluntary contractions several minutes after previous contractions has been referred to as post-activation performance-enhancement (PAPE) [1]. Factors that influence PAPE still need to be defined, but changes in muscle temperature, increases in muscle strength and/or contraction speed triggered by changes in fluid in the muscles can improve muscle function [2]. These elements depend on muscle strength, fiber-type and individual training background [3-5]. Repetitive stimulation may result not only in fatigue, which may negatively impact performance, but also may lead to improved performance through this phenomenon. Identifying the conditions that increase contractile force will enable the refinement of strategies that can optimize force production.

Recent PAPE studies have investigated its effects on explosive power or motor performance [5-8]. Since performing loaded exercises can improve short-term performance via PAPE it has been recommended that warm-up procedures should integrate activities that create PAPE effects before competing in events that require explosive power [9,10].

Fatigue and potentiation can coexist, but fatigue diminishes faster than PAPE [4]. It is reasonable to assume there is probably an optimal period of time when the muscle has recovered but it is still potentiated, but previous studies indicate improved performance can be attained over various delays ranging from immediately up to as much as fifteen minutes [4]. The time delay, intensity of pre-load activity, and type of muscle contraction needed to elicit PAPE can vary between individuals [11]. This difference in response has been attributed to stronger individuals having a greater proportion of type 2 muscle fibers than less strong individuals [9,11] and it is well-known that type 2 muscle fibers have greater capacity for muscle power generation due to higher shortening velocity.

PAPE may improve performance in sprint running [7,12,13] and performance of explosive activities for basketball, luge and throwing [11]. Chatzopoulos et al., reported improvement in 30m sprint after performing 10 sets of 1 repetition at 90% of 1RM of back squat in team sport players [11]. Linder et al., reported a 0.19s improvement with PAPE in 100m track running times for female collegiate runners [12]. The results described above mostly utilize muscle activation and coordination patterns of the lower-body. The main contribution to overall propulsion in freestyle swimming, however, is the upper-body with the contribution for arm stroke and leg kicking of 66.6% versus 33.4% respectively for females [15,16]. This makes it reasonable to assume that PAPE interventions for sprint freestyle swimmers should combine upper and lower body stimuli. Ng et al., examined the effects of a warm-up with PAPE using countermovement jumps on kicking thrust in male swimmers and reported a significant increase in peak pulling thrust and a trend for increased mean thrust by 15.14% and 14.60% respectively; they also found a change in kicking kinematics, where speed and speed fluctuation improved by 10% [8]. Barbosa et al., reported a large improvement in in arm-pull mean thrust (participant range of 13% to 19%) and a small improvement in overall performance (about 3%) using swim-pattern specific pulling exercises with resistance bands to stimulate PAPE in male swimmers [5]. In addition, PAPE performed by male and female swimmers during warm-up also improved start performance with an increase in vertical force that translates to a higher takeoff velocity compared to a typical warm-up [17]. One study showed a large effect of PAPE on 100m sprint performance (0.54 s) with no differences in improvement between male and female swimmers by using a "Power Rack" to provide the load during warm-up [18], but this type of equipment is not portable and would not be available to athletes during competition.

Therefore, the main objective of this study was to determine if PAPE exercises performed by female swimmers using readily available equipment and body weight exercises can improve sprint performance on a series of short sprints. A second objective was to determine if multiple exposures to PAPE or warm-up style sprints can enhance sprinting and improve times. This study can provide valuable information to coaches and swimmers on how to prepare for maximum sprint.

MATERIALS AND METHODS

Subjects

Twelve female competitive swimmers (age: 19.1±1.6 years, height: 169.0±5.9 cm, body mass: 64.7±9.6 kg, body fat: 24.3±4.6 %, training experience: 10.8±3.7 years) from an NCAA Division 2 swim team were recruited to participate in the study. The team was in its second year of competition after being reinstated as a team by the university after 39 years from its discontinuance; thus, the largest portion of athletes were in their first or second collegiate season. The university does not sponsor men's swimming. One swimmer was not included in data analysis due to Z-scores for sprint times exceeding 2.5. The remaining participants included three freestyle sprinters, four backstrokers, two distance swimmers, one breaststroker, and one medley swimmer. Mean self-reported lifetime personal best record times in the 50 yard freestyle for the group was 25.96±1.13 seconds. All subjects provided written consent to participate and the study was approved by the local institutional review board (IRB Approval #S20-16). Participant characteristics are depicted in Table 1.

Study Design

The study used a randomized cross over design and required subjects to come to the natatorium two times, two days apart. Each session required about one hour. After performing a standardized warm-up (same for both days) subjects performed four 25-yard sprints every 5 minutes. On one day, subjects did not do any activity in between sprints during the resting period. On the other day, subjects completed 5 high effort upper-body exercise repetitions and 5 high effort lower-body exercise repetitions.

Data Collection

All sprints were performed using the "freestyle" stroke in a six lane, 25 yard (22.86 meter) indoor swimming pool. Sprints were timed using an automatic starting (Colorado Time Systems Infinity, Loveland Colorado, USA) and electronic timing system (Colorado Time Systems 6, Loveland Colorado, USA) fitted with touchpads at the opposite end of the pool. All sprints began from starting blocks and all sprints for all swimmers were performed in the same lane with no other swimmers in an adjacent lane. All times were recorded to the hundredth of a second.

Muscle Activation Exercises

Subjects completed 5 upper-body "pull-through" exercises using rubber tubing fitted with paddles (NZ Manufacturing, Talmadge Ohio, USA). Resistance provided by stretching the cord 1 to 3 times its original length has been reported by the manufacturer to provide 3.6 to 10.8 kg of resistance. Subjects were instructed to pull the tubing in a similar stroke pattern to their in-water freestyle stroke and give a strong effort. The tubing was attached to a railing at the participant's hip level. The participant bent at the waist while pulling the tubing back past the hips in a manner that caused the tubing to remain roughly parallel to the pool deck. Then subjects completed 5 lower-body "jump-squat" exercises. Briefly, after squatting down until hips were at the same level as knees, participants immediately jumped from a padded surface and were instructed to jump as high as possible repeatedly, with no rest between jumps. Both exercises were performed immediately upon finishing the previous sprint, exiting the water, and walking back to the starting end of the pool.

Statistics

Statistical analysis was conducted using SPSS 25 (IBM Corp., Armonk New York, USA). A paired t-test was used to compare first sprint times of each session. Since there was no difference between first sprint times, a 2 x 4 Repeated Measures ANOVA with PAPE (2 levels) and sprint number (4 levels) was employed. Normality was verified using Shapiro Wilk ($p \geq 0.05$)

Table 1: Descriptive statistics for participants

	Height (cm)	Mass (kg)	Body Fat %	Age (years)	Years in Swimming	Season best 45.8 meter free (s)*	Lifetime best 45.8 meter free (s)*	Classification in sport
S1	169	61.2	22.7	19	11	25.77	24.71	Sprinter
S2	162	55.6	22.3	20	10	25.06	24.2	Sprinter
S3	166	58.2	20.5	20	9	N/A	25.02	Backstroke
S4	177	61.7	22.8	18	7	25.41	25.41	Backstroke
S5	166	68.8	29.5	18	8	26.52	26.4	Backstroke
S6	168	53.4	15.7	18	10	N/A	N/A	Distance
S7	163	60.2	25.2	20	13	27.36	27.36	Distance
S8	163	65.7	29	18	5	27.2	27.02	Sprinter
S9	172	86.8	31.5	18	14	N/A	27.47	Backstroke
S10	180	75.3	26.6	18	14	26.19	26.19	Breaststroke & IM
S11	173	64.2	21.9	23	18	25.81	25.81	Breaststroke
Mean ± sd	169 ± 5.92	64.65 ± 9.56	24.34 ± 4.58	19.09 ± 1.58	10.82 ± 3.71	26.17 ± 0.82	25.96 ± 1.13	

* The 50 yard freestyle is the shortest sprinting event in the competitive division for the participants. It is colloquially referred to as 50 free. This distance is 45.8 meters and the time reported by the participant was achieved in competition.

and sphericity was confirmed via Mauchly's Test (p≥0.05). Due to the small sample size, paired-sample t-tests were also performed for the difference of each sprint time (mathematical difference of second, third, and fourth sprint change in time from first sprint performed as separate t-tests) from the first sprint of the session. An a priori p-value < 0.05 was considered statistically significant. All variables are presented as mean ± standard deviation.

RESULTS AND DISCUSSION

The purpose of this study was to examine the effects of PAPE exercises performed prior to a 25-yard sprint freestyle. The results did not support the hypothesis as there were no significant improvements in the 25-yard sprint freestyle times. No significant differences in the pre-intervention (i.e. first sprint of four) reference sprint time were determined via paired T-test for the control and PAPE trials respectively (12.91±0.49 vs. 12.99±0.61 seconds, p=0.17). Repeated Measures ANOVA analysis (Figure A) revealed no main effects of intervention condition in PAPE and no PAPE trials (12.95±0.05 vs. 12.91±0.04 seconds, p=0.89) or repeated sprints.

Interestingly, there was a small, non-significant decrease in mean time after each trial in both conditions with repeated sprints but only for the third and fourth sprint in the trials without PAPE [Table 2]. Paired t-tests performed on the change in time from the reference sprint (sprint 1) to the subsequent sprints in the series revealed no significant differences for reference sprint to sprint 2 (p=0.25), reference sprint to sprint 3 (p=0.22), and reference sprint to sprint 4 (p=0.42). Effect sizes calculated as Cohen's d for each of these pairs was small (d = 0.24, 0.23, and 0.35 respectively).

Although non-significant, Figure A shows a small decrease in time from the control trial to sprint 1 in the PAPE condition while the no PAPE condition shows a small increase in time from the control trial to sprint 1. The lack of significance may have been due to variability between subjects, with a wide range of years of experience in swimming and different classifications in sport. Previous studies with higher-level athletes (national and international) reported significant results [13,17,19].

Barbosa et al. found significant improvements in arm pull thrust in male swimmers (age 22.13 ± 3.84 years) after performing conditioning exercises with resistance bands for the upper limbs, showing a large improvement in arm-pull thrust (about 13% to 19%) and a small overall improvement in performance (almost 3%) [5]. Ng et al., reported meaningful increases in peak and mean thrust when PAPE was included in the warm up [8]. Hancock et al., also reported significant improvements in times of a longer sprint while examining the effects of PAPE on performance during a 100-m freestyle in collegiate swimmers, with more than half a second of improvement when performing the PAPE routine [18].

This study is limited to female Division II swimmers, and it is unclear if male subjects would have a similar response. Although male athletes have more muscle mass than female athletes, females are generally more fatigue resistant and can recover faster [20]; therefore, future studies should investigate sex differences. A small sample size due to the number of swimmers on the team in the current investigation may have led to a Type II error and prevented finding differences; therefore, further examination should use a larger number of subjects. Originally, this study intended to also include 14 to 18-year-old subjects from the local high school team, however, Covid-19 safety protocols prevented testing of those athletes. In addition, specificity of training should be considered in study design; the current study had only 27% of the subjects that were considered true freestyle sprint swimmers.

Although not measured in this study, percentage of type II muscle fibers may be playing a role in the response to PAPE for repeated sprints [9,11]. Type 2 muscle fibers undergo greater phosphorylation of myosin regulatory light chains when responding to a conditioning activity [21,22].This means that athletes with a higher percentage of type II fibers exhibit greater force and power production after the use of activation exercises, which can have a significant influence on the early stages of PAPE. However, individuals with more type II fibers will also generate more metabolites associated with fatigue [10] that may affect individualized resting time.

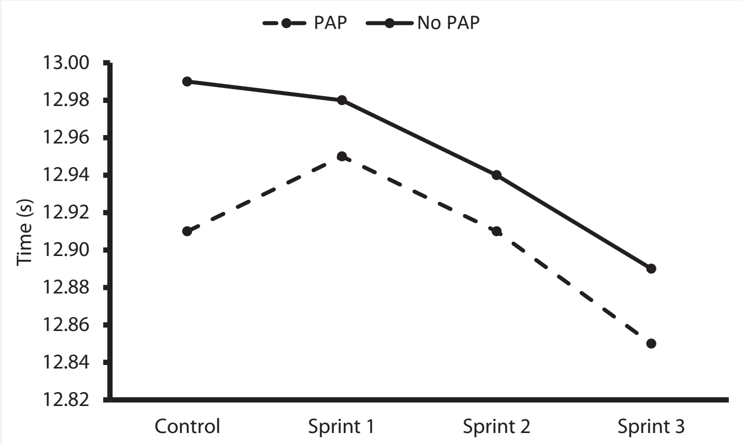

Figure 1 Times for repeated sprints by PAPE condition. PAPE = post-activation performance-enchantement.

Table 2: Mean and standard deviation for each sprint time (s) (T1, T2, T2 and T4) and mean and standard deviation for each participant in reference condition (no PAPE)

Participant	T1 (s)	T2 (s)	T3 (s)	T4 (s)	Mean ± sd (s)
1	12.08	12.08	12.08	12.28	12.13 ± 0.10
2	12.79	12.76	12.73	12.77	12.76 ± 0.02
3	12.38	12.36	12.32	12.25	12.33 ± 0.06
4	13.19	13.27	12.96e	12.72	13.04 ± 0.25
5	12.90	12.88	13.00	12.86	12.91 ± 0.06
6	13.77	13.88	13.84	13.72	13.80 ± 0.07
7	13.49	13.46	13.54	13.53	13.51 ± 0.04
8	12.90	13.18	13.31	12.84	13.06 ± 0.22
9	13.18	13.05	12.98	13.11	13.08 ± 0.09
10	12.49	12.54	12.36	12.39	12.45 ± 0.08
11	12.88	13.00	12.93	12.92	12.93 ± 0.05
Mean	12.91 ± 0.49	12.95 ± 0.51	12.91 ± 0.53	12.85 ± 0.47	12.91 ± 0.04

Table 3: Mean and standard deviation for each sprint time (s) (T1, T2, T2 and T4) and mean and standard deviation for each participant in PAPE condition

Participant	T1 (s)	T2 (s)	T3 (s)	T4 (s)	Mean ± sd (s)
1	12.13	12.10	12.07	12.16	12.12 ± 0.04
2	12.81	12.84	12.61	12.53	12.70 ± 0.15
3	12.22	12.20	12.24	12.31	12.24 ± 0.05
4	13.16	13.14	12.94	12.39	12.91 ± 0.36
5	12.97	12.96	12.97	12.90	12.95 ± 0.03
6	14.06	13.91	13.99	14.03	14.00 ± 0.07
7	13.97	13.76	13.93	13.75	13.85 ± 0.11
8	13.05	13.18	13.17	13.08	13.12 ± 0.06
9	13.15	13.21	13.15	13.12	13.16 ± 0.04
10	12.59	12.65	12.53	12.56	12.58 ± 0.05
11	12.82	12.87	12.74	12.95	12.85 ± 0.09
Mean	12.99 ± 0.61	12.98 ± 0.56	12.94 ± 0.61	12.89 ± 0.59	12.95 ± 0.05

Resting time between the conditioning activity and the explosive activity should be longer for stronger individuals with more type II fibers [11]. Thus, future research should study how to address the effects of differences in strength between individuals. A possibility would be manipulating the amount of load of the exercises for a greater amount of activation as well as manipulating the rest time between the PAPE and sprint performance. Additionally, the longer the recovery period between the activity and the beginning of performance, the greater the recovery from fatigue, but also the greater the decay of the PAPE effect [3,6]. The most effective way to determine the best protocol for an individual may be to try different recovery periods and analyze performance, in other words, using the trial-and-error method [11].

CONCLUSION

Despite the limitations, participants tended to decrease sprint times after performing PAPE exercises. Despite the lack of a main effect of PAPE, no detrimental effects were observed, so athletes may then choose to use PAPE as a warm-up or part of a pre-race routine. Since swimming races are timed in 0.01-second increments, even a small difference could result in the loss of a race, especially in a championship format. It is important to understand that numerous factors not explored in this study may yield individual differences. Thus, a trial-and-error method can help coaches and athletes discover if and what type of PAPE protocol is best for a given individual.

REFERENCES

1. Cuenca-Fernández F, Smith I, Jordan M, MacIntosh B, López-Contreras G, Arellano R, et al. Non-localized postactivation performance enhancement (PAPE) effects in trained athletes: a pilot study. A Phy Nut Met. 2017; 42: 1122-1125.

2. Blazevich AJ, Babault N. Post-activation potentiation versus post-activation performance enhancement in humans: historical perspective, underlying mechanisms, and current Issues. Frontiers Physiol. 2019; 10: 1359.

3. Sale DG. Postactivation potentiation: role in human performance. Exerc Sport Sci Rev. 2002; 30: 138-143.

4. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sports Med. 2009; 39: 147-166.

5. Barbosa TM, Yam JW, Lum D, Balasekaran G, Marinho DA. Arm-

pull thrust in human swimming and the effect of post- activation potentiation. Sci Rep. 2020; 10: 8464.

6. Borba DDA, Gomes L, Coelho M. Effect of post-activation potentiation in athletics: a systematic review. Rev Bras de Cineantropom. Desempenho Hum. 2017; 19: 128-139.

7. Cuenca-Fernández F, López-Contreras G, Arellano R. Effect on swimming start performance of two types of activation protocols: lunge and YoYo squat. J Strength Cond Res. 2015; 29: 647-655.

8. Ng F, Yam JW, Lum D, Barbosa TM. Human thrust in aquatic environment: the effect of post-activation potentiation on flutter kick. J Adv Res. 2019; 21: 65-70.

9. Chiu Lzf, Fry Ac, Weiss Lw, Schilling Bk, Brown Le, Smith Sl. Postactivation potentiation response in athletic and recreationally trained individuals. J Strength Cond Res. 2003; 17: 671-677.

10. Hodgson M, Docherty D, Robbins D. Post-activation potentiation: underlying physiology and implications for motor performance. Sports Med. 2005; 35: 585-595.

11. Gołaś A, Maszczyk A, Zajac A, Mikolajec K, Stastny P. Optimizing post activation potentiation for explosive activities in competitive sports. J Hum Kinet. 2016; 52: 95-106.

12. Linder EE, Prins JH, Murata NM, Derenne C, Morgan CF. Effects of preload 4 repetition maximum on 100-m sprint times in collegiate women. J Strength Cond Res. 2010; 24: 1184-190.

13. Sarramin VG, Turner AN, Greenhalgh AK. Effect of postactivation potentiation on fifty-meter freestyle in national swimmers. J Strenght Cond Res. 2015; 29: 1003-1009.

14. Chatzopoulos DE, Michailidis CJ, Giannakos AK, Alexiou KC, Patikas DA, Antonopoulos CB, et al. Postactivation potentiation effects after heavy resistance exercise on running speed. J Strength Cond Res. 2007; 21:1278-1281.

15. Deschodt J V, Arsac LM, Rouard AH. Relative contribution of arms and legs in humans to propulsion in 25-m sprint front-crawl swimming. Eur J Appl Physiol Occup Physiol. 1999; 80: 192-199.

16. Morouço PG, Marinho DA, Izquierdo M, Neiva H, Marques MC. Relative contribution of arms and legs in 30s fully tethered front crawl swimming. Biomed Res Int. 2015; 67.

17. Cuenca-Fernández F, López-Contreras G, Mourão L, de Jesus K, de Jesus K, Zacca R, et al. Eccentric flywheel post-activation potentiation influences swimming start performance kinetics. J Sports Sci. 2019; 37: 443-451.

18. Hancock AP, E.Sparks K, Kullman EL. Postactivation Potentiation Enhances Swim Performance in Collegiate Swimmers. J Strenght Cond Res. 2015; 29: 912-917.

19. West DJ, Owen N, Cunningham D, Cook CJ. Strength and power predictors of swimming starts in international sprint swimmers. J Strength Cond Res. 2011; 25: 950-955.

20. Glenmark B, Nilsson M, Gao H, Gustafsson ke, Dahlman-Wright K, Westerblad H, et al. Difference in skeletal muscle function in males vs. females: role of estrogen receptor-beta. Am J Physiol Endocrinol Metab. 2004; 287: 1125-1131.

21. Sweeney HL, Stull JT. Alternation of cross-bridge kinetics by myosin light chain phosphorylation in rabbit skeletal muscle: Implications for regulation of actin-myosin interaction. Proc Natl Acad Sci U S A. 1990; 87: 414-418.

22. 22.Vandenboom R. Modulation of skeletal muscle contraction by myosin phosphorylation. Compr Physiol. 2017; 7: 171-212.