Spor Hekimliği Dergisi
Turkish Journal of Sports Medicine
Turk J Sports Med. DOI: 10.47447/tjsm.0821

Research Article / Araştırma Makalesi

Post-Activation Performance Enhancement (PAPE) interventions at different loads may enhance sprint performance in well-trained athletes

Farklı yüklerde Aktivasyon Sonrası Performans Arttırma (ASPA) girişimleri iyi antrenmanlı sporcularda sprint performansını artırabilir

Sümeyye Genç[1], Egemen Mancı[2], Çağdaş Güdücü[3], Erkan Günay[4]

[1]*Department of Physical Education and Sports, Dokuz Eylül University, Izmir, Türkiye*
[2]*Department of Exercise and Sport Sciences, Democracy University, Izmir, Türkiye*
[3]*Department of Biophysics, Dokuz Eylul University, Izmir, Türkiye*
[4]*Department of Sport Science, Celal Bayar University, Manisa, Türkiye*

ABSTRACT

Objective: The aim of this study was to evaluate and compare the effects of back squat exercise on subsequent sprint performance in resistance-based Post Activation Performance Enhancement (PAPE) intervention with two different loads and repetitions.

Material and Methods: Subjects performed three experimental runs in the laboratory for at least 48 hours apart. At the first experimental visit, anthropometric evaluations, sprint performance and one-repetition maximum (1RM) tests were performed. On the next two visits, each subject completed a standardized warm-up on the bicycle ergometer at 30 watt/ 60 cadence for 5 minutes, and after a passive transition phase period of 5 minutes, they performed the resistance based back squat PAPE protocol. After a 12-minute passive transition phase period, subjects performed the sprint cycling performance.

Results: PAPE interventions with 1RM%60x6 reps (moderate rep-moderate load) and 1RM %90x3 reps (low rep-high load) loads resulted in statistically insignificant slight improvement in mean power values ($p<0.47$), and no significant effect on peak power ($p<0.91$), and fatigue index ($p<0.79$) in sprint cycling performance.

Conclusion: The PAPE interventions resulted in a slight increase in the mean power values when compared to the control condition. However, there was no statistically significant difference between the two differential loads.

Keywords: *Post-activation performance enhancement (PAPE), back squat, cycling sprint performance, peak power*

ÖZ

Amaç: Bu çalışmanın amacı, iki farklı yük ve tekrarla yapılan direnç temelli Aktivasyon Sonrası Performans Arttırma (ASPA) girişimlerinde back squat egzersizinin sonraki sprint performansı üzerindeki etkilerinin araştırılmasıdır.

Gereç ve Yöntemler: Çalışma 48 saatten daha uzun aralıklardan oluşan üç oturumdan oluşmaktadır. İlk laboratuvar ziyaretinde katılımcıların antropometrik özellikleri, bisiklet ergometresinde sprint performans ölçümü ve 1 tekrar maksimal (1-TM) back squat testi parametreleri ölçülmüştür. Sonraki iki ziyarette, her katılımcı bisiklet ergometresinde 5 dakika boyunca 30 watt yüke karşılık 60 kadansta standart bir ısınma protokolünü tamamlamış ve 5 dakika pasif geçiş fazı süresinden sonra randomize bir şekilde direnç temelli ASPA protokolünü uygulamıştır. 12 dakikalık bir pasif geçiş fazı sonrası bisiklet ergometresinde sprint performans testi gerçekleştirilmiştir. Katılımcıların, zirve güç, ortalama güç ve yorgunluk indeksi değerleri kaydedilmiştir.

Bulgular: 1-TM %60x6 tekrar (orta tekrar-orta yük) ve 1-TM %90x3 tekrar (düşük tekrar-yüksek yük) yükleriyle yapılan ASPA girişimleri sprint bisiklet egzersiz performansının ortalama güç çıktılarında istatistiksel olarak anlamsız bir iyileşmeyaratmış, ($p<0.47$), zirve güç ($p<0.91$) yorgunluk indeksi değerlerinde ($p<0.79$) ise anlamlı bir etkisi olmamıştır.

Sonuç: ASPA girişimlerinin kontrol koşuluna göre ortalama güç değerlerini ılımlı derecede iyileştirdiği ancak uygulanan yükler arasında anlamlı bir fark bulunmadığı görülmüştür.

Anahtar Sözcükler: *Aktivasyon Sonrası Performans Arttırma (ASPA), back squat, bisiklet sprint performansı, zirve güç*

INTRODUCTION

The capacity to elicit muscle power quickly is critical for successful outcomes in sprinting and sprint-based athletic events. Research shows that Post Activation Performance Enhancement (PAPE) is a phenomenon that can acutely increase muscle strength and, therefore performance (1,3). The physiological underpinnings of this phenomenon are

Received / Geliş: 26.09.2023 · **Accepted / Kabul:** 11.10.2023 · **Published / Yayın Tarihi:** 27.10.2023

Correspondence / Yazışma: Erkan Günay · Celal Bayar Üniversitesi, Spor Bilimleri Bölümü, Manisa, Türkiye · erkan.gunay@cbu.edu.tr

Cite this article as: Genc S, Manci E, Guducu C, Gunay E. Post-Activation Performance Enhancement (PAPE) interventions at different loads may enhance sprint performance in well-trained athletes. *Turk J Sports Med.* 2023 Oct 27th; https://doi.org/10.47447/tjsm.0821

associated with increased sensitivity of the actin-myosin complex to calcium in muscle through maximal or near maximal voluntary contractions, enhanced myosin regulatory light chain phosphorylation or motor unit firing rate and strengthening of the neuromuscular system through recruitment of higher-order motor units (4). In this direction, numerous studies have tried to identify methods to elicit PAPE through various activities during warm-up routines (2,3,5,6-10). Resistance-based studies are associated with optimal resistance repetition numbers (10, 11), the optimal exercise model used (12), as well as the transition phase between stimulation and performance (13, 14).

Sprint performance is considered an important determinant of high-level sports performance (15). Significant research to date has found strong relationships between lower body strength and sprint performance (16). Resistance-based exercises have a strong positive physiological transfer between warm-up and main performance, which creates favorable conditions for enhancing the PAPE effect. Therefore, most of the researches focus on the load-response relationship, and recent findings suggest that both high intensity and heavy resistance exercises with low repetition rates (11, 17–20) are effective in improving performance and that interventions using moderate or low loads (11, 21–23) may also have a positive effect on performance.

The aim of the study was therefore to evaluate and compare the effects of back squat exercise on subsequent sprint performance in PAPE interference with two different loads and repetitions. Our hypothesis is that high-load, low-repetition back squat-based PAPE may improve cycling sprint performance more than moderate-load, moderate-repetition.

MATERIAL and METHODS

Experimental approach to the problem

Subjects participated to three experimental sessions in the laboratory, at least 48 hours apart. Anthropometric measurements, sprint cycling performance, and the one-repetition maximum (1RM) tests were performed before the first experimental visit. In the next two visits, each subject completed a standardized warm-up for 5 minutes at a power of 30 watt/ 60 rpm, on the cycle ergometer. Subsequently, subjects performed the PAPE protocol after 5 min. passive rest. Subjects performed the cycling sprint performance after 12 min. passive transition phase (Figure 1).

Subjects

We used version 3.1.9.7 of the G*Power program to determine the number of participants required in this study. We measured the effect size as 0.7 from the variance. The alpha error was determined as 0.05. Regarding these values, the minimum number of participants was calculated as 7 (24). However, 10 male competitive athletes (seven basketball and three martial arts athletes) were included in our study (Table 1). The criteria for inclusion in the study were the absence of any injury or illness, a regular training activity with at least 3 training sessions per week, and regular participation in competitions. The athletes were prohibited from intense physical activities for 3 days before and alcohol and caffeine consumption for 24 hours before the study. Data were obtained at specific time intervals of the day (02.00–05.00 PM) for each participant. Participants were informed of potential risks associated with the study and about experimental designs before all the tests and gave their signed consent before their participation. The Ethics Committee of Dokuz Eylül University approved all procedures and the experimental design (GOA 2022/39-08). The study protocol is in accordance with the latest version of the Declaration of Helsinki.

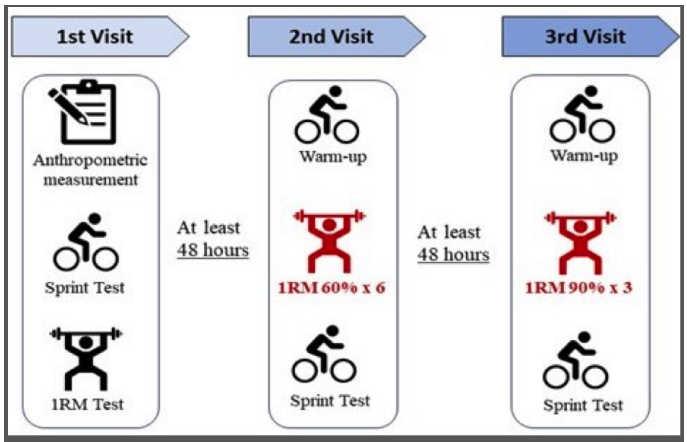

Figure 1. Experimental design 1RM: One repetition maximum

Procedures

Anthropometric data collection

The height measurements of the participants were obtained with a manual stadiometer. The distance between the top of the head and the sole of the foot was determined in an upright position with the back turned and recorded in centimeters (cm). Body weights were measured using an electronic scale and recorded in kilograms (kg).

One repetition maximum back squat test

The starting load for 1RM test is defined as the weight that athletes feel they can or they are capable of lifting during the back squat process based on their previous experience with a minimum of 4 repetitions. If the participants successfully lifted less than 4 repetitions, a 5-minute rest was provided and the test was repeated with a reduced load. On the other hand, if the participant successfully lifted more

than 12 repetitions, a 5-minute rest interval was given and the load was increased for the next round of lifting (26). The lifts during the back squat were obtained using Olympic bars and free weights**.** In terms of lifting technique, the bar was at shoulder level, feet shoulder-width apart and knees and hips fully extended (2-s eccentric and 2-s concentric actions with a 1-s rest between each repetition). A Google metronome (60 bpm) was used to control the speed of the movement.

The estimated 1RM of the participants was obtained using the Epley formula (1RM= [weight lifted x number of reps x 0.0333] + weight lifted) **(25).**

Post-activation performance enhancement protocol

Participants performed 1 set of back squats using olympic bars and free weights, either 1RM 90%x 3 reps or 1RM 60%x 6 reps at normal speed (2-s eccentric and 2-s concentric actions with a 1-s rest between each repetition) after a standard warm up protocol. A Google metronome (60 bpm) was used to control the speed of the movement**.** To standardize the depth of the back squat during repetitions, the eccentric phase of the movement was performed until the knee angle was 90°.

Sprint cycling test

To measure peak power, average power and fatigue index, participants completed a 20-second sprint cycling test on a bicycle ergometer (Monark, LC6, Sweden). A five-minute warm-up at 30 watts with 60 rpm was done before the sprint performance. Following that, a 20-second sprint was completed, applying the load created by multiplying the participant's weight by 0.75 watt. During the 20 s sprint performance, all participants were verbally motivated by the researcher.

Statistical Analyses

The JASP 0.16.2. (JASP Team, 2018; https://jasp-stats.org/, accessed on 3 Sep 2023) program was used for statistical analysis and to create the raincloud plots. The absence or presence of the normal distribution of the data was assessed using the Shapiro–Wilk test. According to the results of the Shapiro–Wilk test, all variables were normally distributed Sprint performance (peak power, mean power, and fatigue index) results. Therefore, we used a parametric test (one-way repeated measure ANOVA for within-group comparisons). The significance level was set for all statistical tests at $\alpha < 0.05$, and 95% confidence intervals (CI 95%). Post hoc comparisons were performed with the Bonferroni test. The effect sizes were reported as Partial Eta squared (np^2). The effect size was rated as follows: small effect <0.01, medium effect <0.06, large effect <0.14 (27).

RESULTS

Table 1. Descriptive statistics

	Height (cm)	Weight (kg)	Age (years)	Training Age (years)	1RM (kg)
Mean	190	82.60	20.20	10.40	117.53
Std.Deviation	10	16.20	2.48	2.98	30.67
Minimum	177	62.00	18.00	5.00	85.97
Maximum	208	114.00	26.00	15.00	171.88

One-way repeated measures ANOVA was used to examine the effect of control condition, 1RM 60% load and 1RM 90% load on peak power. The main effects of loads on peak power were no**t** significant [$F (2, 18) = 0.08$, $p<0.91$, $np^2 = 0.009$); Figure 2]

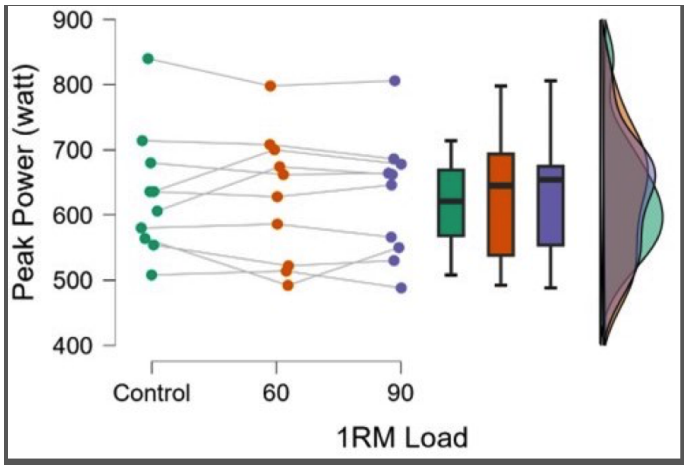

Figure 2. Peak power outputs during the cycling sprint performance

One-way repeated measures ANOVA was used to examine the effect of control condition, 1RM 60% load and 1RM 90% load on mean power. The main effects of loads on mean power were no**t** significant [$F (2, 18) = 0.77$, $p<0.47$, $np^2 = 0.079$); Figure 3].

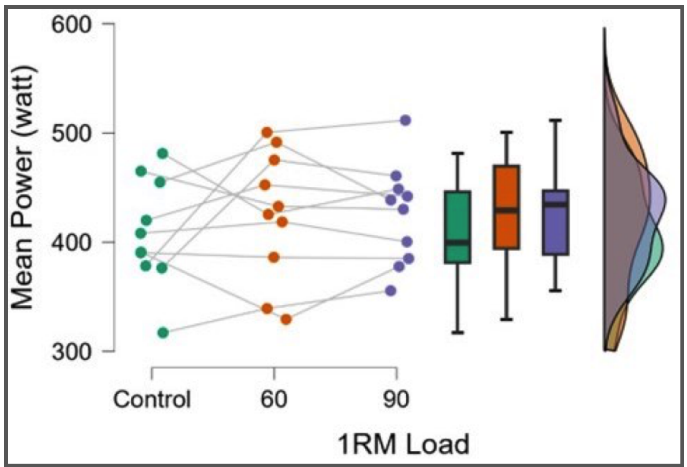

Figure 3. Mean power outputs during the cycling sprint performance

One-way repeated measures ANOVA was used to examine the effect of control condition, 1RM 60% load and 1RM 90% load on fatigue index. The main effects of loads on fatigue index were not significant [F (2, 18) = 0.23, p<0.79, np^2 = 0.025); Figure 4].

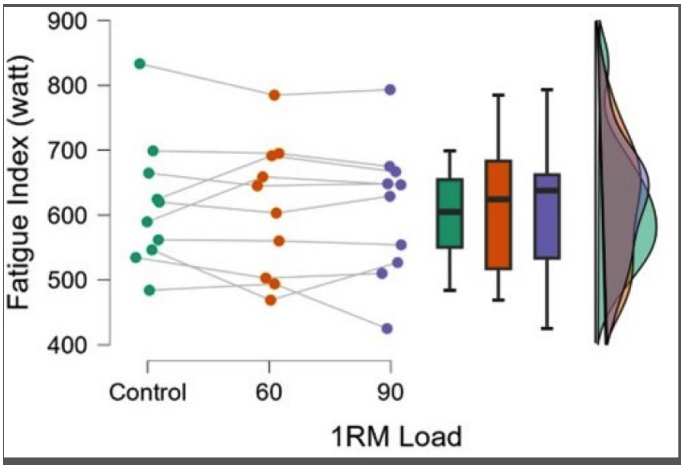

Figure 4. Fatigue index during the cycling sprint performance

Table 2. Peak power, mean power, and fatigue index mean power output values for baseline, 1RM 60%, and 1RM 90% conditions

Load (1RM %)	Peak Power Output	Mean Power Output	Fatigue index
Baseline	631	408	615
60%	628	425	610
90%	627	425	607

DISCUSSION

The aim of this study was to investigate the effect of moderate repetition-moderate load and low repetition-high load PAPE interventions on sprint performance outcomes. The main finding of the study was that the PAPE intervention, with one set of 1RM 60% x 6 repetitions and 1RM 90% x 3 repetitions of back squats, had a slight positive effect on the mean power level compared to the control condition. While this effect may not appear statistically significant, it should be considered that even slight improvements in well-trained competitive athletes could have a noticeable and significant impact on competition performance. On the other hand, no significant difference was found between the two loads, thus our hypothesis has not been confirmed.

Interventions to obtain PAPE are influenced by the balance between fatigue and neuromuscular potentiation (28,29) and the intensity of the load used (30). When the studies were examined, previous findings on the effects of PAPE interventions on performance have shown different results; some indicated that high load-low repetition (11, 17-20) positively affected performance, while some showed the positive effects of low load-high repetition (11, 21–23). In a similar study, researchers observed a significant difference in the sprint test result performed 4 minutes after 3 repetitions of back squat exercise at 1RM 90% load (18). In another similar study, Kilduff et al. (31) observed an improvement in Counter movement jump **(**CMJ**)** performance values (especially after 12 minutes) at 15 seconds, 4, 8, 12, 16, and 20 minutes after squat exercise with a load of 3RM. Atalag et al. (40) reported that they did not observe any improvement in 20-m yard and 40-m yard dash performance after an eight-minute transition phase with 1RM 90%x3 repetitions of back squat. Petisco et al. (32) found positive results in peak power output after 10 min. with 60%x10 repetitions, 80%x5 repetitions, and 100%x1 repetitions of 1RM, especially after 80%x5 repetitions of 1RM. In a different study with 40x3%, 60x3%, and 80x3% repetitions, the 30 m sprint improved significantly after 9 and 12 minutes, especially at low loads. The above-mentioned study results showed that resistance-based pope interventions contributed to performance increase, but performance responses might vary depending on the applied load. It is also understood that there are improvements in certain phases between intervention and performance. In the light of this information and our research results, we think that the ideal protocol should be created by coaches who have previously experienced the load and transition phases that provide maximum performance increase in resistance-based PAPE interventions. On the other hand, in real competition conditions, athletes complete all warm-up movements approximately 10 minutes before the competition and begin other preparation processes for performance (such as clothing, material preparation or psychological preparation). It is thought that competition-oriented PAPE applications would be useful in well-trained athletes.

The mechanisms underlying the effects of PAPE interventions using resistance on field-based sprint performance are not clear (18). Maximal sprint speed (distances >30 m) may depend on the strength of the hip extensor muscles to re-engage the leg in the swing phase and thus maintain an adequate stride length (33,34). Although PAPE intervention can increase muscle strength (1), this increase is dependent on the PAPE load (36). From a different perspective, heavy loads (>90% 1RM) and recovery times of >8 min may improve sprint performance (37). On the other hand, these results show differences according to the individual characteristics of the athletes (3). It is known that potentiation formation is lower in athletes with low strength potential, but the situation is different in those with high strength potential (11). The fact that the athletes who participated in our study were at the elite level with a long training background, and that might have influenced the findings. In athletes at peak performance levels, acute interventions may produce mini–

mal improvements, but minimal improvements may determine the first and second place at competitions.

Differences between the findings of the studies presented also have the potential to vary according to the duration of the transition phase of performance (35, 38) and the method of measurement (39). The use of the 1RM 60%x6 reps and 1RM 90%x3 reps protocols could be an effective strategy to improve the physical performance of well-trained athletes, with potential consequences for better performance, especially at the beginning of competitions. Although improvement is seen in physiologically based measurements, differences may be seen in field and laboratory-based performance measurements due to psychological, motivational, and environmental factors. Coaches should carefully consider the recovery time between PAPE administration and the start of the match to reduce the risk of fatigue. Furthermore, although the PAPE protocol in the present study led to a moderate improvement in the mean power outcomes, it should be elaborated considering the individual characteristics of the athletes.

Limitations

There are some limitations that need to be addressed. The number of participants was limited due to the small number of teams in the province where the study was conducted and the intense training and match schedule of the athletes. Therefore, further studies should be conducted with a larger sample size (if possible) to confirm, refute and/or extend our findings. In addition, the number of repetitions we determined may have been insufficient to show the outcomes of both loads.

CONCLUSION

Resistance-based high load-low repetition or medium load-moderate repetition PAPE interventions moderately increase the mean power value among sprint cycling performance of well-trained athletes. On the other hand, no potential difference was observed between the two applied loads. Future research should investigate the effects of different resistance loads on large groups of participants with similar 1RM values.

Acknowledgments / Teşekkür

We would like to thank all the participants in the study.

Ethics Committee Approval / Etik Komite Onayı

The Ethics Committee of Dokuz Eylül University approved all procedures and the experimental design (GOA 2022/39-08). The study protocol is in accordance with the latest version of the Declaration of Helsinki.

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

This study was carried out within the TUBITAK project and supported by the approval number 222S720 (TUBITAK 1002-A).

Author Contributions / Yazar Katkıları

Concept – EG; Design - EG; Supervision – EG, CG; Materials – Data Collection and/or Processing – SG, EM; Analyss and Interpretation – SG, CG; Literature Review – SG, EG; Writing manuscript – SG, EG, CG, EM; Critical Reviews – EG, EM, CG. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

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