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Original research papers

DIURNAL POST-ACTIVATION PERFORMANCE ENHANCEMENT (PAPE) EFFECT OF RESISTANCE PRIMING IN COLLEGE BADMINTON PLAYERS

SUDHEESH CHAKKUMMOLEL SUDHAKARAN[1], TADUNG DADA[2], RENJITH RAJAN[1], MUHAMMED SHAFI[1], NABEELA NAAZ SYED NISAR[3]

[1]Lakshmibai National College of Physical Education, Department of Exercise Physiology, India
[2]Rajiv Gandhi University, Department of Physical Education, India
[3]Sports Authority of India, Western Center, Gandhinagar, Gujarat, India

Mailing address: Sudheesh Chakkummolel Sudhakaran, Department of Exercise Physiology, Lakshmibai National College of Physical Education Kariavattopm P.O., Trivandrum, Kerala, India – 695 581,
e-mail: cssudheesh493@gmail.com

Abstract

Introduction. Badminton is characterized by intermittent power actions including high-intensity jumps, turns, strikes and lunges. Power, maximal strength, agility and speed endurance are of paramount importance for varied formats of badminton. Resistance priming (RP) aids in attaining post-activation performance enhancement (PAPE) in muscular activities. The study was aimed at examining the potential effect of resistance priming exercise on improving anaerobic variables in college badminton players measured at various time points. ***Material and Methods.*** Using a repeated measures design with within subject comparisons, the impact of resistance priming exercises on speed, jump height, agility, peak power, peak velocity and decline in power was examined at different points of time. Data were collected at the baseline, 30 minutes after, 8 hours and 24 hours following the intervention. SEMO agility test, 20 m sprint test, Kistler Force platform with MARS software and Wingate Anaerobic Power tests were used to test the players. ***Results.*** Repeated measures ANOVA determined that mean agility ($F(3,15) = 4.24$, $p = 0.013$, partial $\eta 2 = 0.458$), peak power ($F(3,15) = 11.46$, $p = 0.000$, partial $\eta 2 = 0.696$) and decline in power ($F(3,15) = 5.525$, $p = 0.009$, partial $\eta 2 = 0.525$) scores differed significantly across four time points. There were no significant differences in jump height ($p = 0.174$), speed ($p = 0.14$) and peak velocity ($p = 0.874$). ***Conclusions.*** Morning RP with exercises targeting upper body, lower body and full body induced a significant impact on agility, peak power and decline in power. The improvements were maximum eight hours following the intervention. Future studies may be conducted by incorporating Electromyography (EMG) analysis to examine the muscle activation as well.

Key words: resistance priming, post-activation performance enhancement, badminton

Introduction

Badminton is characterized by fast execution of skills such as attack, defense and changes in strategies [1], which require muscular endurance along with maximal and explosive muscle strength [2]. Varied aspects of strength such as arm strength, leg strength, abdominal strength and grip strength have a positive relation with badminton performance [3, 4]. In the male category, most of the winning shots are smashes [5], which are positively correlated with peak force and rate of force development. Peak force and rate of force development in badminton are associated with speed, jump height and agility [6]. Activation and controlling of distal muscles impact the accuracy of smash control in badminton [7]. Jump height affects the smash accuracy in badminton [4].

Resistance training (RT) and plyometric training (PT) are often used to improve the rate of force development, anaerobic power and agility [2, 8]. Previous studies have extensively examined the chronic effect of various strength training modalities on badminton performance [8, 9, 10, 11]. However, acute effects of activation or conditioning using resistance exercises have not been extensively studied in badminton.

Resistance priming (RP) denotes the strategic application of resistance training prior to competition to maximize performance [12]. Velocity based high-load low-volume resistance priming has a proven impact on jump performance [13]. Post-activation performance enhancement refers to the enhancement in voluntary muscle performance resulting from a prior high-intensity voluntary conditioning/activation contraction [14, 15]. RP causes post-activation performance enhancement. However, there are no known studies that have examined the impact of resistance priming on performance enhancement in badminton. Considering the nature and demand of badminton, the scope of using resistance priming in order to elicit post-activation performance enhancement is worth researching.

The study was aimed at examining the potential effect of morning RP on selected physiological variables of college level male badminton players measured at different points of time. Furthermore, the study aimed to compare the selected variables between baseline, 30 minutes after the intervention, 8 hours after the intervention and 24 hours after the intervention. It was hypothesized that the performance in the selected variables would vary between points of time and would be the best after eight hours of intervention.

Material and Methods

Participants

Eight male college level badminton players (height = 173.83 ± 6.49 cm, weight = 70.79 ± 3.82 kg, BMI = 23.41 ± 1.28, relative back strength = 1.76 ± 0.36, relative dominant hand grip strength = 0.63 ± 0.07 and relative non-dominant hand grip strength = 0.62 ± 0.07) volunteered as participants for the study. An a priori power analysis was performed by employing G*Power Software 3.1.9.4 [16] to determine the minimum sample size required for the study. It was estimated that a minimum of five participants were required to test the hypothesis for a medium effect size [17], power = 0.80, number of groups = 1, number of measurements = 4. However, considering the chances of injury or drop out during the study protocol, sample size was fixed as eight. The subjects were identified and chosen based on a public call made through social media. They were screened based on the inclusion and exclusion criteria. College level badminton players who were practicing for at least one hour per day, with prior experience of resistance training and devoid of any musculoskeletal injuries were selected as participants. Players who had not played any competition for the past one year and who had no background of resistance training were excluded. The subjects were briefed about the procedure of the study and informed consent was obtained as per the declaration of Helsinki. The study was approved by the Departmental Research Ethics Committee of the Department of Exercise Physiology (REC/DEP/2024-25/ES1 - 03.08.2024).

Procedure

The study employed an experimental design with repeated measures within group comparison. It was conducted in two phases: a familiarization phase and an intervention phase. The familiarization was held two weeks before the baseline test, which helped the researcher to establish rapport with the participants, understand their abilities, teach them the right form of performing exercises and evaluate 1RM for each exercise [18]. The familiarization phase included practicing the exercises used in the priming to gain mastery in the form to ensure maximum effectiveness, correct usage and techniques. Further, the 1RM of the participants in the selected exercises was estimated using the Epley's Equation [19]. During familiarization, the participants were oriented to the testing protocols and the demographical characteristics were assessed.

Intervention

The resistance priming intervention was held on 30.04.2024 at 6.00 AM (IST) in a strength and conditioning hall with temperature maintained at 21°C as per the recommendation of American College of Sports Medicine (ACSM) [20]. The participants underwent a 15-minute warm-up protocol as outlined in Table 1. Following the warm-up, they were exposed to a Resistance Priming (RP) session using the protocol mentioned in Table 2. All participants performed the exercises in the same order simultaneously at eight different stations. All participants were supervised and supported by one strength and conditioning instructor, under the overall supervision of the research team.

Testing Procedures

The selected physiological variables were tested before the RP intervention (pre-test), 30 minutes after the intervention (post-test 1), 8 hours after the intervention (post-test 2) and 24 hours after the intervention (post-test 3). Speed and agility were measured in an indoor hall, while jump height, peak power, peak velocity and decline in power were assessed in an exercise physiology laboratory. The sequence of the tests and the participants remained the same at all the testing points of time.

Table 1. Warm-up protocol used

Time	Order	Exercises
5 Min	Static Stretching	Gastrocnemius Stretching
		Hamstring Stretching
		Quadriceps Stretching
		Groin Stretching
		Gluteus Stretching
		Abdominis Stretching
		Adductors Stretching
		Abductors Stretching
		Deltoid Stretching
		Triceps Stretching
		Biceps Stretching
3 Min	Cardio	Slow Jogging
		Jogging with High Knees
		Sideward Shuffles
		Galloping
		Back Run
4 Min	Dynamic Exercises	Shoulder Rotation
		Lunges
		Jumping Jacks
		Pogo Jumps
		High Knee
		Butt Kicks
3 Min	Potentiation	Stride Running
		Sprints

Table 2. Resistance Priming Protocol used

Exercise	Target Segment	Intensity	Repetition	Set	Rest between sets
Bench Press	Upper Body	85% of 1RM	3	2	2 Minutes
Back Squat	Lower Body	85% of 1RM	3	2	2 Minutes
Deadlift	Whole Body	85% of 1RM	3	2	2 Minutes

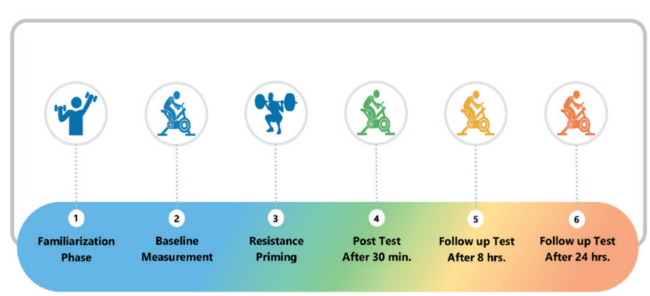

Figure 1. Experimental research design

Jump Height and Peak Velocity

Jump height (cm) and peak velocity (m/s) were assessed by Counter Movement Jump (CMJ) protocol performed on a force platform (Kistler, model 9260AA6, Winterthur, Switzerland) attached with signal processing software (MARS, Winterthur, Switzerland), which demonstrated satisfactory reliability [21]. The participants began by standing erect on the force platform where their mass was assessed. On the command of the tester, the participants initiated a downward preparatory movement approximately up to 90º flexion at the knee. Following the flexion, the subjects performed maximal upright jumps. In order to facilitate a natural movement mimicking on field badminton performance, arm movements were not restricted [22, 23]. Three trials were given with sixty to ninety seconds rest between sets, where a trial was considered valid when the take-off and landing were done on both legs. The intraclass correlation coefficient (ICC) for jump height and peak velocity was 0.99 (95% confidence interval (CI): 0.993-0.999, $p < .001$) and 0.99 (95% confidence interval (CI): 0.996-0.998, $p < .001$) respectively.

Peak Power (PP) and Decline in Power (DP)

The Wingate Anaerobic Test (WAnT) 30 s protocol was used to assess peak power (W) and decline in power (W). The test protocol as described by Zupan et al. [24] was followed for the assessment. The test started by weighing the subject on a digital weighing scale (Seca 284, Seca GmbH & co. kg, Hamburg) and loading the resistance 7.5% of the participant's weight on a Monark Cycle Ergometer (Monark Ergomedic 894E, Sweden) attached to the Monark Software to test the Wingate protocol. The subject warmed up by pedaling for 3 to 5 minutes to achieve a target heart rate of 130 to 140 beats per minute. Approximately five seconds before the start of the test, the participant started cadence at maximum speed against a resistance of 1/3rd of the actual load. Following the five second countdown the weight was added instantly by dropping the weight rack. Then the data were collected for 30 seconds (24). The intraclass correlation coefficient (ICC) for peak power and decline in power was 0.99 (95% confidence interval (CI): 0.994-0.998, $p < .001$) and 0.98 (95% confidence interval (CI): 0.989-0.998, $p < .001$), respectively.

Speed

Sprint speed was assessed using 20 m sprint test conducted in an indoor hall. The subjects wore appropriate indoor footwear. The procedures described by John et al. were employed to assess sprint speed [25]. The timing was recorded using timing gates (Humotion SmarTracks, Munster, Germany). The intraclass correlation coefficient (ICC) for speed was 0.98 (95% confidence interval (CI): 0.875-0.998, $p < .001$).

Agility

Agility was assessed using Modified Southeast Missouri (SEMO) Agility Test as detailed by Guo et al. [26]. The participants warmed up properly and started from cone 1. The test began with the player shuffling sideways from starting point (cone 1) to cone 2, then backpedaling diagonally to cone 4, followed by sprinting to cone 1. Then the participant backpedaled diagonally again to cone 3, further a sprint to cone 2 and a side shuffle to finish at cone 1. The time taken to finish the course was recorded to the nearest second. The highest value of the three trials, separated by 2 minutes of active recovery, was considered for the analysis. The intraclass correlation coefficient (ICC) for agility was 0.99 (95% confidence interval (CI): 0.994-0.997, $p < .001$).

Statistical Analysis

IBM SPSS Statistics (version 22.0) was used for data analysis. Data are represented as mean ± standard deviation for all the variables. Normality was tested using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Furthermore, a Repeated Measures ANOVA with within group comparison was used for comparing the selected variables at different time points. Assumptions of sphericity and homogeneity were tested using Mauchly's test and Levene's test, respectively. Greenhouse-Geisser or Huynh-Feldt correction was used when the assumption of sphericity was violated. Post-hoc pairwise comparisons were performed with Bonferroni corrections. A p-value of 0.05 was considered significant for all tests.

Results

Repeated Measures ANOVA determined that mean agility ($F(3,15) = 4.24$, $p = 0.013$, partial $\eta^2 = 0.458$), peak power ($F(3,15) = 11.46$, $p = 0.000$, partial $\eta^2 = 0.696$) and decline in power ($F(3,15) = 5.525$, $p = .009$, partial $\eta^2 = 0.525$) scores differed significantly across four time points. Table 3 illustrates that there were no significant differences in jump height ($p = 0.174$), speed ($p = 0.14$) and peak velocity ($p = 0.874$) measured at different points of time.

A post hoc comparison using the Bonferroni correction showed an increase (3.07%) in agility time in post-test 1 and a subsequent decrease in post-test 2 (4.91%) and post-test 3 (4.03%). However, the difference in agility was statistically significant only when comparing post-test 1 and post-test 2 (11.74 vs 10.83, $p = 0.013$). Further, maximum power exhibited increases in post-test 1 (11.78%), post-test 2 (23.86%) and post-test 3 (15.44%), respectively when compared with baseline performance. Maximal power showed a statistically significant difference between baseline test and post-test 2 (10.1 vs 12.51, $p = 0.021$). Decline in power demonstrated an increase in post-test 1 (36.89%), post-test 2 (75.86%) and post-test 3 (33.15%). Nonetheless, the difference was significant only between baseline and post-test 1

Table 3. Anaerobic parameters of badminton players measured at various points of time

	Baseline	Post 1	Post 2	Post 3	p (η^2)
Agility (s)	11.39 ± 1.03	11.74 ± 0.91	10.83 ± 0.68	10.93 ± 0.70	0.013 (0.458)
Peak power (W/kg)	10.1 ± 1.42	11.29 ± 1.52	12.51 ± 1.63	11.66 ± 1.05	0.000 (0.696)
Decline in power (W)	303.73 ± 109.15	415.78 ± 18.5	534.16 ± 203.99	404.43 ± 100.6	0.009 (0.525)
Jump height (cm)	41.06 ± 3.6	42.68 ± 3	44.22 ± 1.63	44.06 ± 2.33	0.174 ^{ns}
Speed (s)	3.40 ± 0.16	3.48 ± 0.14	3.28 ± 0.10	3.39 ± 0.16	0.14 ^{ns}
Peak velocity (m/s)	2.84 ± 0.55	2.90 ± 0.35	2.90 ± 0.24	2.98 ± 0.26	0.874 ^{ns}

(303.73 vs 415.78, p = 0.04) and baseline and post-test 2 (303.73 vs 534.16).

Discussion

The study aimed at exploring the impact of morning RP on jump height, peak velocity, peak power, decline in power, speed and agility of college male badminton players measured at various points of time. Following the morning RP intervention, agility, peak power and decline in power of the badminton players differed significantly. Nevertheless, there was no statistically significant difference in jump height, peak velocity and speed when compared between the baseline, after 30 minutes, 8 hours and 24 hours following RP intervention.

The present study is one of the first of its kind to investigate the effect of RP on physiological variables of badminton players. Although statistically not significant, only jump height and peak velocity improved on post-test 1, whereas agility, peak power, decline in power and speed deteriorated when assessed 30 minutes following the RP intervention. This indicates that RP intervention with 90% 1RM may not be effective in bringing in PAPE effect if deployed just 30 minutes before the competition. The finding is in agreement with the results of previous studies by Harrison et al. [27]; Kilduff et al. [28]; and Harrison et al. [29], wherein the PAPE effect was identified between 1 to 12 hours following the RP intervention. The potential reason for this acute deterioration of agility, peak power, decline in power and speed may probably be attributed to the onset of fatigue and accumulation of metabolites during the RP contractions.

There was an improvement in all the variables when tested 8 hours following the intervention, in which specifically agility, peak power and decline in power showed statistically significant improvements. In line with our findings, Ekstrand et al. [30] and Cook et al. [31] also noted an enhancement in strength parameters of rugby players and throwers 4-6 hours after high-intensity RT intervention. Conversely, low volume RT using 80% 1RM load did not bring in significant improvements in strength parameters in elite lifters [32]. This indicates that improvements elicited as a result of PAPE are highly load specific, wherein high-intensity low volume activation tends to have a better improvement window. Also, maximal concentric leg press and acute heavy resistance warm-up consisting of three sets of exercises with 50, 60 and 90% of 1RM has proven to improve agility [33, 34]. Agility and plantar flexion strength are positively correlated and thus contribute directly to the explosiveness of lower body muscles [35]. All the variables remained enhanced even after 24 hours following RP. However, this enhancement of the variables was comparatively smaller than the margin of improvement showed in the post-test taken after 8 hours following RP. In other words, high load low volume RP would be potential enough to elicit and maintain PAPE effect on badminton players for 24 hours.

Badminton is a high-intensity intermittent sport and the tournament formats demand the players to play approximately one to three matches per day for 4 to 5 days [36]. Motor abilities such as speed, agility, explosive strength, shoulder strength and muscular endurance are strongly correlated with and decisive in badminton performance [37]. Badminton players are supposed to demonstrate and maintain high level of intensity in movements in order to meet the fast-paced game. Strength serves as the foundation for excellence in power, change of direction, speed and agility. Match-induced fatigue reduces shoulder strength [38] and jump height of the badminton players [39]. Most points in badminton are scored by attacking shots such as smash, which in turn is affected by shoulder strength and jump height. Thus, attaining and maintaining the quality in contraction for a longer period during competitions would be of paramount importance in badminton.

Post-activation performance enhancement is often understood in light of the impact of phosphorylation of the myosin regulatory light chains (MRLC) during a muscle contraction on the enhanced rate of crossbridge attachment [14]. Additionally, it also boosts the sensitivity of the contractile proteins to calcium [40 41, 42]. Greater motor unit recruitment during the potentiation activity may also influence PAPE [43].

High-intensity low volume RP can help college level male badminton players in activating and inducing PAPE effect on agility, peak power and decline in power. Evidence from the present study suggests that morning RP could be used if the player has a match scheduled in the evening or the next morning. Along with the concepts of loaded warm-up and plyometrics, RP may also be considered for eliciting PAPE effect in badminton players. Furthermore, in addition to isotonic activities such as bench press, squat and deadlift, movements with jumps may also be incorporated in RP protocol. Moreover, the PAPE effect varies between strong and weak athletes, where strong athletes elicited better impact [26]. Therefore, while considering RP for badminton players, a differentiated training plan is required for players with greater and lesser strength profiles.

The findings of the current study have to be considered in light of some limitations. The first limitation concerns the lack of empirical evidence from prior research pertaining to RP interventions and badminton. Secondly, the present study recruited, though statistically enough, only a few participants. A larger sample size would be able to provide a more generalizable finding. However, the research team prioritized more on availability of a homogenous participant group than a large sample size. Therefore, it is suggested that future studies should include a larger sample size to conclude the impact of RP on badminton players.

Conclusions

While the role of resistance training gains greater attention in badminton training, it is of paramount importance to understand the diurnal effect of RP in eliciting PAPE impact. By examining the impact of a high-intensity low-volume RP assessed at various time points, the study found that speed, agility, peak power, peak velocity, jump height and decline in power improved after 30 minutes following the RP and remained elevated up to 24 hours. Furthermore, these variables showed maximum improvement when tested after 8 hours following RP. This suggests that RP may be included as an activation protocol in badminton, at least eight hours before the competition to elicit maximum contractile quality of the muscles.

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