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Effect of Post-Activation Potentiation on CMJ Performance of Chinese Male Collegiate Basketball Players: A Pilot Study

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Abstract
The ability to exert explosive force in the lower limbs is of paramount importance for the performance of basketball players. It enables basketball players to complete high-quality sprints, jumps, quick direction changes and other actions in high-intensity competitions. The countermovement jump represents an effective method for assessing lower limb explosive force. Nevertheless, there is a paucity of research examining the impact of post-activation potentiation on the performance of countermovement jumps among male collegiate basketball players. This study investigated the effects of post-activation potentiation (PAP) intervention on the performance of countermovement jumps in Chinese male collegiate basketball players. A cluster randomised controlled trial (C-RCT) was conducted with participants aged 18-24 years, who were divided into three experimental groups (EG1-70% 1RM, EG2-80% 1RM, EG3-90% 1RM) and a control group (CG). The intervention period was two weeks, with countermovement jump performance evaluated at the pretest and following the intervention. The results demonstrated that the three experimental groups exhibited significantly enhanced outcomes compared to the control group, with EG3 (90% 1RM) proving the most pronounced intervention effect. These findings indicate that PAP intervention can enhance countermovement jump performance in Chinese male basketball players and suggest that PAP should be incorporated into future lower limb explosive force training programmes.
Keywords: Post-activation Potentiation, Collegiate Basketball, Explosive Force, Load Intensity, Pre-Activation

Introduction

Basketball is a high-intensity interval sport that relies on explosive force. (Arede et al., 2019). The execution of basketball movements with and without the ball, including sprinting, quick stops, quick direction changes, acceleration, and different vertical jumps, is significantly influenced by the athlete's level of lower limbs explosive force (Li & Liu, 2024). In addition, previous studies have confirmed that the countermovement jump is a highly reliable and valid method for measuring lower limb explosive force for basketball players (Krzyszkowski et al., 2022; Xu et al., 2023).

A quantitative analysis of the performance of the Chinese men’s basketball team in international competitions, conducted by Chinese experts and scholars, has revealed that the Chinese men's basketball team exhibits deficiencies in several key areas when compared to its opponents. These include offensive speed, shooting percentage, offensive and defensive rebounds, defensive efficiency, defensive steals, and blocks (Liu, 2020; Yuan, 2024). The competitive level of basketball players is influenced by numerous factors, including their psychological state, training status, and health level (Impellizzeri et al., 2019). However, the main reason for the Chinese men's basketball team's substandard performance in international competitions can be attributed to their technical statistics. Previous studies have indicated that the level of these techniques is contingent on the athlete's lower limbs’ explosive force (Che et al., 2020; Niu, 2023). Consequently, it can be deduced that Chinese men's basketball players’ poor lower limb explosive force contributes to their subpar performance in international competitions.

In recent years, it has been demonstrated that specific pre-contraction traces can influence the capacity of skeletal muscles to contract. In other words, following muscle contraction under certain conditions, the explosive force of the muscle group in question will be enhanced for a defined period. This phenomenon is referred to as "post-activation potentiation" (PAP) (Fernández-Galván et al., 2022). The current research consensus is that the PAP effect can effectively enhance the explosive force of athletes' lower limbs (Li et al., 2024).

As research into PAP continues to evolve, it has become evident that the PAP produced by different induction methods varies considerably. The distinction between induction methods is primarily apparent in the characteristics of the induced muscle force (dynamic induction or static induction) and the induced load (induced intensity and amount). The current focus of PAP research is on dynamic induction, although the optimal induction load under these conditions remains a topic of debate (Zhao et al., 2022). The implementation of PAP has been demonstrated to enhance the lower limbs explosive force in Chinese college men's basketball players, thereby improving their performance in high-level competitions (Liu & Guo, 2019; Guo et al., 2018).

Consequently, this study examined the impact of inducing PAP with varying induction intensities on the countermovement jump performance of Chinese male college basketball players. Its purpose was to provide a reference point for developing scientific training methods optimised for this group.

Literature Review

Effect of Post-Activation Potentiation on Explosive Force

The phenomenon that high-intensity warm-up activities help improve muscle strength and explosive force performance is called post-activation potentiation (PAP), which is a training method that uses high-intensity stimulation to induce more type II muscle fibre activation (Fernández-Galván et al., 2022). The prevailing physiological mechanism for generating PAP is increased myosin regulatory light chain phosphorylation and motor unit recruitment (Fernández-Galván et al., 2022). Subsequent studies have confirmed that a high-intensity resistance warm-up with one maximum repetition contraction (1 RM) or close to 1 RM stimulation can significantly increase subsequent explosive exercise performance (Eken et al., 2022; Gago et al., 2020). It is important to note that PAP is not produced under all conditions and may be affected by various factors, including load mode, intensity, volume, recovery time, individual characteristics, and the type of subsequent exercise (Fernández-Galván et al., 2022).

The Current Situations of Chinese Male Basketball Players

Previous study has conducted a quantitative analysis of the performance of the Chinese men's basketball team in previous Basketball World Cups and found that there are obvious differences in the team's offensive and defensive indicators when competing against high-level opponents (Yuan, 2024). A plethora of other studies have identified a disparity between the Chinese team and their opponents in pivotal areas, including but not limited to offensive speed, shooting percentage, offensive and defensive rebounds, defensive efficiency, defensive steals, and blocks (Liu, 2020). According to previous studies, the level of these techniques mainly depends on the lower limbs explosive force of the athletes. (Che et al., 2020; Niu, 2023). Therefore, it can be concluded that the main gap between the Chinese men's basketball team and its international opponents lies in the weak lower limb explosive force.

Methodology

Participants

The participants of this study were 24 male college basketball players (6 in the control group and 6 in each of the three experimental groups) from Wuhan Institute of Physical Education and Hubei University, Hubei Province, China. Inclusion criteria were: (1) college male basketball players aged 18 to 24 years; (2) participation in this study was based on an apparent willingness to participate and the ability to complete all required tests; (3) two years of training experience; and (4) participants were physically active but had no experience in post-activation potentiation training. Exclusion criteria were: (1) participants who took medications that could affect body composition and muscle activity (e.g., diabetes); (2) athletes who had a recent (less than one year) sports injury (e.g., knee or various arthritis and lumbar injuries); and (3) participants who were currently participating in regular explosive training.

The Wuhan Institute of Physical Education Ethics Review Committee granted ethical approval for this study (Ethics Approval Number: 2023006). During the study, participants were instructed not to perform other physical interventions and only maintained the standard and post-activation potentiation training interventions. In addition, participants were asked to follow their regular diet, which the researchers recorded. Repeated measures were conducted after the two-week intervention to assess its effectiveness and feasibility.

Participant Characteristics

Basic demographic and physical testing were performed on college male basketball players, including age, height, and weight measurements. Height was measured with a height tape and recorded in centimetres, and weight was recorded with a weight scale in kilograms. Participants were asked to wear slippers for height measurement and to keep the head, shoulders, and hips straight. The mean age of the post-activation potentiation intervention group EG 1 was 18.922±0.615, EG 2 was 18.969±0.493, EG 3 was 19.244±0.589, and the mean age of the control group (CG) was 19.282±0.358. The mean height of EG 1 was 181.102±3.95 cm, EG 2 was 81.137±2.838 cm, EG 3 was 80.345±3.127 cm, and the mean height of the CG group was 181.297±3.12 cm; the weight of the EG 1 was 81.023±2.323 kg, EG 2 was 182.951±4.116 kg, EG 3 was 182.064±4.776 kg, and the weight of the CG group was 79.209±3.346 kg.

Training Program

The post-activation potentiation intervention programme was developed based on the most recent research (Liu & Guo, 2019). It was subsequently subjected to an expert panel review to ascertain its applicability and efficacy in college men's basketball. The intervention design is based on the FITT principle, which entails the systematic and individual optimisation of training parameters to meet the specific needs of college men's basketball players and achieve optimal results within a limited time frame. The application of the FITT principle ensures the effectiveness of the intervention. It improves lower limb explosive power within a limited time frame, enhancing athletes' competitive level and sports performance.

Before the commencement of the experiment, the research team provided a comprehensive explanation of the experimental procedure to each subject and recorded their height, weight, age, training history and the side jump leg they typically utilise. Before the commencement of the primary experiment, the half squat 1RM weight of all subjects was evaluated. For safety reasons, the study only tested the half squat weight of each subject for 2-3 RM, then calculated its 90%, 80% and 70% 1RM as the pre-stimulation weight. The half-squat movement standard is based on the 2011 standard back-squat technique of the International Weightlifting Federation (IPF).

During the squat process, the subjects were required to ensure that their knees did not exceed their toes, squat until the thigh and calf were approximately 120 degrees, and then rapidly elevate the heel and complete the heel raise. The subjects were instructed to engage their abdominal muscles, maintain a straight back, and adduct their shoulder blades throughout the procedure. The barbell was positioned on the deltoid and trapezius muscles of the subjects. In this study, the half squat weight test and the main experimental content employed free weight half squats, with the same squat rack and barbell used to ensure test consistency.

i. Routine Warm-Up & Pre-activation prescription (30 minutes): To prepare for the pre-activation or post-activation potentiation, participants first perform a 15-minute routine warm-up, including Jogging, Knee Hugging, Quad walks, Squats without load, and a Glute Bridge. Then, they perform another 15 minutes of pre-activation, which is weighted squats.
ii. Main exercises for lower limb explosive force (50 minutes): Lower limb explosive force is a compound training consisting of weighted squats and deep jumps.

iii. Relaxation (10 minutes): Finally, the subjects stretch and relax, mainly static stretching of the lower limbs, buttocks muscles, waist, and abdomen. They also adjust their breathing rhythm to ensure a good stretching effect.
iv. Frequency: The post-activation potentiation intervention lasts for two weeks, three times a week, 90 minutes each time, to ensure that there is enough intervention time to achieve the effect of improving lower limb explosive power.
v. Guidance: The researcher and a coach with many years of physical training experience in professional basketball club teams implement and guide the training content. The coach instantly detects the subjects' training movements and time and adjusts to ensure adequate training.
vi. Safety considerations: The entire intervention process is carried out in a professional physical training hall (Physical Center of Wuhan Sports University), ensuring that the training is at a constant temperature and in a safe environment. Professional physical coaches monitor the whole process to ensure the subjects' safety.

Test Instrument
This study aimed to evaluate the effects of post-activation potentiation (PAP) intervention on countermovement jump (CMJ) performance in college-level male basketball players. To this end, a force plate was employed to measure CMJ height. Previous studies confirmed this measurement tool's scientific validity (Kotsifaki et al., 2023).

Data Analysis
Statistical analysis was performed using SPSS (version 29) with a two-tailed significance threshold of $p < 0.05$. Descriptive analysis ensured data quality. Continuous and categorical variables were summarised as mean ± SD and frequencies. The homogeneity and normality of variables were assessed using ANOVA, Shapiro-Wilk, and Levene's tests before analysis. The GEE model was applied for a longitudinal study to evaluate intervention effects intervention on countermovement jump height.

Results
Primary Outcomes
Content validity is usually confirmed through evaluation by a panel of experts or scholars to verify its applicability (Beckstead, 2009). Although the size of the expert panel is not strictly regulated, it generally includes three to ten experts (Lynn, 1986). In this study, six experts participated in the content validity evaluation of the intervention program and research tools to ensure the relevance of the content. The content validity index (I-CVI) analysis showed that the relevance score of the strength items (I-CVI = 0.833, kappa = 0.816) reached the acceptable content validity standard, thus supporting the high content validity of the intervention program. Detailed data are shown in Table 1.

Table 1
Correlation and consistency of strength qualities

Variables	**Measurement Method**	**Number in Agreement**	**Clarity**	
			I-CVI	**KAPPA**
CMJ	Jump Height	6	1.000	1.000

Noted: CMJ, Countermovement Jump

In a pilot study, the GEE method was used to evaluate the effect of post-activation potentiation on jump height among young Chinese male basketball players. GEE analysis was performed for jump height related to countermovement jump in pretest and posttest to determine whether there were differences between and within groups. Descriptive data (marginal mean and standard error) for jump height are shown in Table 2.

Table 2
Descriptive Statistics (Mean and SE) of jump height (CMJ) in intervention and Control Groups at pretest and posttest

	PAP 70%	**PAP 80%**	**PAP 90%**	**Control**
Pretest	0.596(0.04)	0.598(0.03)	0.62(0.02)	0.59(0.03)
Posttest	0.679(0.04)	0.682(0.03)	0.722(0.04)	0.565(0.03)

According to the results of GEE, it was found that the main effect of the group on jump height was significant ($\chi 2$= 68.522, p<0.001). These results also, indicated that there was shown a significant effect of time on jump height ($\chi 2$=41.453, p<0.001). According to these findings, the interaction between time and group was also substantial ($\chi 2$= 35.238, p<0.001), indicating that all groups had different patterns of jump height at the pretest and posttest.

Results of within-group comparison using Bonferroni showed that in all three intervention groups, the difference in student jump height (CMJ) between the pretest and posttest was statistically significant (p<0.05). At the same time, there was no significant difference between the pretest and posttest in the control group (p=902). Effect size results indicated a large effect of time in all intervention groups on students' jump height (CMJ). The largest effect size was observed in PAP90% (d=3.505), followed by PAP80% (d=2.990) and PAP70% (d=2.035), which all showed a large effect.

Table 3
Within-group Comparison between Pretest and Posttest in Control and Intervention groups for jump height (CMJ)

Group	**Comparison**	**Mean Difference**	**SE**	**P value**	**95% CI for Difference**		**d**
					Lower	**Upper**	
PAP 70%	Pre vs Postest	-.08267a	0.020	0.001	-0.142	-0.024	2.035
PAP 80%	Pre vs Posttest	-.08400a	0.019	<0.001	-0.141	-0.027	2.990
PAP 90%	Pre vs Posttest	-.10183a	0.021	<0.001	-0.165	-0.038	3.505
Control	Pre vs Posttest	0.025	0.015	0.902	-0.018	0.067	0.794

The result of the between-group comparison at the pretest and posttest revealed that the respondent's jump height (CMJ) in the pretest was not statistically significant (p>0.05). According to the comparison results in the posttest, there was no significant difference among the three intervention groups (p>0.05). In comparison, there were significant differences between all three intervention groups and the control group (p<0.001). For the respondent's jump height (CMJ), the effect size was calculated between three intervention groups and a control group at the pretest and posttest. The results indicate that there was almost a small to large effect size on respondents jump height (CMJ) at the pretest (d: 0.064- 1.24), while in the posttest, there was a large effect size between groups. The largest effect size was the differences between control and PAP90% (d=4.511) and PAP80% (d=3.822).

Table 4
Between-group Comparison at the Pretest and Posttest for Jump Height (CMJ)

	GROUP	Mean Difference	SE	P value	95% CI		Cohen's d
					Lower	Upper	
Pretest	PAP70 VS PAP80	-0.002	0.020	1.000	-0.041	0.037	0.064
	PAP70 VS PAP90	-0.024	0.018	0.931	-0.070	0.022	0.784
	PAP70 VS CON	0.006	0.019	1.000	-0.034	0.046	0.185
	PAP80 VS PAP90	-0.022	0.015	0.931	-0.061	0.017	0.867
	PAP80 VS CON	0.008	0.016	1.000	-0.033	0.049	0.293
	PAP90 VS CON	0.030	0.014	0.358	-0.010	0.070	1.240
Posttest	PAP70 VS PAP80	-0.004	0.021	1.000	-0.045	0.038	0.098
	PAP70 VS PAP90	-0.043	0.023	0.582	-0.107	0.021	1.094
	PAP70 VS CON	.11333a	0.022	0.000	0.045	0.181	2.934
	PAP80 VS PAP90	-0.040	0.018	0.358	-0.092	0.013	1.254
	PAP80 VS CON	.11683a	0.018	0.000	0.062	0.172	3.822
	PAP90 VS CON	.15650a	0.020	0.000	0.094	0.219	4.511

Figure 1 displays the mean jump height (CMJ) score of students. This score was calculated both pretest and posttest and demonstrated an increase in the level of jump height (CMJ) (centimeters) in all three intervention groups. On the other hand, the control group did not experience any changes over time.

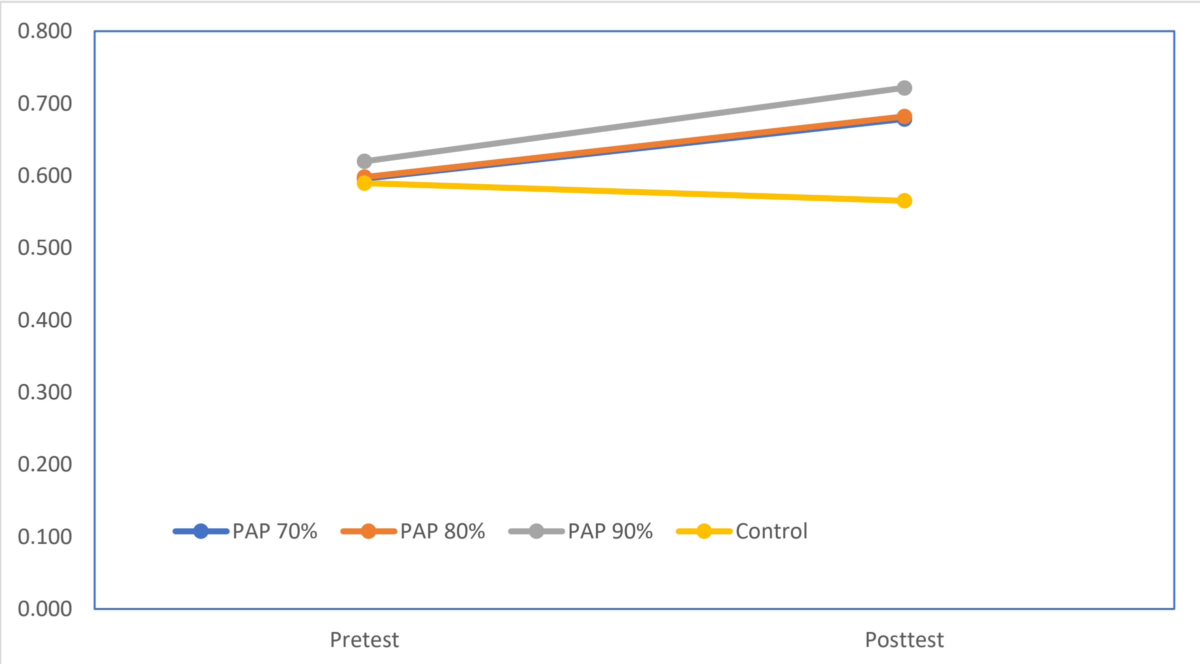

Figure 1. Level of Students' CMJ Jump Height (Centimeters) in Intervention and Control Groups Across Time

Discussion

The countermovement jump is a reliable and valid measure of lower limb explosive force for basketball players (Krzyszkowski et al., 2022). The primary effect of time was used to elucidate the comprehensive impact of the time factor on the CMJ height of the subjects. It was ascertained that the time factor exerted a notable influence ($p < 0.05$). The main effect of time×group interaction was employed to elucidate the impact of the interaction between the time factor and the group factor on the CMJ index. The findings indicated that the CMJ significantly influenced the CMJ height. Given the significant main effect results, a simple time pairwise comparison analysis was conducted. This analysis revealed that all three experimental groups exhibited notable enhancements in jump-related performance ($p < 0.05$). In the posttest, the effect size between the groups was considerable. The largest effect size was observed between the control group and PAP90% (d=4.511).

In the study of the optimal load intensity for muscle enhancement, the findings of domestic and foreign scholars have been inconsistent. Borba et al. (2017) posited that a 30% to 95% 1RM load intensity can effectively induce muscle enhancement. However, Fernández-Galván et al. (2022) conducted a meta-analysis and concluded that a 60% to 84% pre-stimulation intensity is more conducive to improving sports performance. A further group of researchers posits that varying intensities of MVC can induce disparate degrees of PAP. In general, the greater the stimulation intensity, the more pronounced the PAP effect (Suchomel et al., 2016; Piper et al., 2020), a finding that aligns with the results of this study.

The discrepancy in opinion may be attributed to the experimental subjects engaging in disparate sporting activities. Given that the subjects selected by previous scholars were involved in disparate sports, the subjects' muscle fibre type, proportion, and muscle cross-sectional area will inevitably exert a discernible influence on the experimental outcomes (Borba et al., 2017; Del Rosso et al., 2016). It is also possible that the results are influenced by individual differences, gender, and age of the subjects, as well as the duration of the training programmed.

From the perspective of physiological mechanism, the load intensity applied to male college basketball players is within an appropriate range, as evidenced by the following findings. It can be observed that an increase in load intensity results in a more significant induction effect of the post-activation enhancement. This may be attributed to increased phosphorylation of the myosin regulatory light chain. Applying a substantial load stimulus to the muscles of male college basketball players results in enhanced sensitivity of the troponin and actin-binding sites to calcium ions. Because of this increased sensitivity, a considerable number of ATP enzymes will also be activated, resulting in the continuous acceleration of the ATP release capacity and, consequently, the muscle contraction speed and strength will continue to increase (Del Rosso et al., 2016; Dolan et al., 2017).

Limitations

The small sample size may have limited the ability to identify significant training effects when comparing pre-and post-intervention measures. However, this pilot study aimed to provide preliminary data to establish systems and norms for subsequent research. The reliability of measures was ensured by applying the “Rule of 12” (Moore et al., 2011). Future research should consider extending the training period to further increase the potential for training effects.

Sample Size Limitations

Only 24 subjects were recruited to participate in the experiment, which limits the statistical power due to the relatively small sample size. In addition, the small sample size will also limit the generalisability of the research results. Although the sample size was affected by the recruitment criteria and time constraints, it is also comparable to other similar studies. For example, some studies on basketball players and post-activation potentiation also used small sample sizes (e.g., 15-30 subjects) to ensure strict control of experimental variables. However, future studies on PAP should reasonably increase the sample size to enhance statistical power and reduce the impact of data variability.

Intervention Duration

The duration of the post-activation potentiation intervention in this study was two weeks, three times a week, for a total of six training sessions. This schedule was mainly affected by time constraints and the academic commitments of the participants. However, Liu et al. (2022) claimed that a 12-week training intervention is enough to improve explosive performance.

Generally, a two-week physical training intervention has limited effects on athletes' explosive force. However, this study shows that a short-term post-activation potentiation intervention can still affect the quality of athletes' explosive force. Future studies suggest a longer intervention time to observe long-term changes in lower limb explosive force.

Limitations of the Study Population

The population of this study was college male basketball players from Hubei, China. The homogeneity of this group helps control research variables but also limits the generalisability of the results. The effect of post-activation potentiation on the strength and power of athletes is affected by gender, age, training experience, and muscle fibre type (Liu & Li, 2017). Therefore, it is recommended that future researchers expand the scope of subjects when studying the effect of PAP on the vertical jump performance of athletes, such as athletes of different genders, different sports, and different training levels, to evaluate the effect of PAP more comprehensively on various populations.

Conclusion

The findings indicated that following two weeks of PAP intervention, PAP with pre-activation intensities of 70% 1RM, 80% 1RM, and 90% 1RM could effectively enhance the rebound ability of male college basketball players. These findings demonstrate that PAP can effectively influence the rebound ability of college basketball players. In the posttest, the pre-stimulation intensity of 90% 1RM was observed to induce the most pronounced post-activation potentiation. It can be concluded that PAP intervention has more significant potential than traditional explosive training in improving countermovement jump performance in male college basketball players. Nevertheless, when designing a PAP intervention programme, it is essential to consider the individual characteristics of the subjects to determine the optimal pre-activation load intensity.

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Conflict of Interests

The authors declare that there are no conflicts of interest.

Author Contributions

All authors contributed equally to the conception and writing of the manuscript.

Data Availability Statement

The datasets used and analysed in this study are available from the corresponding author on reasonable request

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