



# Acute effects of weighted plyometric exercise on sprint, agility and jump performance in university football players

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## Abstract

**Background:** Conditioning activities such as resistance training can cause excitation of central nervous system resulting in Post-activation Potentiation phenomenon. Plyometric exercise also has an important role to develop Post-activation Potentiation following a resistance stimulus. So the purpose the study was to investigate the immediate effects of weighted plyometric exercise on sprint, agility and jump performance. **Materials and methods:** Twenty male university football players (age=21.3±1.5 years, body mass=63.3±9.5 kg, height=169.8±6.4 m) participated in this Single group pre-test post-test study. Agility Time (AT), Sprint Time (ST) and Counter-Movement Jump (CMJ) height were measured prior to and 1<sup>st</sup> and 5<sup>th</sup> minutes following plyometric exercise. **Results:** A repeated measures ANOVA employed at baseline (T0), 1 minute (T1), and 5 minutes (T5) post intervention showed significant effect for all the three outcome measures ( $p<0.001$ ). Post-hoc Bonferroni pairwise comparison showed a significant decrease in both AT and ST from baseline to assessments at both T1 ( $p<0.001$ ) and T5 ( $p<0.001$ ), whereas there was a significant increase in the CMJ height. However, no statistical difference was found between T1 and T5 ( $p=0.058$ ) in ST, but AT was significantly lower at T5 than at T1 ( $p=0.008$ ), and CMJ height showed significant increase from T1 to T5 ( $p=0.001$ ). **Conclusion:** Our results suggest that weighted plyometric exercises have an acute response on sprint, agility and counter movement jump (CMJ Height) following Post-Activation Potentiation (PAP) effect developed after plyometric exercises.

**Keywords:** weighted plyometric; plyometric exercise; agility; jump; university football players

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## INTRODUCTION

The Postactivation Potentiation (PAP) is an elevation the overall motor activity to higher level with conditioning stimulus such as plyometric exercise [1,2]. A plyometric exercise has an important role to develop PAP effect after a heavy resistance stimulus [3]. Although the relationship between plyometrics and PAP seems intuitive, the biological relationship that correlates the two entities are extremely useful. Plyometric drills can produce an acute increment of muscle performance following PAP phenomenon by influencing the mechanical performance of subsequent muscle contractions. It shows an enhancement in performance that exceeds those attributable to warm-up alone. Heavy conditioning activity causes excitation of CNS resulting in PAP phenomenon. CMJ performance has showed an improvement following loaded squat jump revealing the phenomenon of PAP [4].

The primary theories suggested to describe the PAP phenomenon are: (a) Preload conditioning activity causes increased motor-unit excitability as a result of activation of motor-unit recruitment and synchronization, as well as decreased presynaptic inhibition, and (b) phosphorylation of myosin light chain (MLC) were increased with the preload activity leading to an increase in sarcoplasmic  $Ca^{2+}$  and actin-myosin cross bridging with MLC kinase activation [5]. Increased phosphorylation of MLC explains the mechanisms of PAP more clearly based on alpha motor neuron excitability and increased levels of myoplasmic calcium. The findings have shown an increase in H reflex after preload activity with certain recovery period with a greater improvement in planter flexion force production . Recent research has reported an individual response with recovery time to preload stimulus and the subsequent explosive activity [6].

Sport like football is a very well-recognised sport and profession, also it is considered as a good recreational activity. Plyometric training programs in sports like football, volleyball, basketball etc. has shown an improvement in muscle coordination and synchronization. Muscle power has vital role in individual and team-based sports, mainly for sprinting and agility. Plyometric exercise involving the stretch-shortening has been reported to improve the speed and power of an athlete. Many studies have reported that plyometric exercises cause an increment in muscle power and sports specific skills such as agility and jump performance [7].

Muscle power is regarded as the principal or the crucial component for all the sport activities especially in team sports. Rapid and short duration muscle activity has a key role in soccer game as it affects the athlete's fitness and skills. Sprinting, jumping and twisting movement has been implemented in soccer training to achieve potential performance. Numerous training protocols has been proposed to take the advantage on speed, jump and agility by using sprint drills, speed training, weighted exercise and plyometric exercise. Plyometric training alone and combined with strengthening exercises shows positive outcomes in sprint performance [8]. High intensity plyometric involves sprinting, acceleration, deceleration and change in directions which have been recommended to develop agility in footballers. Sprint specific training programs have revealed dramatic positive changes in 10 and 100m sprint times [9] . In addition, the research in professional sport like football has demonstrated that PAP enhances the sprint performance by heavy resistance. Specific exercises, such as bounding, is used for enhancing dash performance and studies have also documented that sports specific training program have positive results on running velocity [10]. Non-specific soccer training is another pivotal component of overall training program and a great influencer integrant for the soccer play which can be implemented with specific soccer training program to induce the possible elevation in jumping, sprinting and soccer specific skills [11].

Recently, various studies have revealed to account that plyometric training protocol have greater role in eliciting sprint and jump performance for both adult and young soccer players [12] . In contrast, numbers of studies have reported that the effect of potentiation was not shown on jump performance after plyometric exercise [13]. Warm-up exercises attempt to enhance the exercise performance. Villarreal, Kellis [14] noted that with a 5-minute rest period, a sports-specific warm-up regimen consisting of plyometric exercises exhibited improvement in jump performance. Few researchers suggested that PAP movements are used as a part of warm-up, as it is assumed to create improved PAP neuromuscular activity [15,16].

PAP has restricted practical application in pre-competition exercise (e.g., warm-up) in many sports including football, basketball etc. According to the current literature based on relationship

between heavy resistance exercise protocol and PAP phenomenon, there is limited information available for the effect of plyometric exercise on subsequent performance for soccer play [17]. Few studies have been performed to study the effect of PAP on sprint performance and agility [18] following plyometric stimulus approving the notion that only limited researches have studied the effects of plyometric exercise on functional indices of sports performance, such as sprint, agility and jump [18]. No previous study has investigated the PAP effect on sprint, jump, and agility after weighted plyometric stimulation to the best of our knowledge. The purpose of this study is to find out the “Acute effects of weighted plyometric exercise on sprint, agility and jump performance in university football players”.

## METHODS

### *Participants & Ethical Consideration*

Twenty male university football players were recruited from a Central University for the study (age =  $21.3 \pm 1.5$  years, body mass =  $63.3 \pm 9.5$  kg, height =  $169.8 \pm 6.4$  m and BMI =  $21.9 \pm 2.9$ ). Descriptive information was collected through screening and data collection form. Male participants from the age of 20 to 25 years with a playing experience of one to five years at university level having knowledge of English language were included in the study. The participants were excluded from the study if they suffered from any systemic disease which may affect the testing and training, injured lower limb in past six months and exposed to plyometric training prior to the study.

Ethical approval (IRB NO: 5/12/152/JMI/IEC/2017) by the institutional ethical committee of the Jamia Millia Islamia (central university, New Delhi, India) and Clinical Trials Registry registration (CTRI/2018/03/018955), a single group pre-test post-test design was used in the study. Prior to conducting the study, the sample size was calculated by using software G Power 3.1.9.2 (Franz F, Universitat Kiel, Kiel, Germany). All research procedures were explained to participants and written informed consent was obtained in accordance with the Declaration of Helsinki. Keeping the power of study at 80% and level of significance at 0.05, the data from previous studies [18] have been used to give a total sample size of 20.

### *Study Protocol*

Following the basic demographic assessment, participants were recruited through the simple random sampling on the basis of inclusion criteria. Participants were asked to refrain from caffeine ingestion in the 24 hours before the assessment and report for the testing day. After a minimum of one day of rest from all forms of training or competition, a traditional warm-up was started which consisted of 10 squats of body weight, 10 forward lunges on each side, 3 minutes of dynamic stretching exercises of the related lower limb musculature which was executed dynamically in full kinematic range for: hamstrings, quadriceps, adductors, hip flexors and soleus, repeated twice, with each stretch lasting for 10 seconds, starting in small motion arc and increasing the arc in each repetition so that the last few were exaggerated. The cycle was repeated twice for each muscle or muscle group. After 1 minute of recovery, baseline pre-plyometric exercise Sprint, Agility and Counter Movement Jump (CMJ Height) values were recorded. Three repetitions of 20m sprint [19], agility T-test [20,21] and CMJ were performed before plyometric exercise (T0) and at 1 (T1) and 5 (T5) minutes after plyometric exercise. The average performances of the three repetitions were used for statistical analysis. A rest period of 15 seconds was given between each repetition.

Two sets of 10 ankle hops, 3 sets of 5 hurdle hops, and 5 drop jumps were performed to complete a total of 40 jumps with the bounding exercise for the plyometric action [19]. Bilateral ankle or bunny hops were performed with a stiff lower limb action and a quick, reactive rebound off the floor. Hurdle hops required a series of tuck jumps to clear the height of each hurdle which was set at 70 cm, while attempting to spend as little time as possible on the ground between each jump. Alternate lower limb bounding was performed alternatively from both the lower limbs. For the drop jumps, participants jumped off the ground from squat position with hands on hips and were asked to jump as high as possible while minimizing the ground contact time [19]. A rest period of 30 seconds was given between the sets of ankle hops and hurdle hops, and a rest period of 15 seconds was given in between the repetitions of the drop jump and lower limb bounding.

To assess the sprint performance, agility, counter movement jump height, the 20-meter sprint test, agility T-test, CMJ height test were used respectively. For sprint performance, two cones were placed 20 meters apart on football ground, participant ran on a call of ready-get-set-go [20]. Four cones were placed in T shape, 9.14m straight and 4.57m sidewise to test the agility [21]. Participants were instructed to run straight from starting point and touch bottom of cone and shuffle to left and right sidewise and return back to starting point. Ink was applied to middle finger tips of participants by using a stamp pad, to perform the CMJ Height test. Following this, participants were told to stand 15 cm away from the marking board, holding both feet on the ground (starting from 90-degree knee flexion) and reaching as high as possible with one hand and marking with fingertip on marking board [17,18].

### Statistical analysis

Data analysis was performed through Statistical Package for Social Sciences (version 25, IBM, Armonk, US). Normalisation of the data was confirmed by Shapiro-Wilk test. Three separate repeated-measures analyses of variance were performed to check the immediate effect on sprint, agility and CMJ Height at 3 time points: (a) before plyometric exercise (T0), (b) 1 minute after plyometric exercise (T1), and (c) 5 minutes after plyometric exercise (T5). The level of statistical significance was set at  $p < 0.05$ . When the main effect was statistically significant, a Bonferroni *post-hoc* test was employed.

## RESULTS

All the 20 participants completed the study procedure. 20 Metres Sprint Time: The results showed a significant effect for time ( $F(2, 38) = 22.252, p < 0.001$ ) (Table 1). Post-hoc Bonferroni pairwise comparison revealed a significant decrease in sprint time from baseline to post plyometric exercise at 1-minute ( $p < 0.001$ ) and from baseline to post at 5-minutes ( $p < 0.001$ ) (Table 3). No statistical difference was found between post 1 and 5 minutes ( $p = 0.058$ ).

Agility: The results showed a significant effect for time ( $F(1.466, 27.846) = 29.577, p < 0.001$ ) (Table 1). Post-hoc Bonferroni pairwise comparison showed a significant decrease in agility time from baseline to assessments at both post 1-minute ( $p < 0.001$ ) and 5-minutes ( $p < 0.001$ ) (Table 3). Moreover, the agility time at 5-minutes was also significantly lower than 1-minute ( $p = 0.008$ ).

Counter movement jump height: The results revealed a significant effect for time ( $F(2,38) = 97.300, p < 0.001$ ) (Table 1). Post-hoc Bonferroni pairwise comparison showed significant increase in height from baseline to assessments at both post 1-minute ( $p < 0.001$ ) and post at 5-minutes ( $p < 0.001$ ) (Table 3) and also showed significant increase in CMJ height from post 1-minute to 5-minutes ( $p = 0.001$ ).

Table 1. Summary of Repeated measures of ANOVA for Sprint, Agility and CMJ Height.

Variable	Source	p-value	Partial Eta Square
Sprint	Time	< 0.001*	0.539
Agility	Time	< 0.001*	0.609
CMJ Height	Distance	< 0.001*	0.837

CMJ - Counter Movement Jump; \* - Significant difference.

Table 2. Summary of repeated measures of ANOVA at T0,T1,T5.

Variables	T0 mean $\pm$ SD	T1 mean $\pm$ SD	T5 mean $\pm$ SD
Sprint Time	3.46 $\pm$ 0.045	3.39 $\pm$ 0.044	3.45 $\pm$ 0.037
Agility Time	11.45 $\pm$ 0.14	11.30 $\pm$ 0.13	11.23 $\pm$ 0.13
CMJ Height	41.11 $\pm$ 1.86	42.38 $\pm$ 1.88	43.38 $\pm$ 1.85

SD - standard deviation; T0 - measurement before plyometric exercises; T1 - measurement at 1-minute after plyometric exercises; T5 - measurement at 5-minutes after plyometric exercises.

Table 3. Post hoc analysis.

Variable	Sprint	Agility	Counter Movement Jump
T0 vs T1	< 0.001*	< 0.001*	< 0.001*
T0 vs T5	< 0.001*	< 0.001*	< 0.001*
T1 vs T5	0.058	0.008*	< 0.001*

T0 - measurement before plyometric exercises; T1 - measurement at 1-minute after plyometric exercises; T5 - measurement at 5-minutes after plyometric exercises; \* - significant difference, significance level was set at  $p < 0.05$

## DISCUSSION

The findings of this study suggested that weighted plyometrics showed significant effect for all the three outcome measures and a significant decrease was noted in both AT and ST from baseline to assessments at both T1 and T5, whereas there was a significant increase in the CMJ height.

The study investigated about the induction of greater enhancement in sprint, agility and CMJ Height performance after the series of weighted plyometric exercises as included in the Table 1. The results of the study revealed that the weighted plyometric (WP) exercise exhibits improvement in sprint time in comparison to baseline values. It supports the hypothesis that the WP induces greater enhancement of sprint performance, thus indicating that weighted plyometric exercises can induce a PAP response. 20m sprint time significantly decreased from baseline to 1 and 5 minutes following WP as included in Table 2. Furthermore, when compared, 20-m sprint performance between 1 and 5 minutes after WP exercise did not produce a significant increment in performance (Table 2). In addition to the findings of this study, significantly more improvement following PAP effect were observed after different kind of plyometric exercises with weight as compared to those without WP, this concurs with previous research in sprint performance. Wilson, Duncan [22] proposed that following a conditioning activity protocol, muscular fatigue and potentiation mechanisms co-exist; however, balance between two factors affects the power output and overall performance. Interestingly, a large proportion of the novice participants sought advice from experienced participants to increase the power and overall performance because the training experience facilitates the balance between fatigue and potentiation. According to the available literature, fatigue and potentiation are coexisting entities and when the level of potentiation overcomes the effect of fatigue, it will augment the performance. The notable finding of this study showed a reduction in performance between 1 and 5 minutes when compared with baseline (Table 2) which might have occurred due to fatigue.

Recent evidence reported an improvement in 30 m sprint time following PAP warm-up. An increase (1.11%) in 100 m sprint time has been recorded after the PAP warm-up protocol [23]. Matthews, Matthews [24] concluded 3.3% improvements in 20 m sprint times following conditioning exercise. According to a study, PAP warm-up protocol containing resisted sprint exercise resulted in 2.6% increment in 25m sprint times [25]. Studies have found that 10% load has less effect [26], while some studies have suggested that a load of 10-15% is essential for resistance training effect. These studies reported that the weighted exercise showed an improvement in sprint performance. The findings of our study concur with the previous researches and support the concept that weighted exercises have the ability to produce an improvement in sprint performance.

In the present study, the observed improvement in CMJ height was 1.27 and 2.27 at 1 and 5 minutes after plyometric exercise, respectively. The results of this study strengthen the previous findings of Tobin and Delahunt [19] showing improvement in CMJ height after series of plyometric exercises. The hypothesis of this study was confirmed by an acute enhancement in CMJ performance following weighted plyometric exercise at 1 and 5 minutes. It is noteworthy that the weighted plyometric (WP) exercise was responsible to achieve improvement in CMJ height in majority of participants and it reveals the generality and suitability of WP exercise in producing PAP effect rather plyometric alone.

There is paucity of researches available that support the findings of the current study. Villarreal, Kellis [14] documented that the plyometric exercises in form of sports specific warm-up have a positive result on CMJ height at interval of 5 minutes. Tobin and Delahunt [19] also reported that improvement in CMJ height ranged from 1.53 to 2.09 cm during the 5-minute period after

repeated plyometric exercise protocol. The current study revealed a range from 1.27 to 2.27 cm at 1 minute and 5-minute respectively after which the WP exercise showed a greater increment in jump height when compared with baseline plyometric exercise. No improvement was noted on CMJ performance following tuck jump [13] which might be because no sufficient stimulus was provided to produce potentiation. In contrast, a study by Esformes and Bampouras [27] stated that the threshold level of activity is essential to induce the potentiation. This study also revealed that loaded plyometric exercise has an ability to achieve threshold level quickly with minimal fatigue, similar to PAP effect after heavy resisted exercise. It showed that the volume of exercise performed influences both potentiation as well as fatigue. Considering the findings of our study which support Tobin and Delahunt [19] and Villarreal, Kellis [14] it seems that a plyometric volume of 25–40 jumps is an effective stimulus to produce an acute enhancement in CMJ performance with minimal fatigue.

These notable findings of our study regarding the improvement in CMJ height after WP exercise contrast those which observed an improvement in CMJ height after heavy conditioning activity (CA). Crewther, Kilduff [4] also reported an increase in CMJ height after heavy loading protocol following PAP. The fast-twitch muscle fibers have to be effectively fired during the CMJ performance following plyometric exercise. The intensity of the plyometric exercise used in the study may have increased the excitability of motor units along with considerable amount of fast-twitch muscle fiber recruitment, thereby improving CMJ performance. Moreover, plyometric exercise produce high muscle temperature, which intensify higher muscle activation to enhance performance, tendinous tissue storage and recoil of the elastic energy [28]. Enhanced phosphorylation of the MLC elicits an increment of sarcoplasmic  $Ca^{2+}$  in preload phase to activate the MLC kinase and greater formation of actin-myosin cross-bridges. It could be the reason for greater performance of CMJ in the study.

Another important component of current study is that the agility and results of this study revealed a greater improvement in agility performance after WP exercise in collegiate football players. The findings of our study revealed the time to complete the agility T-test decreased for both 1 and 5 minutes after WP exercise when compared with baseline. In contrast to straight sprinting, agility involves deceleration and acceleration along with change in direction. Power and strength qualities contribute little to agility performance [29] as it involves quick movements. Likewise, in the present study, WP exercise showed changes in agility measures, which confirms our hypothesis that the WP exercises enhance agility performance. The findings of the study are consistent with previous research which showed that adequate recovery periods are needed to reduce fatigue and improve PAP [30]. The agility time in this study showed an improvement which is supported by documentations of Chiu, Fry [31]. The association of agility with the PAP phenomenon was documented along with the explanation of neural activation following PAP phenomenon. The study conducted by Cochrane et al. [28], on agility following PAP by using Whole Body Vibration (WBV) failed to find positive outcomes. The findings of the present study explained that WP exercises show changes in agility time following PAP phenomenon. It may be as result of increased motor neuron excitability and abundant amount of rate of force development which results in greater power production [32]. There are certain limitations to the present study. The individual fitness and differences in training may have influenced the performance of the participants. Use of stop watch method for the measurement of the sprint and agility time might have added to some errors, as it is not accurate exactly. Advanced methods like Infra-Red timing gates help to measure accurate value. Loaded plyometric exercise with weight cuffs are difficult to execute in field, the weighted vest is more comfortable than weight cuffs. Electromyographic analysis along with other components of the study would be more noteworthy approach to understand the effect of weighted plyometric on sprint, agility and CMJ performance of the participant. The study was conducted in collegiate male football players, so the results cannot be generalized to whole population.

This study has several practical implications worthy of discussion. The results of the study provide knowledge regarding the concept of PAP with the weighted plyometrics that can be included in training programs to produce an acute improvement in soccer game. Furthermore, the warm-up protocols with loaded plyometrics can be added both on-field and off-field training programs. For appropriate training to increase the performance and to yield the chronic adaptation as well as short effects, loaded plyometric drills can be used in pre-competitive training. There is a scope for the study to check the potentiation and fatigue with the help of biomarkers among different populations by

measuring. More researches can be performed for measuring the potentiation and muscle activity during loaded plyometric exercises using surface EMG in the future.

## **CONCLUSION**

The findings of our study are very lucrative and clearly indicate the effect of weighted plyometric in soccer players. The results revealed that weighted plyometric exercises have an acute response on sprint, agility and counter movement jump following PAP effect. It is recommended that series of weighted plyometric exercise is worth full method for obtaining the benefits of PAP phenomenon. This mode of exercises provides a distinct benefit for those performing group sports. Further research is needed to investigate the effect of weighted plyometrics in other populations. The results also imply that sports-specific warm-up protocols consisting of plyometric exercises might help exhibit improvement in sports performance.

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