ISSN: 2476-5279; International Journal of Musculoskeletal Pain Prevention. 2021;6(4): 613-621.

# A Prophylactic Effect of PNF Stretching on Mechanical Parameters of Agility, Squat and Continuous Jumps following Exercise-induced Muscle Damage

ARTICLEINFO

*Article Type*
**Original Research**

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**How to cite this article**

Jalalvand A., Khaksari Gh. A Prophylactic Effect of PNF Stretching on Mechanical Parameters of Agility, Squat and Continuous Jumps following Exercise-induced Muscle Damage. IJMPP. 2021; 6(4): 613-621.

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*Article History*
Received: Aug 1, 2021
Accepted: Oct 11, 2021
ePublished: Oct 25, 2021

ABSTRACT

**Aim:** The purpose of this study was to examine the effects of Proprioceptive Neuromuscular Facilitation (PNF)stretching combined with plyometric training on agility and Squat/Continuous jumps in non-athlete male students.

**Method and Materials:** Thirty non-athlete male students were volunteered to participate in this study. Participants were assigned into control (n=21) and intervention (n=21) groups. Dependent variables were recorded at baseline and 48 hours after post-exercise. A Vicon (200 Hz) motion analysis system with six T-Series cameras and two Kistler force plates (1000 HZ) were used to record kinematic and kinetic data. A two-way repeated measure ANOVA (group x EIMD) was used to compare the data between the two groups.

**Findings:** The agility in the intervention group was higher than in the plyometric group at 48 hours (P=0.015). Within-group comparison of agility showed a difference in the plyometric & PNF group from pre- to post-training (P=0.003). There were no significant differences in Squat jump test parameters from pre- to post-test between groups (P>0.05). Also, within-group comparison of continuous jump of variables (maximum vertical displacement and power average) showed no difference in the plyometric & PNF group at 48 hours (P>0.05).

**Conclusion:** A prophylactic effect of PNF stretching on agility and components of continuous jumps following exercise-induced muscle damage was useful. Therefore, PNF can be useful with a preventative method in reducing the symptoms of exercise-induced muscle damage in some functional parameters of the exercise.

**Keywords**: Proprioceptive Neuromuscular Facilitation (PNF), Squat Jump, Continuous Jump, Plyometric, Exercise-induced Muscle Damage.

## Introduction

Plyometrics is one of the types of exercise that increases strength and explosive power in athletes [1, 2]. In many sports such as soccer, tennis, golf and many others, the use of plyometric training is a useful tool for fitness exercises [3]. Plyometric training includes a quick eccentric stretch immediately followed by a concentric contraction, as a result of elastic energy stored in the muscles, thus producing more force than the concentric contraction alone. Research shows plyometric training "to improve strength acceleration power joint awareness proprioception and agility. Although plyometric exercises have been shown to be beneficial, it does produce an eccentric contraction that can ultimately lead to joint and muscle soreness [4]. The effects of Exercise-Induced Muscle Damage (EIMD) are especially vital for inactive people, particularly taking after the primary work out preparing sessions and unaccustomed works out [5]. Generally, unaccustomed work out can lead to EIMD (i.e. muscle discomfort characterized by indications of torment, firmness and/or delicacy) 24 hours after a work out session. The top of EIMD happens between 1-3 days taking after a work out session, as a rule related to muscle harm and irritation, and its greatness can change from slight muscle solidness to extremely weakening torment and development confinement [5].

The reason of this study was to determinde the intense impacts of PNF stretching combined with plyometric training on agility and jumping sports execution in non-athlete male understudies. The effects of delayed-onset muscle soreness on agility and jumping sports performance in some limited research has examined. Limited studies have examined the effects of muscle soreness on the ability to change direction quickly (agility). The ability to rapidly create force and a higher neuro-muscular coordination are significant components of performance of agility and speed [6]. The examination of these factors potentially affecting EIMD is possible. Therefore, the aim of the present study was to examine the effects of EIMD on agility and jumping sports performance and to explore its effects on performance further.

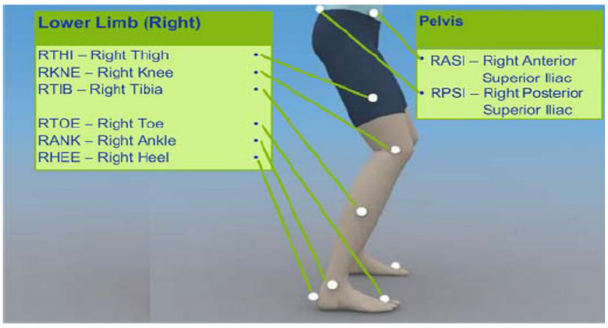
There are lists of popular treatments to reduce the severity of EIMD; The authors state that this treatment includes massage, cryotherapy, stretching, ultrasound, light exercise, stretching, immobilization [7]. Generally, there is a broad consensus that nothing really decisively helps exercise-induced muscle damage[7] and the best way to prevent delayed onset muscle soreness. Pre-exercise warm-up with stretching is used routinely in clinical practice to reduce the risk of muscle injury for numerous types of injuries.

Previous studies have demonstrated no efficacy of static stretching treatment in preventing of EIMD[8]. The results of some studies suggest that PNF stretching increase Range Of Motion (ROM) is more than that static stretching (SS) [9, 10]. The PNF stretching techniques are significantly increased ROM in patients with bilateral hamstring tightness, So PNF stretching preferred over static stretching [11]. According to scientific reports, treatment by PNF stretching techniques leads to a reduction of pain in musculoskeletal patients [12] and improving functional ability [13]. Hence, the use of PNF may be more effective than static stretching for reducing its symptoms; it may have some potential benefit as a preventive effect. The efficacy of this technique has not been evaluated in subjects with EIMD. Some studies have shown that the prior PNF stretching application may have value as a preventive effect, which could be useful for attenuating the signs and symptoms of muscle damage after eccentric exercise [14]. Yuktasir and Kaya (2009) showed that ROM significantly for both the intervention groups (passive static stretching and contract-relax PNF) was higher, but the control group did not show change. As a result, stretching exercises improve ROM, but the type of stretching did not have a significant influence on the deep jump[15]. However, results from other studies have shown a negative association between the effects of PNF stretching and performance. The belief that although increases in ROM were significantly greater after PNF than after static stretching, the decreases in maximal voluntary contraction were similar between the two treatments. These results suggest that, although PNF stretching increases ROM more than static stretching, PNF stretching and static stretching is detrimental to maximal isometric strength[9]. Due to the conflicting results and the lack of investigation of prophylactic effect of PNF stretching on improving performance, We need to examine prophylactic effect on agility and jumps following exercise-induced muscle damage.

## Method and Materials

The present research is a quasi-experimental study. Thirty voluntarily non-athlete male understudies (age: 21.71 ±1.93 years; height: 175.25 ±5.31 cm and body mass: 74.35 ±10.11 kg) taken an interest in this study. Subjects were allowed into control (n=21) and intervention (n=21) homogeneous groups. Subjects had no postponed onset muscle soreness for at least six months recently at the starting of the study. Additionally, they had not experienced any extra lower-body resistance preparing or broad physical action within the past six months. The sample size was calculated using the GPower 3.0.10 software program [16].

The clinical assessment indicates that the subjects are suitable for active exercises. The intervention group of the subjects experienced PNF stretching some time recently muscle harm actuated by plyometric workout and after as well. The control groups of the subjects gotten as it was muscle harm caused by the plyometric workout. The dependent factors at that point were measured at some time recently work out as a pattern and 48 hrs after muscle harm actuated by plyometric work out. A vicon motion analysis framework with six T-series cameras (200 Hz) and 2 Kistler force plates (1000 HZ) (Sort 9281, Kistler Instrument AG, Winterthur, Switzerland), utilized to record the kinematics and energy, individually. A low pass filter (Butterworth) was used to filter the kinematic data with a cut off frequency of 8 Hz, while the kinetics data were filtered at 20 HZ. Cameras were placed on both sides of a walkway at a distance of 5 m from the center of the calibrated space. Calibration space dimensions were 300*150*200mm (length, width, and height, respectively). The calibration frame length allowed full left and right strides to be placed in the calibrated frame. Sixteen 25-mm diameter markers were put on left and right superior anterior iliac spine, superior posterior iliac spine, thigh, lateral condyle of the knee, shank, lateral malleoli, heel, and second distal metatarsal (Figure1). The markers reflected the infrared light toward the cameras. All markers were set concurring to Plug-in-Gait convention Direct, 2010. Information were calculated by Vicon Nexus 1.8.5 computer program and were extricated by Polygon 3.5.1.




**Figur 1)** Marker placement for plug-in gait lower body models (lateral view).

### Plyometric exercises protocol inducing of muscle damage

A plyometric exercise protocol of the present study was in agreeing to Markovic et al. [17]. Training session started with a planning session: 2 minutes of running, 3 minutes of common warm up exercises, callisthenic and stretching works out (3 minutes). Plyometric preparing program for both groups included 50-cm hurdle jumps (6sets X 7reps), drop jumps from box height of 40 cm (4 sets X 6 reps). The stop between each rebound being almost 5 seconds (i.e., the duration required for the subject to step on the box once more). Rest intervals between sets and repetitions were 3 and 1 minute, respectively. Upon landing from a drop, the subject was instructed to jump for greatest height and least ground contact time. Members in both groups were instructed to perform works out in a preparing session with the most noteworthy exertion (i.e., maximal intensity). It implies that each hop ought to be carried out to reach a maximal stature with negligible ground contact time. Especially, both jump bounced and D Specifically, both hurdle jumps and DJs were performed with little angular knee movements, touching the ground with the ball of the feet as it were, subsequently pushing the calf muscles basically [17].

**Therapeutic exercise protocol**

This program incorporates pre-exercise PNF stretching (prophylactic). The PNF method (contract-relax) was performed for stretching. The subjects were treated with 10 seconds of isometric contraction after five seconds of relaxation, and at long last 20 seconds of extending. In addition, they were every day treated for three days some time recently the test. The works out were divided into six sessions, two sessions a day (10 o'clock within the morning and five o'clock within the evening) and each session endured 10 minutes.

**Measurement criterion**

**Force plate agility test**

The force plate test was used to measure quickness and power (ground contact time while hopping) in Figure 2. This test was created to shift their body weight in several different directions [3]. The testing procedure is as follows:

Participants at the center of the force plates, and Then subjects on their dominant leg to maintain balance, participants jump from center forward and back to the center, then to the right and back to the center, then backward and back to the center, and finally to the left and back to the center.

**Figur 2)** Force Plate Agility procedures. Force Plate – going clockwise on dominant foot

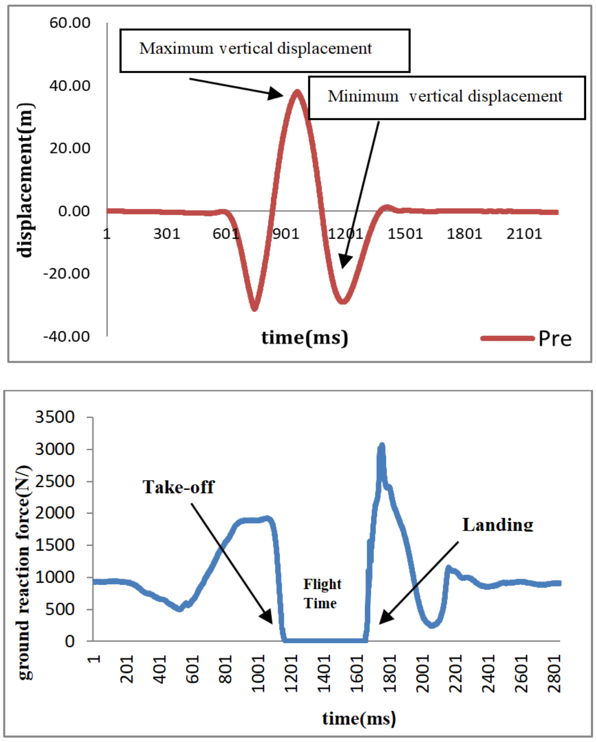
**Squat Jump**

The Squat Jump (SJ) test is regularly utilized to measure an athlete's explosive lower-body control (i.e. speed-strength capacity) [17]. The squat jump test measures explosive strength. This test is performed by beginning together with knees bent in a 90 degree angle, and jumping vertically as high as possible from that position. Hands ought to be held on the hips to avoid the impact of arm swinging to the test. Knees and ankles ought to be extended at take-off, and they ought to be in a similar extended position when landing on the ball of the foot.

**Continuous Jump**

The continuous jump test measures anaerobic control. The point of the continuous jump test is to perform the highest number of jumps with maximum height in the set time period. The continuous jump test is performed by squatting down until the knees are bent in a 90 degree point, and after that quickly jumping vertically as tall as conceivable, and landing with both feet at the same time, bending the knees, and repeating the vertical jumping movement until the set time period (15 seconds) is over. The test ought to be begun with maximal exertion, bouncing as tall as possible as quickly as conceivable.

As the test continues you'll normally gotten to be exhausted but keep maximal exertion all through the test. Squat and continuous jumps test parameters through Vicon Nexus 1.8.5, and Polygon 3.5.1 software were calculated. The parameters acquired are: Maximum vertical displacement, minimum vertical displacement, flight time, power average, a maximum landing force, peak take off instantaneous velocity (Figure 3).




**Figur 3)** A: Displacement -time Curve; B: Force-time curve

### Statistical analysis

Statistical analyses were undertaken utilizing the measurable program for social sciences (SPSS Inc., adaptation 20). The Shapiro-Wilk normality test analyzed a normal distribution of data. A two-way repeated measure ANOVA (group x EIMD) was used to compare the data between the two groups. Additionally, Effect size (d) for the intervention group was calculated as a ratio of mean difference divided by the standard deviation of the differences between measurements. A p-value < 0.05 was considered to be measurably critical. All values are represented as mean ± SD.

### Findings

The demographic characteristics of the two groups are summarized in Table 1. No difference was observed between the groups in age, height, and weight (P > 0.05).

### Force plate agility test

The baseline agility t-test was not different between groups (P=0.416). Between-groups comparison of agility showed a difference in the control group compared with the intervention group (P=0.015). Within-groups comparison of agility showed a difference at post-training in the Plyometric & PNF groups. A decrease was seen in agility for the intervention group at 48 hours (by 4.62%) post-exercise compared with the pre-test (P=0.003; d=0.705). Also, Group × Time interaction was significant for agility (P=0. 000). However, within-group comparison of agility showed no difference in the control group at 48 hours post-exercise compared with the pre-test (P=0.415) (Table 2).

**Table 1)** Demographic characteristics of study subjects (Values are presented as mean ± SD)

| Variables | Groups | | p-value |
|---|---|---|---|
| | Plyometric | Plyometric&PNF | |
| Age (yr) | 21.14±2.19 | 22.28±1.6 | <0.05 |
| Height (cm) | 177.14±5.60 | 174.17±5.1 | <0.05 |
| Weight (kg) | 76.28±11.56 | 72.42±10.1 | <0.05 |

### Squat jump

There were no significant differences in Squat jump test parameters from pre- to post-test between groups (P>0.05). Also, a within-group comparison of the Squat jump of variables showed no difference in the Plyometric & PNF group at 48 hours. Similar to the Plyometric & PNF group did not show any significant differences in the Plyometric group at 48 hours. However, Time

**Table 2)** Agility Changes in outcome measures before and 48h after the Plyometric exercise of groups (Values are presented as mean ± SD)

| Variable | No EIMD | | EIMD | | Time effect | Time & group |
|---|---|---|---|---|---|---|
| Agility(s) | Plyometric | Plyometric&PNF | Plyometric | Plyometric&PNF | | 1. |
| | 4.11±0.42 | 4.28±0.28 | 4.13±0.44 | 3.56±0.22 a | < 0.001 | < 0.001 |

[a] Significantly different from No EIMD

**Table 3)** Squat jump Changes in outcome measures before and 48h after the Plyometric training of groups.

| Variables | No EIMD | | EIMD | | Time effect | Time& group |
|---|---|---|---|---|---|---|
| | Plyometric | Plyometric&PNF | Plyometric | Plyometric&PNF | | |
| Maximum vertical displacement (m) | 0.404±0.088 | 0.407±0.09 | 0.384±0.108 | 0.395±0.09 | * | <0.05 |
| Minimum vertical displacement (m) | -0.153±0.038 | -0.157±0.041 | -0.156±0.017 | -0.161±0.020 | <0.05 | <0.05 |
| Flight time (ms) | 470.00±47.16 | 491.42±63.16 | 496.42±52.97 | 500.71±53.80 | * | <0.05 |
| Power average (W/Kg) | 25.55±6.46 | 26.28±7.00 | 24.64±8.17 | 25.77±6.39 | <0.05 | <0.05 |
| Maximum landing force (N/kg) | 42.31±3.79 | 42.32±2.51 | 39.49±6.33 | 39.01±7.01 | <0.05 | <0.05 |
| Peak Take off instantaneous velocity(m/s) | 2.75±0.248 | 2.67±0.186 | 2.80±0.313 | 2.82±0.335 | <0.05 | <0.05 |

*p: result of the repeated measurement ANOVA (Time effect)

**Table 4)** Continuous jump Changes in outcome measures before and 48h after the Plyometric training of groups.

| Variables | No EIMD | | EIMD | | Time effect | Time & group |
|---|---|---|---|---|---|---|
| | Plyometric | Plyometric&PNF | Plyometric | Plyometric&PNF | | |
| Maximum vertical displacement (m) | 0.350±0.068 | 0.349±0.080 | 0.292±0.036 [a] | 0.313±0.040 | * | <0.05 |
| Minimum vertical displacement (m) | -0.284±0.26 | -0.253±0.65 | -0.273±0.08 | -0.267±0.05 | <0.05 | <0.05 |
| Power average (W/Kg) | 22.83±5.58 | 23.08±6.28 | 20.08±3.58 [a] | 21.23±4.20 | * | <0.05 |
| Maximum landing force (N/kg) | 24.98±2.56 | 24.044±2.17 | 23.09±2.95 | 24.28±3.52 | <0.05 | <0.05 |
| Peak Take off instantaneous velocity (m/s) | 2.49±0.274 | 2.36±0.201 | 2.44±0.199 | 2.48±0.242 | <0.05 | <0.05 |

[a] Significantly different from No EIMD
*p: result of the repeated measurement ANOVA (Time effect)

interactions were significant for maximum vertical displacement (P=.033) and flight time (P=.047), which was due to the fact that maximum vertical displacement decreased non-significantly in both group after fatigue (Table3).

**Continuous jump**

There were no significant differences in Continuous jump test parameters from pre- to post- between groups (P>0.05). Within-group comparisons showed a decrease in maximum vertical displacement by 15.71% from pre- to post-test in the plyometric group (P=0.047; d=0. 76), while these changes were not observed in the Plyometric & PNF group. Also, Time interaction was significant for maximum vertical displacement (P=.013). There were no significant differences in maximum vertical displacement from pre- to post-test in the Plyometric & PNF group (P=0.151).

Within-group comparisons showed a decrease of power average variable by 14.97% (p=.05; d=.74) from pre- to post-training in the plyometric group, while these changes were not observed in the Plyometric & PNF group. Also, Time interaction was significant for Power average (P=.015). There were no significant differences in power average from pre- to post-test in the Plyometric & PNF group (P=0.161) (Table4).

## Discussion

The findings from this study indicate there is a statistically significant difference in agility performance between/ within groups after PNF stretching. Thus, a result of this study suggests that applying a prophylactic treatment help to attenuate symptoms of EIMD on agility performance. Several studies have found an adverse correlation between stretching and performance; there are also studies that have shown no decrement to performance [18]. Amiri khorasani et al. (2010) showed that static stretching does not seem to reduce the agility performance when combined with a dynamic warm-up. However, dynamic stretching during the warm-up is one of the most effective methods for agility performance [19]. Previous study found no significant difference in acute effects of static and PNF stretching on agility Performance [18]. While a few studies have been investigated to assess the effect of PNF stretching on agility performance, but the present study to support the effect of prophylactic (before exercise) on agility performance in subjects with EIMD. Speed and agility are two important skill related fitness components in sports performance. Agility has been an important topic of study in multiple sports, including tennis volleyball, soccer, ultimate Frisbee, and basketball [20]. Agility has been defined as ‘‘a rapid whole-body movement with change of velocity or direction in response to a stimulus’’[21]. PNF stretching is believed that can be the cause of musculotendinous unit (MTU) stiffness, thus can reduce the time of contraction and agility. Three times per week for four weeks of PNF stretching on the ankle joint help to cause MTU stiffness (increased 8.4%). A stiffer MTU system is associated with improving the ability to store and release elastic energy .Thus it is believed that PNF stretching could improve the individual's performance or even helping to reduced contraction time [22].

The comparison between/within groups of Squat jump parameters did not show any significant differences from pre- to post-training. Thus, the result of this study suggests that applying EIMD cannot have a significant effect on Squat jump parameters. This ineffectiveness could be due either to non-influence of exercise-induced muscle damage on power parameters, or the low sensitivity of this type of jump in estimating the performance loss of exercise-induced muscle damage.

Chatzinikolaou et al. (2010) showed that performing an acute bout of intense plyometric exercise may cause short-term muscle damage and inflammatory responses, but transient. It seems the performance of the jump up to 72 hours after the workout gets worse, while the power seems to remain unchanged[23]. The results of studies have been suggested to static active stretching in active tension can be improved explosive force disciplines [24].

The findings from this consider show there is not a statistically significant difference in Continuous jump parameters between groups at 48 hours post work out. Hence, a result of this considers recommends that applying a prophylactic treatment may did not offer assistance to weaken side effects of EIMD on Continuous jump parameters. The findings from this study indicate there was observed significantly jump height reduction in the plyometric group after 48 hours. This decrease may be due to the effects of exercise-induced muscle damage in this group. However, this decreasing trend was not shown in the plyometric & PNF group at 48 hours. Thus, a result of this study suggests that applying the PNF stretching helps to attenuate symptoms of EIMD on Continuous jump height. The findings from this study indicate there was marked Power average reduction in the plyometric group after 48 hours. This decrease may be due to the effects of exercise-induced muscle damage in this group. Nevertheless, this decreasing trend was not shown in the plyometric & PNF groups at 48 hours post-exercise. Thus, a result of this study suggests that applying the PNF stretching helps to attenuate symptoms of EIMD on the Power average in Continuous jump.

## Conclusion

A Prophylactic effect of PNF stretching on agility and components of Continuous jumps following exercise-induced muscle damage was useful. Therefore, PNF can be useful with preventative methods in reducing the symptoms of exercise-induced muscle damage in some functional parameters of the exercise.

## Acknowledgements

The authors express their thanks to the participating individuals for their time and effort.

**Authors' contribution:** AJ was principal researcher of this study. GhR Kh was co-worker of the study. Both authors read and approved the manuscript.

**Conflict of Interest:** There is no conflict of interest for this study.

**Ethical Permission:** All methods performed in the study were in accordance with ethical standards of the national research committee and with Helsinki Declaration.

Informed consent was obtained from all individual participants included in the study.

**Funding:** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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