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A Prophylactic Effect of PNF Stretching on Mechanical Parameters of Deep Jump following Exercise-Induced Muscle Damage

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Abstract

Purpose: Prophylactic effect of PNF stretching is performed with an expectation to reduce the risk of eccentric exercise-induced muscle damage and enhance drop jump performance. The purpose of this study was to examine the effects of proprioceptive neuromuscular facilitation stretching combined with plyometric training on deep jump in non-athlete male students. **Method:** The study design was a single blinded, randomized, concurrent parallel trial. Forty-two non-athlete male students were volunteered to participate in this study. Participants were assigned into plyometric (n=21) and plyometric & PNF (n=21) groups. Maximum and minimum vertical displacements, flight time, joint power, maximum landing force, peak take off instantaneous velocity were measured at baseline and 48 hours following the plyometric exercise protocol. 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, respectively. A two-way repeated measure ANOVA (group x DOMS) was used to analyze data. **Results**: There was a significant difference between the pretest and the posttest scores in the intervention group for maximum vertical displacement (p=0.028), flight time (p=0.042), and Power average (p=0.026). **Conclusions:** This prophylactic treatment on mechanical parameters of deep jump during timing was useful. Eventually, results suggest that preventative treatments can have a significant effect on maintenance functional parameters or even helping to slow exercise-induced muscle damage for alleviating its symptoms.

***Keywords**:* Proprioceptive neuromuscular facilitation (PNF); Deep jump; Plyometric; Exercise-induced muscle damage

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INTRODUCTION

Delayed onset of muscle soreness (DOMS) commonly occurs following increment in intensity and volume of training or when the training program changed. Symptoms and consequences of DOMS include: loss of strength, pain, swelling, stiffness, and tenderness, decreased the range of motion, and reduce force and movability. Muscle soreness may disappear up to 5-7 days after exercise. Some of the therapeutic approaches attempt to reduce the symptoms caused by damage or to accelerate the recovery process (Hatchett et al., 2016). Studies, which have examined the effects of exercise-induced muscle damage (EIMD) on vertical jump parameters are limited and equivocal. Furthermore, the results are controversial due to the variety of exercise-induced muscle damage protocols and the types of intervention applications. Numerous interventions such as warm-up, stretching, massage, acupuncture and drug therapy have been examined in order to find the most effective interventions technique to reduce the severity of these EIMD (Weerapong, Hume, & Kolt, 2004). In general, the most of these studies have not yielded consistent results on treatment outcomes. Particularly, warming up and stretching are activities that improve the performance and decline the risk of muscle injury through biomechanical mechanisms, neurological and psychological mechanisms. However, previous studies have not shown the effectiveness of static stretching in the avoidance of EIMD (McGrath, Whitehead, & Caine, 2014) . PNF stretching techniques has been frequently used in the rehabilitation setting, and its effects have been documented in the literature. A previous study reported that this method is effective in reducing pain and improving functional capability (Lee, Park, & Na, 2013). Hence, therapist applied the PNF stretching techniques in EIMD for reducing its symptoms; it may be much more effective than static stretching. PNF technique has not been evaluated adequately in subjects with EIMD, and it may prove that the use of PNF could have some potential benefit as a preventive effect.

Other studies have shown a negative association between acute effects of PNF stretching and sports performance. These negative influences relate to performance in squat jump, countermovement jump. The result of some studies has shown that PNF stretching methods did not affect squat jump, and countermovement jump performances.

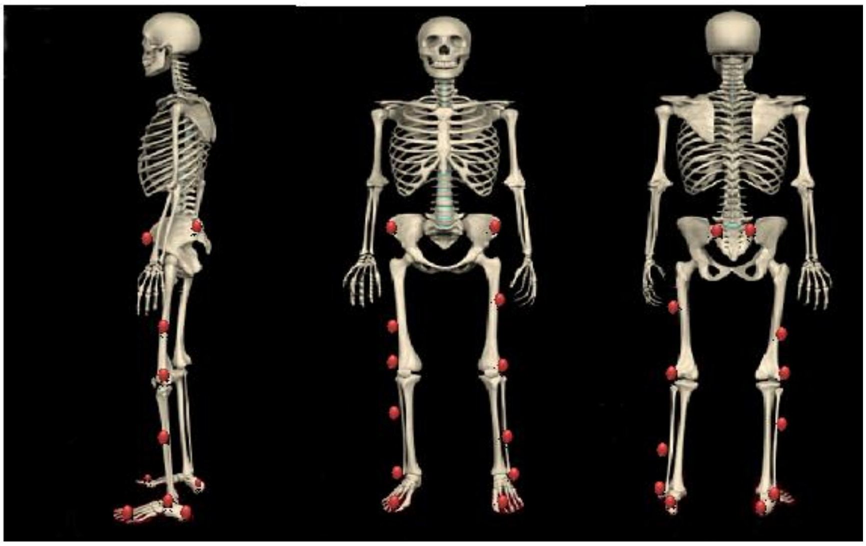
Therefore, they have not changed in maximal voluntary contraction force, voluntary activation level, M-wave and twitch contractile properties that could be attributed to PNF stretching. The belief that "the present self-administered PNF stretching of the quadriceps with short (5-second) stretches is not recommended before sports where flexibility is mandatory for performance" (Place et al., 2013). Some research has shown that vertical jump performance reduced after applying static or PNF stretching for 15 minutes, while ballistic stretching has little effect on jumping performance. Therefore, PNF or static stretching shouldn’t be practiced immediately before performing an explosive movement (Bradley, Olsen, & Portas, 2007). The results of some studies show that acute and temporary effects of PNF stretching are a reduction in yield 4.4%. Thus, although a previous study reported notable performance impairments, PNF stretching generally induces small-to-moderate changes in performance that may be meaningful only in some clinical or athletic environments" (Behm, Blazevich, Kay, & McHugh, 2016). However, the acute effects of stretching after several hours on the rehabilitation process have not been well studied in the literature; there have been only a limited number of studies investigating the impact the same factor for improving performance as a protective effect. Hence, conducting similar studies on persons regarding PNF stretching on performance might produce new data as a key to improving their performance. In this research, we report on the preventive effects of PNF stretching on healthy subjects. In particular, the present study was designed to investigate prophylactic effects of PNF stretching combined with plyometric training on exercise-induced muscle damage (EIMD) and sports performance.

METHOD

The study design was a single blinded, randomized, concurrent parallel trial. Forty-two non-athlete male students were volunteered to participate in this study. Subjects were assigned into control (n=21) and intervention (n=21) homogeneous groups. The participants said that they had not experienced delayed onset muscle soreness for at least six months before the beginning of the study. Moreover, they hadn’t experienced any additional lower body resistance training or extensive physical activity in the past six months. A statistical power analysis program (G*power) done prior to our study indicated that for a statistical power of 0.80 at an effect size of 0.80 with an alpha level of 0.05 is required for a sample size of at least 21 subjects (Faul, Erdfelder, Lang, & Buchner, 2007).

Procedures

The intervention group underwent PNF stretching before muscle damage induced by plyometric exercise and, after as well. The control groups of the subjects received only muscle damage caused by plyometric exercise. The dependent variables then were measured at before exercise as a baseline and 48 hrs after muscle damage induced by plyometric exercise A Vicon motion analysis system with six T-series cameras (200 Hz) and 2 Kistler force plates (1000 HZ) (Type 9281, Kistler Instrument AG, Winterthur, Switzerland), used to record the kinematics and kinetics, respectively. 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(Farahpour, Jafarnezhad, Damavandi, Bakhtiari, & Allard, 2016). Sixteen 25-mm diameter markers were placed 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(Figure 1). All markers were placed according to Plug-in-Gait protocol (Guide, 2010). Data were calculated by Vicon Nexus 1.8.5 software and were extracted by Polygon 3.5.1.



Figur1: Marker placement for plug-in gait lower body models (anterior, posterior and lateral view)

Plyometric exercises protocol inducing of muscle damage

Plyometric exercises protocol of the present study was in according to Markovic et al. (2007). Training session began with a preparing session: 2 minutes of jogging, 3 minutes of general warm up exercises, callisthenic and stretching exercises (3 minutes). Plyometric training program for both groups included 50-cm hurdle jumps (6 sets X 7 reps), drop jumps from box height of 40 cm (4 sets X 6 reps). The pause between each rebound being about 5 seconds (i.e., the duration required for the subject to step on the box again). Rest intervals between sets and repetitions were 3 and 1 minute, respectively. Upon landing from a drop, the subject was instructed to jump for maximum height and minimum ground contact time.

Participants in both groups were instructed to perform exercises in a training session with the greatest effort (i.e., maximal intensity). It means that each jump should be carried out to reach a maximal height with minimal ground contact time. Specifically, both hurdle jumps and DJs were performed with small angular knee movements, touching the ground with the ball of the feet only, thereby stressing the calf muscles mainly (Markovic, 2007).

The Subjects had to fill out a visual analog pain scale. Participants rated muscle soreness (0 - 10 cm) before and after muscle damage induced by plyometric exercise by drawing a mark across a printed visual analogue scale line 10 cm in length, anchored at the beginning by the descriptor "No soreness at all" and at the end by "Worst soreness imaginable" (Glasgow, Ferris, & Bleakley, 2014)

Therapeutic exercise protocol

This program includes pre-exercise PNF stretching (prophylactic).The PNF technique (contract-relax) was performed for stretching. The subjects were treated with 10 seconds of isometric contraction after five seconds of relaxation, and finally 20 seconds of stretching. Moreover, they were daily treated for three days before the test. The exercises were divided into six sessions, two sessions a day (10 o'clock in the morning and five o'clock in the afternoon) and each session lasted 10 minutes.

Measurement criterion: Deep jumps from 40 cm

The movement begins on top of a 40cm box. As soon as participants land on force plates, immediately jump up as far as possible. Maximum vertical displacement (Rise of the center of gravity), minimum vertical displacement (lowest value of the center of gravity height), flight time, power average, a maximum landing force, peak take off instantaneous velocity through Vicon Nexus 1.8.5, and Polygon 3.5.1 software were calculated.

Statistical analysis

The Shapiro-Wilk normality test was used to determine whether the data followed a normal distribution. A two-way repeated measure ANOVA (group x time) was used to compare the data between the two groups (SPSS Inc., version 20). 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 the paired measurements (Cohen, 1977).

RESULTS

Demographic characteristics the two groups are summarized in Table 1. No differences were observed between the groups in age, height, weight, and BMI ($p > 0.05$).

Table 1: Demographic characteristics of study subjects, Mean+SEM.

Variables	Groups		p-value
	Plyometric	Plyometric&PNF	
Age (yr)	21.14±2.19	22.28±1.6	0.289
Height (cm)	177.14±5.60	174.17±5.1	0.349
Weight (kg)	76.28±11.56	72.42±10.1	0.538
BMI(kg/m^2)	24.29±3.65	24.04±3.34	0.894

A decrease was seen in maximum vertical displacement for the plyometric group in at 48 hours post-exercise (by 17.47%; P=0.028). But, within-group comparison of maximum vertical displacement showed no difference in the Plyometric & PNF group at 48 hours (p=0.731; d=0.057). In addition, a trend toward significance for time interaction effect was found for maximum vertical displacement (p =0.055).

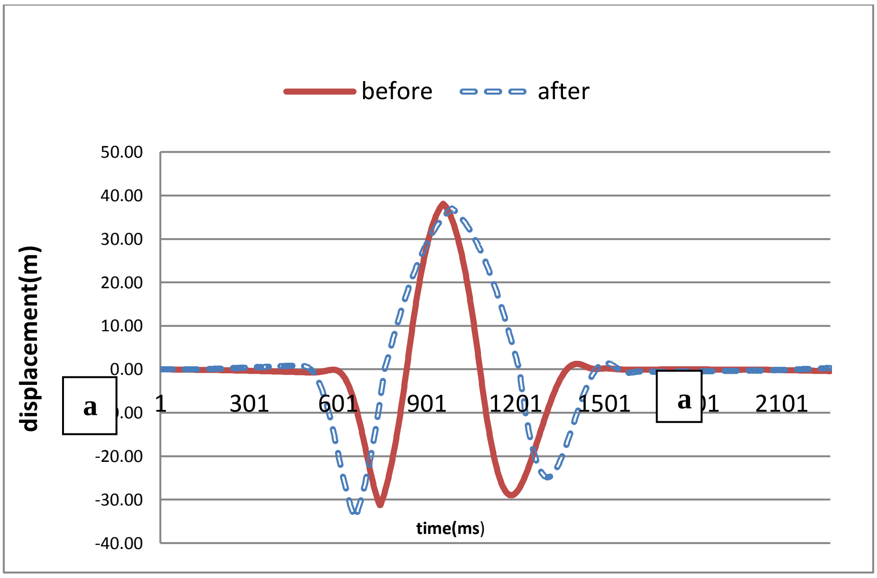
A decrease was seen in flight time for the plyometric group in at 48 hours post-exercise (by 11.84%; P=0.042). In addition, time interaction effect was significant for flight time (p =0.032). While the within-group comparison of flight time showed no difference in the plyometric & PNF groups at 48 hours (p=0.453; d=0.77).

A decrease was seen in power average for the plyometric group in at 48 hours post-exercise (by 14.16%; P=0.026). But, within-group comparison of power average showed no difference in the plyometric & PNF group at 48 hours (p=0.757).

In the intervention group, the maximum landing force decreased 48 hours post-exercise by 18.02% below baseline(p=0.002; d =3.83), compared with a 17.28% reduction in the control group(P=0.009). Between-groups comparisons of maximum landing force did not show a significant difference evident between the control and intervention groups at 48 hours post exercise (P=0.233). But, time interaction effect was significant for Maximum landing force (p =0. 000) (see Table 2 and Figure 2).

Table 2: Depth Jump (40 cm height) Changes in outcome measures before and 48h after Plyometric training of groups

Variables		maximum vertical displacement (m)	minimum vertical displacement (m)	flight time(ms)	Power average (W/Kg)	Maximum landing force (N/kg)	Peak Take off instantaneous velocity (m/s)
No DOMS	Plyometric & PNF	0.381±0.28	-0.313±0.04	514.28±31.11	25.02±4.83	45.27±5.53	2.65±0.21
	Plyometric	0.412±0.42	-0.316±0.034	542.85±43.42	26.48±4.25	47.79±6.87	2.79±0.17
DOMS	Plyometric & PNF	0.370±0.09	-0.331±0.028	495.71±55.03	24.50±6.74	37.11±3.40	2.69±0.63
	Plyometric	0.340±0.06	-0.326±0.039	478.57±54.29	22.73±4.84	39.53±3.79	2.69±0.41
P-value (within group)	Plyometric	0.028	0.417	0.042	0.026	0.009	0.631
P-value (within group)	Plyometric & PNF	0.731	0.058	0.453	0.757	0.002	0.894
P-value (Time)	DOMS	.055	.063	.032	.060	.000	.839
P-value (Time& group)	DOMS & group	.142	.271	.204	.143	.971	.678
P-value (between groups) in Pre-test	P- PNF	0.305	0.887	0.177	0.561	0.465	0.216
P-value (between groups) in Post-test	P- PNF	0.492	0.426	0.568	0.585	0.233	0.977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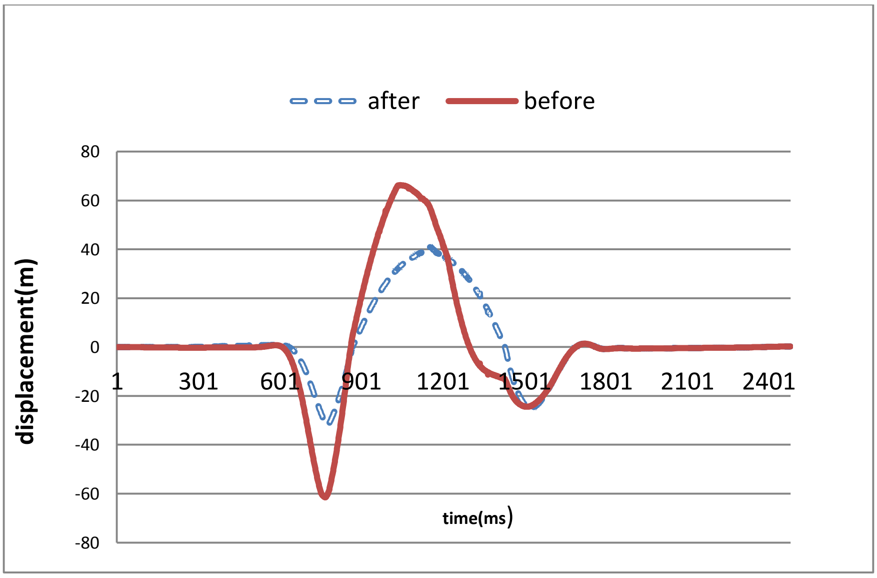
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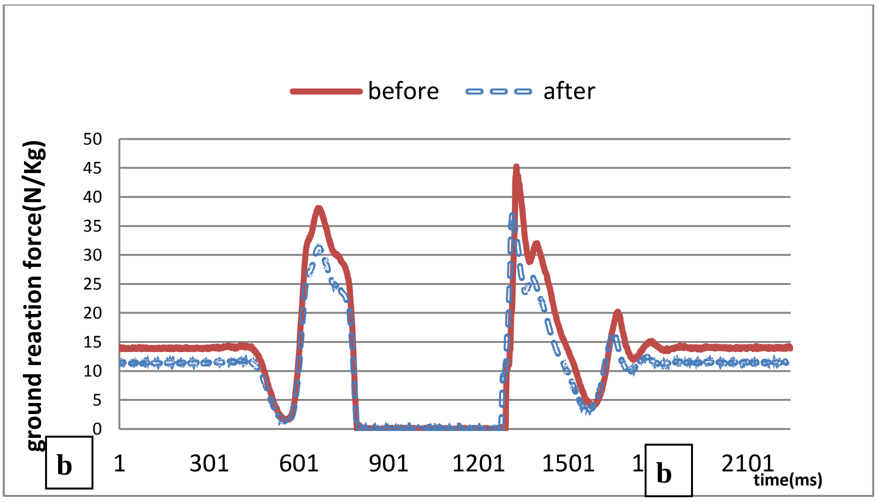

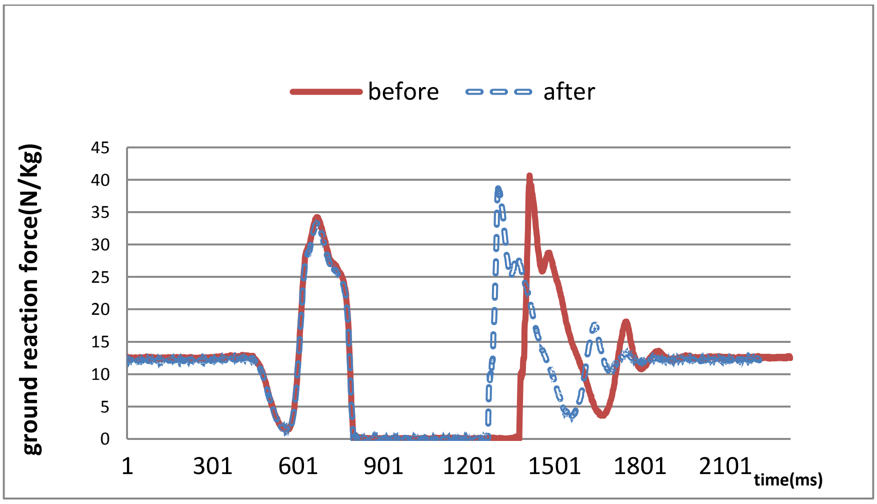

Figure 2: Kinematics and kinetics data of deep jump before and after the protocol in the intervention group (left column) and control group (right column) for displacement-time (a) and force-time (b)

DISCUSSION

Numerous recovery strategies have been used in an attempt to minimize the symptoms of exercise-induced muscle damage (EIMD). However, scientific evidence to support the effect of prophylactic (before exercise) on muscle damage is lacking. Thus, the aim of the present study was to evaluate the effects of combined interventions in markers and determine its prophylactic in the prevention of EIMD related to plyometric training. The possible preventive (before exercise) of a combined treatment in functional parameters related to plyometric exercises: maximum vertical displacement, minimum vertical displacement, flight time, power average, a maximum landing force, and peak take off instantaneous velocity) of exercise-induced muscle damage was investigated. A few differences exist between the present study and other studies: First, male participants were included in the present study, second: the current study tested the protective effects of PNF stretching.

The findings from this study indicate there isn't statistically significant difference in deep jump (40 cm) parameters between groups at 48 hours post exercise. Thus, the result of this study suggests that applying PNF stretching did not help to attenuate symptoms of EIMD on deep 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. But this decreasing trend wasn't shown in the plyometric & PNF group at 48 hours. Thus, a result of this study suggests that applying the PNF stretching help to attenuate symptoms of EIMD on jump height. The findings from this study indicate there was marked flight time reduction in the plyometric group after 48 hours. This decrease may be due to the effects of exercise-induced muscle damage in this group. But this decreasing trend wasn't shown in the plyometric & PNF groups at 48 hours post exercise. Thus, a result of this study suggests that applying the PNF stretching help to attenuate symptoms of EIMD on flight time. The result of our study was similar to previous studies that demonstrated a change in jump parameters following exercise-induced muscle damage (Chatzinikolaou et al., 2010; Twist & Eston, 2007). Possible reasons for reducing in jump parameters following exercise-induced muscle damage: an inflammatory response leads to reduced tolerance to impact forces that use the stretch shortening cycle to generate a jumping movement, a reduced glycogen resynthesis may be related to muscle damage, perceived muscle pain rate that leads to reduced tolerance to exercise and a reduced neural drive to the muscle as a protective mechanism due to prevent full muscle activation from exacerbating damage (Arazi, Eston, Asadi, Roozbeh, & Saati Zarei, 2016; Chatzinikolaou et al., 2010; Komi, 2000).

The findings from this study indicate there was observed 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. But this decreasing trend wasn't shown in the Plyometric & PNF group at 48 hours. Thus, a result of this study suggests that applying the PNF stretching help to attenuate symptoms of EIMD on power average. The peak ground reaction force significantly decreased for the intervention group in at 48 hours post-exercise compared with a pre-test. Possible reasons for reducing a maximum landing force following exercise-induced muscle damage to protect the joints of the lower limb from injury (Santamaria & Webster, 2010). This study has few limitations that must be considered. First, there is a non-training control group. Subjects were all healthy, college-aged, untrained males, and aged between 19 and 25 years, therefore results may not be representative of the entire population in terms of gender and age.

CONCLUSIONS

This finding will enable physical therapists and coaches to develop strategies focused on the found protective effects to improve muscle function and sports performance or even helping to slow EIMD for alleviating its symptoms.

Declaration of Interest

The authors declare that there is no conflict of interest.

Acknowledgment

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