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Original Article

EMG and peak force responses to PNF stretching and the relationship between stretching-induced force deficits and bilateral deficits

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Abstract. [Purpose] The aim of the present study was to investigate the possibility of an interaction between stretching induced deficit (SFD) and bilateral deficits (BLD) during maximal voluntary isometric hand flexion under PNF stretch and no-stretch conditions through measurement of EMG and force production. [Subjects and Methods] Ten physically active male Caucasian students (age, 24.1±2.38 years; body mass, 79.48±11.40 kg; height, 174.15±0.8 cm) volunteered to participate in this study. EMG and force measurements of the subjects were recorded during either unilateral or bilateral 3-second maximal voluntary isometric hand flexion (MVC) against a force transducer. The paired sample t-test was used to examine the significance of differences among several conditions. Pearson product-moment correlation was used to evaluate the associations between different parameters. [Results] Stretching-induced deficits correlated with bilateral deficits in both force (r=0.85) and iEMG (r=0.89). PNF stretching caused significant decrements in the bilateral and unilateral conditions for both the right and left sides. [Conclusion] Since both force and iEMG decreases were observed in most measurements; it suggests there is a neural mechanism behinnd both the BLD and the SFD.
Key words: EMG, PNF, Stretching

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INTRODUCTION

Stretching is frequently performed before exercise[1, 2)], and athletic events[3)]. It was reported that the most commonly used techniques are static stretching and PNF stretching techniques[3)]. Recent studies have reported that static stretching before an exercise or performance event reduces isometric muscle strength[4–8)]. Consequently, this phenomenon has been called the stretching-induced force deficit (SFD)[9)]. Additionally, studies have reported a reduction in muscle motor unit activation and electromyogram (EMG) activation after static stretching[6)]. Two main hypotheses have been proposed to explain the stretching-induced force deficit[10)]: (a) mechanical factors such as decreases in muscle stiffness may affect the length-tension relationship; and (b) neural factors such as altered motor control strategies and/or reflex sensitivity.

Bilateral deficit (BLD) is a type of force deficit. It is defined as the decrease in force produced in a homonymous muscle when unilateral forces are summed compared to bilateral force[11, 12)]. BLD has been observed during isometric muscle contractions. Changes in EMG seem to cause comparable force output decreases during BLD[11, 12)]. Many causes have been proposed for BLD, including inhibitory spinal reflexes, and inhibition of one cerebral hemisphere when the opposite hemisphere is activated[13)].

Proprioceptive neuromuscular facilitation (PNF) stretching is also a form of stretching. It has been reported that stretching using the responses of the nervous system such as proprioceptive neuromuscular facilitation is presently attracting attention in the field of sports[13)]. Proprioceptive neuromuscular facilitation (PNF) has been reported to be effective at relieving pain and improving functional abilities[14)]. Although several studies have evaluated the effect of PNF stretching on the range of motion and vertical jump performance[15–17)], there have been few studies of the effect of PNF stretching on force production and EMG activity. This lack of studies on PNF force production is astonishing since trainers commonly use PNF stretching before or during recovery at athletic events. Knowledge pertaining to PNF's effect on performance is considered necessary to verify whether PNF enhances performance in sports requiring high levels of force production.

While stretching-induced deficit and bilateral deficits have been observed during isometric force production and have been measured with EMG, not many studies have evaluated the effects of PNF stretching on force production and EMG activity, and it is not known whether there is an additive effect of these two deficits. Because the real causes of both deficits are not known, it is uncertain whether they employ the same inhibitory pathway or rely on different mechanisms. Also, it is not certain whether or not the pathways or mechanisms

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Table 1a. Force (N) during maximal voluntary isometric hand flexion in the PNF stretching and no-stretch conditions of both sides

Condition	Bilateral right	Bilateral left	Unilateral right	Unilateral left
Pre-PNF force	416.2±3.3	385.7±13.3	413.7±21.4	420.8±8.4
Post-PNF force	345.0± 40.7*	322.3±68.0*	351.7±32.6*	344.4±60.4*

p<0.05, *: Significantly smaller than the no-stretch condition of the same side side

interact. The chance of identifying the association of the two deficits has implications for the prescription of detailed training modalities for the best probable performance or for recovery methodologies. Thus, the aim of the present study was to examine the possibility of an interaction between PNF stretching and BLD during maximal voluntary isometric hand flexion under PNF stretch and no-stretch conditions through measurement of EMG and force.

SUBJECTS AND METHODS

Ten physically active Caucasian male students, (age, 24.1±2.38 years; body mass, 79.48±11.40 kg; height, 174.15±0.8 cm) volunteered to participate in this study. All subjects were right-hand dominant. Written and oral consent from each participant was obtained at the beginning of the study once the subjects had been informed of the potential risks of the experiment. The Ethics Committee of the University of Seljuk approved the experimental protocol. The participants were not informed of the outcomes until the study had been concluded. Physically active male kinesiology students were enrolled in the study as participants. The subjects who volunteered to participate in the study who had health problems or disability were excluded from the study.

Preparation trials of bilateral flexion against the force transducers were performed to familiarize the subjects with timing and voice commands during the test, as well as the clarity of signals from the electrodes. EMG and force measurements of the participants were recorded during unilateral (UL) and bilateral (BL) 3-second maximal voluntary isometric hand flexion MVCI against a force transducer. Three trials of the unilateral and bilateral conditions were performed. The same procedure, in a randomized fashion with 30 seconds PNF stretching was performed using the dominant hand (unilaterally and bilaterally when this included the dominant hand, but only unilateral non- dominant hand trials. PNF stretching was performed using the hold-relax method according to published guidelines[18]. The hold-relax PNF was used to assist the relaxation and flexion of the hand to increase the range of motion, and uses an isometric contraction. The limb is placed in a pain-free position and an isometric contraction is performed and sustained. The limb is then moved to a new position.

Subjects sat, relaxed, facing ahead, with the knees bent and both feet on the floor, and the upper arms hanging naturally beside the body with the elbows flexed at about 90°. Subject's f the left and right flexor digitorum superficialis (FDS) was detected by palpation.

Testing was completed in a day. Three non-stretch trials of MVCI of both UL and BL conditions were performed followed by three stretch trials of MVCI of both the unilateral and bilateral conditions. Subjects were given a 1-minute break between each trial, (bilateral, unilateral left, unilateral right) and 3 minutes between each series of trials as well as before beginning the stretched segment of the trial. The EMG collection software package was used to extract the maximum-recorded peak force (PF) (N) and integrated EMG (iEMG) (mV•s). The raw signal from each transducer was amplified by a transducer coupler (type A, S72-25, Colbourn Instruments, Allentown, PA, USA) with a gain of 266 and analyzed using an analog software package [Ariel Performance Analysis System (APAS), Ariel Dynamics, Trabuco Canyon, CA, USA]. The differences in force output and iEMG between the UL and BL conditions for MVIC were calculated by subtracting the values of the stretching from the no-stretching conditions.

The paired sample t-test was used to test differences between the bilateral and-unilateral conditions and stretched and and no stretch mean values. The Pearson product-moment correlation was used to evaluate the correlations between the different parameters. Statistical significance was accepted for values of p<0.05.

Table 1b. Force (N) in PNF stretched and no-stretch conditions uring bilateral and unilateral maximal voluntary isometric hand flexion

Condition	Pre-test	Post-PNF
Bilateral right	416.2±3.3	345.0±40.7*
Unilateral right	413.7±21.4	351.7±32.6
Bilateral left	385.7±13.3*	322.3±68.0*
Unilateral left	420.8±8.4	344.4±60.4

p<0.05, *: Significantly smaller than the unilateral condition of the same side

RESULTS

Significant deficits in force and iEMG were observed during the various conditions. There was also a significant correlation of force and iEMG values between the unilateral and bilateral conditions (p<0.05). Parallel force output and iEMG decreases were observed. Stretching-induced deficits correlated with bilateral deficits for both force (r=0.85) and iEMG (r=0.89) (p<0.05).

Significant differences were observed in force and iEMG between PNF-stretching and no-stretch in the bilateral and unilateral conditions on both sides (p<0.05) (Table 1a, 1b, 2a, 2b). PNF stretching caused significant decrements in force and iEMG values in bilateral and unilateral on both the right and left sides (Table 1a).

Bilateral conditions caused decrements in force com-

Table 2a. iEMG during maximal voluntary isometric hand flexion for PNF stretching and no-stretch conditions of both sides

Condition	Bilateral right	Bilateral left	Unilateral right	Unilateral left
Pre-PNF iEMG	0.06±0.02	0.05±0.01	0.07±0.01	0.07± 0.01
Post-PNF iEMG	0.05±0.02*	0.04±0.00	0.06±0.02*	0.06± 0.00

p<0.05, *: Significantly smaller than the no-stretch condition of the same sides

Table 2b. iEMG in PNF stretching and no-stretch conditions during bilateral and unilateral maximal voluntary isometric hand flexion

Condition	Pre-test	Post-PNF
Bilateral right	0.06±0.02*	0.05±0.02*
Unilateral right	0.07±0.01	0.06±0.02
Bilateral left	0.05±0.01*	0.04±0.00*
Unilateral left	0.07±0.01	0.06±0.00

p<0.05, *: Significantly smaller than the unilateral condition of the same side

Table 3. Force (N) and iEMG in PNF stretching and no-stretch conditions during bilateral and unilateral maximal voluntary isometric hand flexion

Condition	Force (N)	iEMG
No-stretching unilateral right	413.71±21.40	0.075±0.017
PNF-stretching bilateral right	345.08±40.79*	0.058±0.021*
No-stretching unilateral left left	420.86±8.46	0.073±0.017
PNF-stretching bilateral left left	322.33±68.07*	0.044±0.006*

*: Significantly smaller than the unilateral no-stretch condition of the same side

pared to unilateral conditions. PNF stretching resulted in significant differences the between bilateral and unilateral conditions on both the right and left sides, except on the right side for the no- stretch condition ($p<0.05$) (Table 1b).

Significant differences were found between the PNF stretching and no-stretch conditions in the bilateral and unilateral conditions for only the right hand ($p<0.05$) (Table 2a). No significant differences were found between PNF stretching and no-stretch conditions under both the bilateral and unilateral conditions for the left hand, even though stretching caused reductions in iEMG under both conditions. The reduction in iEMG in the stretched hand was significantly smaller than that of the right hand in the unstretched condition ($p<0.05$) (Table 3). Consequently, the effect of the stretch on the right hand in unilateral MVCI was a decline in force with a decrease in iEMG activity (Table 2a)

Bilateral conditions caused decrements in iEMG compared to unilateral conditions. PNF stretching resulted in significant differences between the bilateral and unilateral conditions for both the right and left sides ($p<0.05$) (Table 2b).

Bilateral force and iEMG in PNF stretching was significantly smaller than the right hand UL force and iEMG in the unstretched condition ($p<0.05$). Likewise, the left hand BL force and iEMG in PNF stretching was significantly less than the left hand UL force and iEMG in the no-stretch condition ($p<0.05$) (Table 3).

DISCUSSION

The aim of the current study was to determine whether there is an interaction between the stretching-induced deficit (SFD) and bilateral deficits (BLD) during maximal voluntary isometric hand flexion under PNF stretching or no-stretch in the bilateral and unilateral conditions. Through measurement of EMG and force, the effects of stretching were evaluated on maximal voluntary hand contractions unilateral and bilateral conditions. Parallel reductions in force output and iEMG during SFD were also observed in other studies[11, 12].

In the present study, significant (combined sum of both limbs) bilateral deficits were found in the stretch (S) versus the no-stretch (NS) condition. The dominant hand was found to be significantly weaker in the unilateral stretched condition compared to the unilateral no-stretch condition. Bilateral stretched condition values were found to be smaller than the unilateral no-stretch condition. This implies that the dominant hand is significantly suppressed in the stretched condition. These results are consistent with prior reports of short-term decreases in force and EMG activity. Cramer et al. and Costa et al. reported similar deficits in both EMG and force[9, 19]. Several studies have also reported similar results of performance decrements after a bout of stretching[20, 21]. The present study adds to the findings of earlier studies[15, 22], and the results suggest that PNF stretching reduces the force producing capabilities of the leg extensors and flexors during voluntary maximal concentric isokinetic muscle actions at 60 and 180 degrees[20]. Another study observed decreases in peak torque (PT), mean power (MP), and EMG amplitude as a result of both static and PNF stretching[20]. Another study examined and evaluated the effects of PNF stretching and static stretching on maximal voluntary contraction (MVC). Surface electromyography was recorded over the biceps femoris and vastus lateralis muscles during MVC tests and stretching. The results suggested that PNF and static stretching reduce isometric maximal strength[21]. Another study reported reductions in hamstring EMG activity during the 80-degree static stretching performed in younger adults[23].

Although many studies support the findings of the present study, some studies using PNF stretching have reported conflicting results. For example, one study reported that no significant differences were observed in jump performances between PNF stretching and control conditions[21]. Also, the findings of another study indicated that none of the stretching protocols elicited a decrease in knee extension power[24]. Yet, some other studies have reported performance decrements after PNF stretching. For instance, PNF stretching decreased bench press endurance while low volume static stretching did not have a significant effect[6]. Another study concluded there was a decrease in vertical jump heights after PNF stretching[25], and vertical jump heights after PNF stretching were lower than after static stretching and/or control conditions[15]. Yet, another research group reported there were no significant differences in jump performances between PNF stretching and control conditions[22]. These conflicting results may be the result of differences in stretching protocols and/or the types of jumping test performed, suggesting that the magnitude of the performance decrease may be proportional to the intensity of the stretching exercise[6]. Thus, it is likely that either the degree of stretching or fatigue influenced the vertical jumping abilities or isokinetic knee extension after PNF stretching was conducted in these previous studies[20].

In conclusion, the results support the hypotheses presented in the introduction. Since the deficit in force and iEMG elicited by PNF stretching was similar effects among subjects, neural mechanism for both the BLD and the SFD may interact with each other. The present study's findings have some remarkable implications worthy of further investigation. The possibility of collective deficit effects from bilateral and stretching-induced deficits may have implications for some sports trainers and physical therapy experts. The present study suggests that a central nervous system (CNS) mechanism, such as "supraspinal fatigue", might be responsible for the reductions in muscle activation. A cumulative deficit might indicate activation of multiple inhibitory mechanisms or pathways, or possibly greater activation of a single inhibitory mechanism or pathway. Because the deficit in force elicited by stretching seems to be accompanied by decreases in iEMG, this indicates the contribution of a neural mechanism for both the BLD and the SFD. Based on the hypothesis of Avela et al., these findings suggest that the CNS may influence the decreases in force following an acute bout of PNF[4]. The results of the present study have implications for strength and conditioning coaches and athletes who perform PNF stretching prior to performance events. Future studies are needed to detect the essential mechanisms that effect PNF stretching-induced decreases in maximal force production by athletes and non-athletes.

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