Applying proprioceptive neuromuscular facilitation stretching: optimal contraction intensity to attain the maximum increase in range of motion in young males

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Abstract. [Purpose] Proprioceptive neuromuscular facilitation (PNF) stretching is known to be effective in increasing joint ROM. The PNF stretching technique first induces an isometric contraction in the muscles to be stretched, but no agreement concerning the optimal contraction intensity has yet been reached. The purpose of the present study was to examine the effect of contraction intensity on ROM while applying PNF stretching. [Subjects and Methods] Sixty male subjects were randomly assigned to one of four groups (three experimental groups and one control group). Each experimental group applied one of three contraction intensities (100%, 60%, and 20%) defined by the MVIC ratio, and the control group did not receive any intervention during the experiment. PNF stretching was applied to left knee extensors to compare changes in the knee joint flexion angle. [Results] The results showed that the changes in ROM were larger for the 60% and 100% groups compared with the 20% group. The changes in ROM were lowest in the control group. [Conclusion] The present results indicate that while applying the PNF stretching, it is not necessary to apply the maximum intensity of muscle contraction. Moderate isometric contraction intensities may be optimal for healthy young males, while a sufficient effect can be obtained even with a low contraction intensity.

Key words: PNF stretching, Isometric contraction, Range of motion

INTRODUCTION

Flexibility can be defined as the ability to maintain a suitable range of motion (ROM) of joints by extending the lengths of muscles1). When flexibility is sufficient, exercise quality can be improved significantly with an appropriate ROM. As a result, injuries that occur during exercise or daily living can be reduced considerably2, 3). Flexibility is also an essential element for the rehabilitation of damaged musculoskeletal systems4, 5).

Many stretching techniques are employed by athletes and patients in clinical and sporting settings, to increase flexibility. In particular, proprioceptive neuromuscular facilitation (PNF) stretching is known to be effective for increasing the ROM6–12). PNF stretching has been theoretically explained based on Sherrington’s muscle facilitation and inhibition concept13). Specifically, muscle contraction has been considered to result in muscle relaxation and to then lead to increased ROM via decreased agonist resistance14). More recent evidence, however, demonstrates that simple reflex pathways are unable to explain the mechanism of increased ROM observed with PNF stretching10, 15). Practically, PNF stretching first induces an isometric contraction in the muscles to be stretched before manual stretching16). Studies examining PNF stretching have applied various intensities of isometric contraction (Table 1).

Recent studies have reported different results regarding the optimal intensity of isometric contraction while applying PNF stretching. Feland and Marin26) applied PNF stretching to hamstring muscles using 20%, 60%, and 100% of the maximum voluntary isometric contraction (MVIC). They compared a knee joint extension angle among three groups, but no significant difference was found. Sheard and Paine27) applied PNF stretching to the extension muscle of the hip joints using 20%, 50%, and 100% of the MVIC, and found that about 64.3% of the MVIC produced the greatest increment in the ROM changes.

Many studies have examined various intensities of isometric contraction applied in PNF stretching, but no agreement concerning the optimal contraction intensity has been reached yet. The purpose of the present study was to examine the effect of contraction intensity on ROM while applying...
PNF stretching. Unlike the previous studies, the current study applied PNF stretching to knee extensors. The knee extensors were used in this study because the movement of the pelvis can be controlled easily in the prone position; and the activities of the surrounding muscles can be excluded to a great extent. Two previous studies used the hamstrings and hip extensors, respectively. Since resistance was applied from the back of the lower extremities of the subjects in those studies, it might have been difficult to control the pelvis movement. As a result, contraction of many muscles involved in pelvis movement might not have been avoidable, which might have created difficulties in accurate application of the stretching to the preferred muscles.

SUBJECTS AND METHODS

The protocol and consent form for this study were approved by the Institutional Review Board of the Catholic University of Daegu, Gyeongsan, Republic of Korea. All subjects signed a written consent form prior to participation. All subjects voluntarily participated in the study.

Male subjects with an age of approximately 25 years were chosen. In a pilot study, most females showed near-normal ROM for knee joint flexion and recovered normal ROM (larger than 135°) after the intervention regardless of the contraction intensities applied. Ten females in their 20s voluntarily participated in the pilot study. Five of them who had over 115° ROM for left knee joint flexion were excluded. PNF stretching was applied for the remaining five females who had less than 115° ROM (2, 2, and 1 for 20%, 60%, and 100% of the MVC, respectively). After applying the technique, all of them acquired normal knee flexion ROM (larger than 135°). This result showed a larger difference compared with that of male participants, who showed less than 135° flexion after stretching. Therefore, they were excluded from the present study. The following selection criteria were used to choose the subjects: (1) no current disease (or pain) and no past history of surgery in the lumbar region, hip joints, and knee joints and (2) normal passive ROM (135°) and less than 115° active ROM for left knee joint flexion.

Table 1. Intensities of isometric contraction applied in studies on PNF stretching

| Author                        | Contraction intensities indicated (%) |
|-------------------------------|---------------------------------------|
| Lewit (1991)                  | 10, 20                                |
| Chaitow and DeLany (2002)     | 20, 50                                |
| Burke et al. (2000)           | 50, 75                                |
| Padua et al. (2004)           | 50, 75, 100                           |
| Schmitt et al. (1999)         | 75                                    |
| Bonnar et al. (2004)          | 100                                   |
| Funk et al. (2003)            | 100                                   |
| Pincivero et al. (2003)       | 100                                   |
| Spernoga et al. (2001)        | 100                                   |

Finally, the 60 selected subjects were randomly assigned to one of the four study groups. There were three experimental groups and one control group. Each experimental group was applied one of three contraction intensities (100%, 60%, and 20%) defined by the mean of the MVC ratio, and the control group did not receive any intervention during the experiment except ROM measures.

In the experiment, the subjects lay down on a height-adjustable bed in the prone position. PNF stretching was applied to the left leg of the subjects. To perform effective stretching of the left knee joint, the right leg, to which stretching was not applied, was positioned off the bed and extended to the floor. The hip joint of the right leg was placed in a position of up to 135° flexion by adjusting the bed height while the foot sole was kept in full contact with the floor to minimize slippage. In addition, the subjects were asked to grasp the table edge firmly to maintain the stretching position. This posture prevented the rectus femoris in the left knee extensors from intervening in the anterior tilting of the pelvis by having the pelvis attached firmly in the direction of posterior tilting.

First, the MVC of the subjects was measured. Flexion of the left knee joint was stopped if the subject felt resistance to it. In this position, the subject was requested to extend the knee joint as much as possible in a maximum contraction, and the contraction intensity was measured using a dynamometer (Baseline® Digital Push-Pull Dynamometer, Fabrication Enterprises Inc., Elmsford, NY, USA). In order to prevent a difference in force due to a change in the lever arm length, the dynamometer was always applied in the same position at the anterior border of the tibia, which was 10 cm away from the medial malleolus in the proximal direction. The position was marked with a sticker so that force would always be measured at the same position. The MVC was measured three times for each subject, and the mean value was set as the final MVC value. Eight seconds of rest were given to the subjects between measurements.

To minimize any carry-over effect, a PNF stretching experiment was conducted three days after MVC measurement. The subjects continued left knee joint flexion until they felt resistance in the joint. The knee flexion angle (pre-stretching ROM) was measured at that position using an inclinometer (Dualar™ Inclinometer, JTECH Medical, Midvale, UT, USA) placed right inferior to the tibial tuberosity. Immediately after measuring the knee flexion angle, knee extension was requested for 8 s with the preset contraction intensity according to the contraction intensity group. When contraction was complete, 8 s of rest was allowed, and then the knee was flexed up to the position where resistance was felt. This process was repeated two more times. After the last rest, the knee flexion angle (post-stretching ROM) of the subjects was measured at the maximum flexion position. The knee flexion angle of the control group was measured two times with an interval of 1 min without any intervention.

PNF stretching for each subject was performed by a skilled physical therapist. ROM was measured by an occupational therapist who had no information about this experiment. Subjects were randomly assigned to the experiment, and the
applying the PNF stretching technique. Unlike the result of Sheard and Paine\textsuperscript{27} that of Land and Marin\textsuperscript{26} who found no significant difference in the maximum effect between the groups that applied 60% and 20% of the MVIC. However, our result differs somewhat from that of Feland and Marin\textsuperscript{27} who suggested that a moderate contraction intensity to some extent is better than a lower contraction intensity. In the present study, nonetheless, a sufficient increase in ROM was obtained with the 20% contraction intensity, that is, an increase of about 19° more than the control group.

The increase in ROM caused by PNF stretching can be explained by the activation of inhibitory neurons in the spinal cord followed by stimulation of the Golgi tendon organ\textsuperscript{29}. However, most studies using EMG have not found muscle relaxation after isometric contraction in PNF procedures\textsuperscript{10, 26, 28–34}. These results suggest that muscle relaxation is not always followed by muscle contraction. Sheard and Paine\textsuperscript{27} suggested that isometric contraction larger than 70% of the MVIC might lead to stimulation of the muscle spindle, which might result in inhibition of muscle relaxation. This might support the current result in that the largest ROM increase was found in the 60% MVIC group.

The results of our study and two previous studies indicate that while applying PNF stretching, it is not necessary to apply the maximum intensity of muscle contraction. As shown in our study results, a contraction intensity of around 60% might be optimal for increasing the ROM maximally, while a sufficient effect can be obtained even with a low contraction intensity (20%). This result has several important implications. First, the maximum intensity of muscle contraction is not required of those who are performing PNF stretching. In fact, those who utilize the maximum intensity of muscle contraction can be vulnerable to fatigue more quickly, and the applied muscles may be easily exposed to the risk of injury\textsuperscript{20}. Second, a moderate submaximal intensity may be more effective than too low a contraction intensity in order to derive the maximal effect\textsuperscript{27}. Hence, a moderate contraction intensity, e.g., 60%, may be optimal for healthy normal persons and athletes who need flexibility. Finally, our study result suggested that those who feel difficulty in muscle contraction or muscle pain can sufficiently increase their ROM even with a contraction intensity of 20%\textsuperscript{20}. The applicability of these findings to subjects with other characteristics will need to be determined.

There are some limitations to this study. First, the definition of the end of ROM was subjective and depended on the subjects’ feeling of limitation\textsuperscript{25, 26, 35}. Second, the present study examined the acute effect of PNF stretching. Further study is needed to investigate the long-term effect with different intensities of isometric contraction. Third, the pres-

### RESULTS

Table 2 shows the gender, age, height, weight, and initial knee joint flexion angle of the study subjects for each of the four groups. A one-way ANOVA was conducted to determine the statistical significance between the four groups for each measure. There was no significant difference between the groups in any measures (p > 0.05).

A significant main effect of contraction group on the ΔROM values was found ($F_{(3,56)} = 100.46, p < 0.001$). Post hoc tests revealed that the changes in ROM were lowest for the control group and that the changes in ROM were lowest for the control group (Table 2).

### DISCUSSION

This study aimed to examine the effect of contraction intensity while applying isometric contraction during PNF stretching. Using 20%, 60%, and 100% of the MVIC, PNF stretching was applied to the left knee extensors of healthy young males to compare changes in the knee joint flexion angle. The results showed the largest increase for two groups: 60% and 100% of the MVIC. This result is similar to that of Sheard and Paine\textsuperscript{27}. They proposed that the most efficient isometric contraction intensity could be around 65% of the MVIC while applying the PNF stretching technique to young athletes. Our study also revealed that the most effective contraction intensity to increase ROM was at least 60%, suggesting that a moderate isometric contraction intensity may be optimal for healthy young males.

However, our result differs somewhat from that of Feland and Marin\textsuperscript{26} who found no significant difference in isometric contraction intensity for 20%, 60%, and 100% of the MVIC. This result suggests that a minimal amount of isometric contraction, as low as 20% of the MVIC, is as effective as moderate or maximal contraction intensities when applying the PNF stretching technique. Unlike the result of

| Gender | 20% | 60% | 100% | Control |
|--------|-----|-----|------|---------|
| Male (N=15) | 25±2.0 | 24.9±2.1 | 24.8±1.9 | 24.7±2.0 |
| Height (cm) | 172.2±4.2 | 174.5±4.4 | 173.1±3.9 | 174.3±3.7 |
| Weight (kg) | 66.5±5.7 | 68.3±7.1 | 65.7±4.8 | 66.1±5.0 |
| Knee flexion degree before intervention (°) | 99.5±8.5 | 100.3±7.2 | 102.2±8.0 | 101.1±8.5 |
| ΔROM (°) | 21.4±2.9 | 25.0±4.8 | 23.8±5.7 | 2.7±1.4 |
ent study focused on the knee joint. Although most studies investigating PNF stretching have focused on lower extremities, further studies are needed on other parts such as the upper extremities and trunk. Fourth, the present study used healthy males in their 20s. As mentioned in the Methods section, female subjects showed different results compared with male subjects in a pilot study. This suggests that the present results might not be applicable to subjects with different characteristics (e.g., gender, age) or special populations (e.g., patients, athletes).

There are a variety of factors influencing the use of PNF stretching in the field. Not only isometric contraction intensity but also contraction time, relaxation time after contraction, and the number of contractions can make a difference in terms of the effect. To determine a more efficient stretching technique, the knowledge concerning these factors should be supported by additional studies in the future.

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