The effect of vibration proprioceptive neuromuscular facilitation and combined training on flexibility of hamstring muscles

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Abstract

Introduction:
The present study was conducted to investigate the effect of three stretching training methods (vibration, proprioceptive neuromuscular facilitation, combined) on the flexibility of hamstring muscles in non-athlete male students.

Material and Methods:
We selected 30 male non-athlete students through random goal-oriented sampling and randomized them to three equal groups of vibration, proprioceptive neuromuscular facilitation (PNF) and combined stretching. The flexibility of hamstring muscles was measured using passive straight leg raising. The three groups then underwent training for 4 weeks; subsequently, all participants were evaluated using active knee extension.

Results:
The results of statistical tests indicated that flexibility improved significantly in all groups after training (p=0.001). The vibration and PNF training groups were not significantly different in terms of hamstring flexibility (p>0.05); nevertheless, the combined group was significantly superior in flexibility compared to the other two groups (p=0.000).

Conclusion:
Although each of the PNF and vibration methods alone help improve flexibility, the findings of this study suggest that optimal flexibility is achieved with a combination of these two methods. Thus, we recommend the combined training method to athletes who require very high flexibility.

Keywords: Vibration, Flexibility, Training Programs

Introduction:
Muscular flexibility is a major component of physical fitness and has long been the center of attention for athletes, champions, physical trainers, physiotherapists and rehabilitation professionals (1). The application of stretching exercise for improving flexibility is based on the notion that such exercise may reduce the occurrence, intensity and duration of musculo-ligamentous and articular injuries (1). Muscle sprain is a common complaint of athletes, most frequently occurring in the hamstring muscles. Insufficient flexibility is one of the essential etiologies for this injury. The hamstring muscle group constitutes antigravitational muscles whose insufficient flexibility results in a broad range of sport injuries from simple sprains to ligament rupture (2).
Muscle flexibility is enhanced through various stretching exercises, including static, ballistic, proprioceptive neuromuscular facilitation (PNF) and vibration training. One example of PNF training is contraction-rest which some sources report to be superior to static stretching (3,4). Another study, however, reported that 4 weeks of static stretching yielded better results compared to PNF (5). Some researchers have noted that vibration stretching methods are more efficacious for improving muscle flexibility (6-8). These exercises are now used widely as the appropriate stretching exercise. Tillaar states that vibration training may improve hamstring flexibility significantly for both sexes (9). Considering all these reports, there is no consensus regarding the optimal stretching exercise. Moreover, most studies have dealt with the mechanism of one or more stretching methods and have rarely considered the impact of a combination of these exercises – for instance, PNF and vibration. Thus, it is still uncertain which method will yield the optimal hamstring flexibility. The present study aims to answer this question while investigating the possibility of combined techniques yielding better hamstring flexibility compared to either method alone.

**Material and Methods:**

**Participant**
This is a quasi-experimental study on all male non-athlete students of University of Tehran without any orthopedic or neurologic lesions in the lower limb. We screened these individuals with *active knee extension* to select 30 participants in a goal-oriented fashion. The participants were then assigned to three equal groups of 10, each trained with vibration, PNF, or the combined technique.

**Training protocol**
Initially, the participants’ hamstring flexibility was assessed using *passive straight leg raising*. Each group then underwent its proper training for a period of 4 weeks. In the PNF group, the training consisted of 3 bouts of stretching per week: in each bout, the participant would rest the heel of his foot on a platform with his knee fully extended and then pushed the heel downwards isometrically to contract the posterior thigh muscles for 5 seconds. Then he would flex the waist to stretch the hamstring muscles for 30 seconds. In each bout, this exercise would be repeated three times for each leg. In the vibration group, the participant would warm up for 5 minutes (similar to the other two groups) and then attached to the vibrator (NEMESBOSCO System, Netherlands) at 30 Hz of frequency and 10 mm of range in a semi-squatting position (knees flexed at 90°) for 30 seconds. The vibration would be repeated three times in each bout. It must be noted that vibration training was conducted as whole-body vibration. In the combined group, as the name suggests, the participant underwent PNF and whole-body vibration together. For this purpose, he would begin with 5 minutes of warming up. Then, he would receive whole-body vibration for 30 seconds before one PNF exercise. Afterwards, he would be attached to the vibrator again. Thus, a participant in the combined group would undergo 6 whole-body vibrations and 3 PNFs per bout. The flexibility was quantified using Liton’s flexibility measuring device.

**Statistical Methods**
We used descriptive statistics to describe our data, inferential statistics (including one-way analysis of variance) to compare flexibility between different groups, and dependent t-test to compare the changes within each group before and after the training protocol. In case of significant differences between the training groups, we used post-hoc LSD test to determine points of significance. We also used Kolmogrov-Smirnov test to verify the normality of data. All analyses were accomplished on SPSS version 13 and the
diagrams were prepared using Excel software. P values ≤ 0.05 were considered significant.

**Results:**
Diagram 1 depicts the flexibility of the three vibration, PNF and combined groups on pretest and posttest. As the diagram illustrates, one-way analysis of variance indicated a significant difference between the three groups (p=0.001). The results of post-hoc LSD test showed that this difference results from the difference between the combined and vibration groups (p=0.001) as well as between the combined and PNF groups (p=0.001) whereas no significant difference was found between the vibration and PNF groups (p=0.552). The greatest flexibility was found with the combined method, followed by whole-body vibration and PNF. Nevertheless, the flexibility of the combined group was significantly higher than the two other groups (p=0.000). On the other hand, the comparison of pretest and posttest using dependent t-test indicated that flexibility improved significantly in all three groups after 4 weeks of stretching exercise (p<0.05) most notably in the combined group (p=0.000).

**Discussion:**
The findings of the present study indicate a significant improvement in the flexibility of hamstring muscles after 4 weeks of proprioceptive neuromuscular facilitation (PNF) training, which is consistent with findings of previous studies regarding the impact of PNF exercise on muscle flexibility. Different studies have reported PNF training to be superior to active static stretching, passive static stretching and ballistic stretching in terms of improving muscle flexibility and articular range of motion (10, 11). Fasen et al investigated the impact of 8 weeks of training with PNF, active and passive stretching to report that PNF and active stretching yield better knee range of motion while passive
stretches yields better hamstring flexibility (11).
The impact of PNF stretching on muscle flexibility is mediated via neurophysiologic mechanisms, including the muscle stretch reflex (12, 13). These mechanisms increase the level of stretch endurance alongside improved muscle power and reduced pain sensation. Studies indicate that training aimed at improving neuromuscular control, including PNF training, expedite flexibility and are more appropriate for treatment and rehabilitation of pelvic injuries compared to other stretching exercises (12, 13).

**Whole Body Vibration Training**

Our findings indicate a significant increase in hamstring flexibility with 4 weeks of whole body vibration exercise, which is consistent with previous studies. For instance, Issurin reported that 3 weeks of vibration exercise improves hamstring flexibility four times the static stretching exercises (8). Our findings also corroborate those of Cochrane and Stannard who reported whole body vibration to be superior to fixed bike stretching in terms of hamstring flexibility in female hockey players (5), Fagnani et al who reported a significant improvement in flexibility of female athletes after 8 weeks of whole body vibration stretching (6), Sands et al who reported the beneficial impact of 4 weeks of vibration training on the lower limb muscle flexibility of young gymnasts (10), and Tillaar who reported 3 bouts of whole body vibration training over 4 weeks improves range of motion and flexibility in hamstring muscle of both sexes (9).

Regarding the mechanism of these exercises affecting flexibility, it may be stated that similar to PNF training, whole body vibration affects neuromuscular mechanisms and creates muscle reflex contraction (14,15). These exercises modify the pain sensation. Mechanisms which are involved in PNF exercises are activated by whole body vibration, as well.
The pain threshold is known as a natural limiting factor for flexibility (16). The vibration stimulus creates a state of anesthesia and painlessness in the muscles, thus enhancing their force and flexibility (8). The modification of pain threshold resulting from these exercises will improve the flexibility of athletes and reduce the intensity of pain (17). Another mechanism by which whole body vibration improves flexibility is the stimulation of Golgi tendon organ which suppresses contraction and facilitates muscle relaxation (17). These exercises involve and stimulate soft tissue, thus activating muscle spindles (17). Cardinale and Bosco suggest that vibration stretching suppresses the activity of antagonistic muscles through stimulation of inhibiting neurons. Therefore, activation of the quadriceps muscle may facilitate the activity of hamstring muscles and enhance the stretching exercise. Vibration training improves heartbeat, stroke volume, blood flow and blood pressure (18). The systemic and local increase in blood flow will enhance the perfusion of the stretching muscle. Simultaneously, the increases blood flow in superficial and deep vessels will raise the temperature of the tissue, leading to improved flexibility (19). The role of vibration training in improving range of motion, flexibility, muscle force, and muscular endurance level has been established (20).

**Combined training (PNF and whole body vibration)**
The findings of the present study indicate that the flexibility of hamstring muscles is most improved after 4 weeks of combined training with PNF and whole body vibration exercises. In other words, using a combination of these methods will be more beneficial to muscle flexibility than using either of them alone. Tillaar demonstrated that stretching exercises performed as contraction-rest (a subset of PNF exercises) or whole body vibration may improve the range of motion of hamstring muscles significantly. He
reported that in the whole body vibration group, significant improvements are found after 1 week of training and then continue for every week, whereas in the PNF group, a significant improvement is found only after 2 weeks of training and stops there. Moreover, he reported that whole body vibration yields a greater improvement in range of motion compared to the PNF training on pretest and posttest. He concluded that although each of these exercises improves the range of motion and flexibility of hamstring muscles over 4 weeks of training, a combination of both methods will improve these variables significantly (9). Our findings are also in line with those of Cardinale et al who concluded that despite the improved flexibility of muscles with vibration training, addition of other stretching exercises will enhance and stabilize muscle flexibility even further (18).

Furthermore, Funk et al reported that although each stretching exercise may yield a relative improvement in muscular function and flexibility, their combination will not only circumvent the limitations of each method, but also diversify the exercise bout, prevent boredom caused by a repeated exercise, and expedite the muscular and general relaxation (12).

**Conclusion:** Although our findings confirm the positive impact of proprioceptive neuromuscular facilitation and whole body vibration exercises alone on hamstring flexibility, we recommend athletes (particularly those who require an excellent level of flexibility such as gymnasts, ballerinas, divers and wrestlers) to combine both exercises in order to achieve level of muscle relaxation and flexibility necessary for the complicated motions of their field.

**References:**


