Comparison of the Effect of Proprioceptive Neuromuscular Facilitation Exercises with Mental Imagery and Working Memory on Dynamic Balance, Range of Motion and the Rate of Spasticity in MS Patients

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Abstract

Introduction: The purpose of this study was to compare the effects of Proprioceptive Neuromuscular Facilitation (PNF) exercises with mental imagery and working memory and combining these two types of exercises on dynamic balance, range of motion, and spasticity of Multiple sclerosis (MS) patients. **Method and Materials**: In this quasi-experimental study, 30 male MS patients were randomly assigned into three groups (n=10) of PNF, mental imagery and working memory training, and combination. The study included pre-test, intervention, and post-test. Timed Up and Go test, range of motion, and rate of muscles spasticity in active and passive extension of knee were measure in pre-test, and post-test. Intervention consisted of 6 weeks of exercise in each group. Data were analyzed using Paired Samples t-test, ANCOVA, Kruskal-Wallis, and Wilcoxon Signed Ranks Test. **Results**: The results showed that each of mental imagery and working memory training, and combination had a significant effect on dynamic balance ($P<0.01$), range of motion of passive and active knee extension ($P<0.01$) and spasticity of passive and active knee extension ($P<0.01$) in MS patients. No significant differences were found between training groups in any of the variables ($P>0.05$). Conclusion: Overall, the results of the present study showed that PNF, mental imagery, working memory, and combined training can be used to improve balance, range of motion, and spasticity of MS patients.

Keywords: Balance, Mental Imagery, PNF Exercises, Range of Motion, Spasticity, Working Memory

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Introduction

One of the most prevalent diseases of the central nervous system is multiple sclerosis (MS), a chronic inflammatory autoimmune disease of the central nervous system that can affect the basic motor and sensory systems for control of balance when standing and walking (1). One of the most common disorders of MS is imbalance. The role of balance is vital for independence in the activities of daily living. Imbalance can lead to decreased stability that this can have a profound effect on the daily lives of people with neurological pathologies. Impairment of stability reduces functional independence, the development of disability, and the increased risk of falls. Among the issues which can affect the balance ability of MS patients are muscle weakness and spasticity (2).

Spasticity prevents the stretching of muscles and tendons (3). A person with spastic paralysis has limitations in controlling the movement of the affected limb. Voluntary movement in these people is usually limited in range, with jumping, and movement control is heterogeneous (4). Restriction applied to muscles, which have suffered from spasms, may lead to a restriction of active and passive range of motion in the opposite direction of muscle action, thereby resulting in reduced range of motion and strength (5).

Consistent with such findings, which indicate spasticity, reduced range of motion and strength, and consequent insufficient imbalance in MS patients, the question arises as to how to create more effective motor learning environments for these individuals. Understanding how to best practice motor skills training is important for parents and educators (rehabilitators, occupational

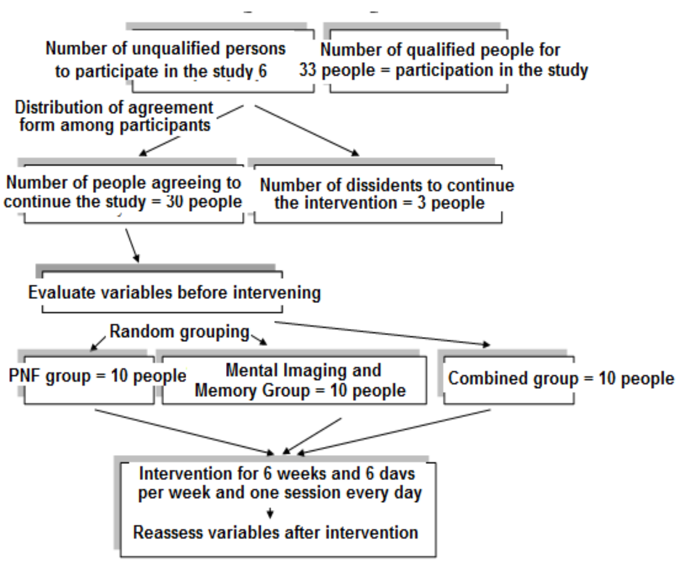

Figure 1. Research flowchart

therapists, physical education teachers, exercise educators, *etc.*) who work with these communities. One of the exercises, which can be considered in the management of spasticity and range of motion, followed by balance, is Proprioceptive Neuromuscular Facilitation (PNF) exercises. The PNF method is a stretching technique first used by Hermann Kabat to treat paralytic patients and then used by other researchers to increase flexibility, range of motion, and strength (6). Studies in this area have reported increased range of motion and flexibility in athletes and healthy individuals using PNG (7-9). In the field of disorders, the effect of PNF exercises on range of motion and flexibility has been confirmed in patients with stroke (10), myofascial pain syndrome (11), and frozen shoulder (12). Therefore, one of the objectives of the present study was to evaluate the effect of PNF exercises on range of motion, balance, and spasticity of MS patients.

Information processing speed is one of the important factors in performing daily activities. Since the conduction of afferent signals is reduced due to demyelination in MS patients, sensory and cognitive functions, including information processing speed, are reduced in these patients. Because information processing occurs in all human voluntary activities; it seems that performing exercises based on cognition can affect information processing. Researchers have emphasized the effect of cognitive exercises on balance. In addition, other dimensions of cognition, including attention, memory, *etc.*, each of which somehow cooperates with information processing, are also affected by these exercises (13). Moreover, Prosperini *et al.* suggested that cognitive exercises could improve functional functions and height control in MS patients. In the field of cognitive interventions, the role of mental imagery and working memory can be mentioned (14). Working memory keeps information active for use and plays a functional role in consolidating information for long-term storage. Through the cooperation of these two components (storage and processing), working memory is able to store, process, and integrate information related to the goal (15). A recent research showed that mental imagery can have a positive effect on the children with the unilateral cerebral palsy (spastic hemiplegia) (16).

The main question was what kind of intervention program can further improve the balance, range of motion, and spasticity of MS patients? Does a combination of cognitive and motor exercises further improve the balance, range of motion, and spasticity of MS patients? Therefore, the aim of the present study was to compare the effect of PNF exercises with mental imagery and working memory on balance, range of motion, and spasticity of MS patients.

Materials and Methods

Participants

The present study was a quasi-experimental research. The research design was pretest -post-test with three experimental groups including PNF exercises, mental imaging exercises and working memory, and combined exercises (PNF exercises with mental imaging exercises and working memory). For this purpose, 30 men with MS referred to the MS Association of Tehran were selected as a statistical sample based on inclusion criteria such as: age range of 20-50 years, scoring less than 6 based on Expanded Disability Status Scale (EDSS) scales, and no visual, cognitive or cognitive impairments. In three groups (10 people in each group), PNF exercises, oral imaging exercises and working memory, and combined exercises were included. The present study was approved by the Ethics Committee of Islamic Azad University, East Tehran Branch, under the code: IR.IAUETB.963104. The flowchart of the present study is presented in Figure 1.

Measuring tools

The tools used in this study were: 1) Consent form: to obtain the individuals' consent to participate in the present study. 2) Manual goniometer: This tool was used to measure range of motion. To measure the active range of knee extension, the subject was placed in a supine position and the examiner placed his/her hip in a 90-degree flexed position. Then, the subject was asked actively to extend his/her knee. Examiner's colleague then measured the angle between the thigh and the leg by placing the goniometer axis on the lateral condyle of the thigh, the fixed arm along the thigh, and the movable arm along the lateral malleolus. The range of passive extension motion of the knee was measured in the same way. Three repetitions were performed on the joint and the mean

Table 1. Spasticity scoring structure based on the Modified Ashworth scale

Degree	Definition
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion in flexion or extension movement
1+	Slight increase in muscle tone, manifested by a catch followed by minimal resistance throughout the remaining (less than half) of range of motion
2	More marked increase in muscle tone through in most range of motion, but the affected limb is easily moved.
3	Significant increase in muscle tone, passive movement is difficult
4	The affected limb in flexion or extension is rigid

Table 2. Paired t-test from pre-test to post-test

Variable	Groups	Stage	Mean (SD)	T	Degree Of Freedom	P-Value
Dynamic balance (Second)	PNF	Pre-test	10.21 (0.95)	4.74	9	0.001*
		Post-test	8.22 (0.64)			
	Mental imagery and working memory	Pre-test	10.29 (0.92)	3.87	9	0.004*
		Post-test	8.34 (0.93)			
	Combination	Pre-test	10.15 (0.79)	4.61	9	0.001*
		Post-test	8.18 (0.86)			
Knee extensive range of motion (Degree)	PNF	Pre-test	155.5 (3.43)	-3.14	9	0.0012*
		Post-test	162.4 (5.12)			
	Mental imagery and working memory	Pre-test	154.26 (2.94)	-7.11	9	0.001*
		Post-test	162.02 (2.60)			
	Combination	Pre-test	155.20 (1.75)	-5.95	9	0.001*
		Post-test	161.99 (3.29)			
Knee range of passive motion of the knee (Degree)	PNF	Pre-test	158.6 (3.27)	-7.55	9	0.001*
		Post-test	165.9 (3.21)			
	Mental imagery and working memory	Pre-test	158.25 (2.87)	-12.56	9	0.001*
		Post-test	166.13 (2.96)			
	Combination	Pre-test	159.00 (1.56)	-6.99	9	0.001*
		Post-test	166.60 (3.30)			
		Post-test	1.40 (0.69)			

*The * sign indicates significance at the 0.01 level and the ** sign indicates the significance at the 0.05 level*

of them was selected as the range of motion of the joint. 3) Timed Up and Go Test (TUG): TUG test was used to assess balance in this study. In this test, the patient sat comfortably in an adjustable chair while his/her hands were resting on the handle of the chair. The chair was placed 3 meters away from the cone. The patient was asked to move to the cone after hearing the "go" command from the raised chair, turn the cone around, and then return and sit on the chair. Time was recorded by stopwatch (17).

Modified Ashworth Scale (Spasticity Scale): This scale (Table 1) was used to measure the spasticity (18).

Procedure

At first, the participants agreed to complete the consent form. Then, the participants were introduced to the study objectives and implementation method. In the pre-test stage, the spasticity, range of motion, and balance were measured. Then, they were divided into three groups: PNF exercises, mental imagery and working memory exercises, and combination exercises (mental imagery and working memory (PNF)).

The group performing the PNF exercises performed these exercises for 6 weeks and 3 days per week for each session. In each session, the stretching time was 2 minutes for each subject. To conduct this, the person was placed in a supine position and the limbs and environment were free of any limiting factors. The hold rest (HR) method was performed for the D1F pattern (Diagonal Flexion) of the lower limb. To perform the D1F pattern, the lower limb was placed in the opposite pattern, i.e. D1E (Diagonal Extension) of the hip joint in extension, internal rotation, abduction, straight knee joint and ankle in plantarflexion. Then, the isometric hamstring contraction was performed in this position for a maximum resistance of 10 seconds (19, 20). The subject was then asked to voluntarily relax the hamstring muscle. Then, after the active contraction of the antagonist muscle group (quadriceps), the movement to lengthen the hamstring (D1F pattern) was performed for 15 seconds. After each stretch, rest was given for 5 seconds and stretch was repeated the 8 times to reach a total of 2 minutes of stretching.

The group that performed the mental imagery and working memory exercises did these exercises for 6 minutes daily for 6 weeks each. Working memory training was performed with N-Back software. This software included reminder of two different stimuli including square location and alphabet of pronunciation pronounced (active visual and auditory memory). This tool was first used in research at 2008 to enhance working memory (21). In each trial, a blue square was appeared in one of the eight locations, accompanied by one of the letters C, R, T, S, K, L, H, and Q. If the square location was the same in two consecutive attempts, the subject would press the key A on the keyboard. If the letters presented were the same in two consecutive attempts, the subject would press the key L on the keyboard. Finally, the software provided a percentage score for the individual considered as working memory performance. In the present study, the subjects, after practicing the previous stimulus recall and obtaining a score of 100%, proceeded to recall the two previous stimuli. The training continued until all the subjects got a 100% score in two previous movement exercises. Mental imaging was performed after active memory exercises for 10 minutes with mental review of balance exercises.

The combined group performed the mental imaging and working memory exercises for 20 minutes. They performed PNF exercises for the rest of the sessions. After completing the exercise, spasticity, range of motion, and balance were measured in the post-test phase. In order to analyze the data, the study variable included dynamic balance, active knee extension range of motion, passive knee range of motion extension, active extension spasticity, and passive extension spasticity.

Statistical analysis

Descriptive statistical methods were used to calculate the central and dispersion indices. Shapiro-Wilk test was used to check the normality of the data. Levene's test was used to evaluate the equality of variance of the variables. The Wilcoxon Signed Ranks Test or paired t-test was used to determine the effect of each exercise on the dependent variables in each group and ANKOA or Kruskal-Wallis analysis were used to compare each of the variables between groups. Data analysis was performed using SPSS software version 22.

Results

The data distribution based on Shapiro-Wilk test for the variables of dynamic balance, active and passive range of motion of the knee extension was normal (P>0.05). Therefore, paired t-test was used to examine the differences within the group (Table 2).

The data distribution for the spasticity variables of active and passive knee extension was not normal, so the nonparametric Wilcoxon test was used to examine the differences within the group. The results of this test showed the spasticity of active extension in PNF group (Z=2.724, P=0.005), mental imagery and working memory group (Z=2.739, P=0.006), and the combined group (Z=2.714, P=0.007), and also passive knee extension in PNF group (Z=2.873, P=0.004), mental imagery and working memory group (Z=2.251, P=0.024), and combined group (Z=2.530, P=0.011), in MS patients from pre-test to post-test, were significantly decreased.

The results of Levene's test showed that the pre-test and post-test data of the groups were not significantly different (P>0.05). Therefore, according to the homogeneity of variances and the assumption of homogeneity of regression slope between the data, ANKOVA univariate analysis of variance for examination of differences between groups was used. Results of univariate analysis of covariance for comparison between groups in dynamic equilibrium variable (ηp2=0.013, P=0.84, F=0.17), range of motion of active knee extension (ηp2=0.004, P=0.950, F=0.052), the range of motion of the passive knee extension (ηp2=0.007, P=0.915, F=0.089), showed that there is no significant difference between the three types of interventions. Also, based on Kruskal-Wallis test in active knee extension spasticity (X2=4.635, df=2, P=0.099) and passive knee extension spasticity (X2=2.735, df=2, P=0.255), there was no significant difference between the groups. Therefore, all three intervention groups had a similar effect.

Discussion

The aim of this study was to compare the effect of PNF exercises and mental imagery and working memory on balance, range of motion, and spasticity of MS patients. The results of the present study showed that PNF exercises have a significant effect on both active and passive range of motion of knee extension. The findings of this study are consistent with the findings of Hill *et al*., Huang *et al*., Yildirim *et al*., Behm *et al*. and Lee (6-8, 10, 11). Huang *et al*. in a study examined the effect of 4 weeks of PNF training on range of motion and upper limb traction in stroke patients. The results showed the effectiveness of PNF exercises with an effect size of 0.379 (10). Yildirim *et al*. in a study compared the effect of 4 weeks of PNF training and static stretching on the range of motion of the hip joint. The findings showed a significant difference between the two groups with improved range of motion using the PNF exercises (7). Lee in a study examined the effect of PNF exercises and deep breathing exercises on range of motion and pain in people with frozen shoulders. The results showed that the combination of PNF and breathing exercises reduced the severity of pain and increased the range of motion of the shoulder joint (12). A number of previous studies have suggested that PNF stretching techniques resulted in more flexibility and range of motion than static techniques. Some researchers stated that because these techniques use active contractions instead of passive stretching, the increase in range of motion is probably due to the ability of PNF techniques to reduce active muscle tension. That is, the effect of PNF techniques resulted from the reduction of reflex activity following the use of these techniques (22). Theorists emphasize on neurophysiological principles, arguing that excitatory afferents from neuromuscular spindles or inhibitory afferents from the Golgi tendon, or both, are responsible for the effects of the techniques (23). Others believe that the reason for the greater effectiveness of dynamic techniques is the increase in metabolic processes; which in turn leads to increase in the temperature and thus reduce in the viscosity of the muscle, thereby allowing the muscle to contract smoothly. The warmed muscle is easily coordinated with the applied forces, thereby leading to increased flexibility and range of motion (24, 25).

Other results of the present study showed that in MS patients, the PNF exercises significantly increased the TUG test time, which is one of the indicators of balance. The principle of reciprocal denervation (Scherrington's principle) can be used to justify this finding. According to the principle of reciprocal denervation, if the stimulation reaches the agonist muscles due to the reverse denervation of the antagonist muscles, an inhibitory system for the antagonist muscles will be activated immediately upon stimulation and then the agonist and antagonist muscles will contract following the movement of the limb. This contraction is a mild eccentric due to the tension applied to the antagonist muscles during the shortening of the agonist muscles. Because this principle is used in PNF exercises to relax or even strengthen antagonist or agonist muscles, it is not unreasonable to expect that individuals' balance can improve, which confirm the findings of the present study (26, 27).

Other results of the present study showed that PNF exercises had a positive effect on the reduction of both spasticity of active and passive knee extension in MS patients. Using PNF exercises, the average spasticity of active knee extension from the pre-test stage (2.5) to the post-test stage (1.5) and the spasticity of passive knee extension from the pre-test stage (2.4) to the post-test stage (1.3) were decreased by about 40%. One of the possible reasons for the improvement in spasticity is the improvement in muscle tone, changes in muscular activity, and mechanical behavior of stretched muscles. Perhaps, one of the most important reasons for improving muscle spasticity is following PNF training (28).

The results of the present study showed that the intervention of mental imagery and working memory improved the dynamic balance of MS patients. This finding is consistent with the results of studies of Enferadi Doughabadi *et al.*, Taheri Torbati *et al.* and Straudi *et al.* (29-31). Enferadi Doughabadi in a study investigated the effect of a period of balance and cognitive combination exercises on height fluctuations in women with MS. The results showed that balance exercises of center of gravity and cognitive combination reduced anterior-posterior and mid-lateral oscillations of women with MS. Taheri Torbati et al. compared two single and dual balance training methods on the equilibrium levels of women with MS (30). The results showed that the mean of general and anterior-posterior balance index in the group of dual exercises was decreased compared to single balance exercises, which demonstrated the importance of dual balance exercises with cognitive task. Straudy *et al.* examined the effect of video cognitive exercises and balance plate therapy exercises on balance and attention in people with brain injury. The results showed that most of the video cognitive exercises had an positive effect on the balance and attention of these patients (31).

The results of the present study showed that mental imagery and working memory exercises had a significant effect on improving the range of motion of MS patients. Based on the findings, the mean range of motion of active knee extension from pre-test stage (154.26) to post-test stage (162.02) and the average range of motion of passive knee extension from pre-test stage (158.26) to post-test stage (166.13) were increased by an average of about 5%. Attention is one aspect of mental imagery and working memory exercises. Attention is focused consciousness. Mental imagery and working memory training can increase person’s ability to maintain attention and individual will be able to focus wherever and however he/she want. Based on awareness, an individual may be aware of stimuli without being the center of attention. Attention and awareness are conscious and increase the degree of positive sensitivity to the limited range of motion (32). In fact, consciousness and attention are intertwined, meaning that attention is measured in the context of consciousness (33). Actually, people who are mentally dynamic approve every thought, every feeling or emotion which enters their attention as it is. This preventative response is for thoughts that make a person sad or anxious and help the person return to balance after experiencing negative emotions. Therefore, according to the argument of Zook *et al.* that by increasing attention to activity, the range of motion can be increased. Therefore, it is not unreasonable to expect that the range of motion of the joints can increase confirmed by the results of the present study (32).

Based on the findings of the present study, the mental imagery and working memory exercises had a significant effect on improving the spasticity of MS patients. The results showed that mean spasticity of active and passive knee extension in the pre-test stage (2.3) to the post-test stage (1.4) was decreased by about 40%. To justify this finding, we would use the argument of Masicampo and Baumister (34) who believe that self-control is associated with a reduction in muscle tension. The researchers suggested that self-control, mental imagery, and working memory and cognitive-based interventions may be related in two ways: First, cognitive interventions involve self-control training that leads to an increase in sources of self-control; second, cognition derived from self-control is successful. Masicampo and Baumister argued (34) that considering all goals, cognitive-based programs could lead to peace of mind that avoids negative thoughts. It increases self-control and thus reduces muscle tension, which in turn can reduce spasticity.

Other results of the present study showed that the combined exercises, which were a combination of PNF exercises, oral imaging and working memory, had a positive and significant effect on dynamic balance, spasticity, and range of motion in MS patients. To justify the effectiveness of these exercises, we can mention a combination of the effectiveness of oral imaging exercises and working memory and PNF exercises mentioned above.

One of the limitations of the present study was that neurological techniques were not utilized to evaluate the effect of the interventions performed. So, future studies using electroencephalography and functional magnetic resonance imaging (FMRI) are recommended to examine the effects of such interventions.

Conclusion

The results of the present study showed that PNF exercises, mental imaging exercises and working memory, and combined exercises had a significant positive effect on balance, spasticity, and range of motion of the knee joint in MS patients. Therefore, according to the results of the study, it is recommended that MS and rehabilitation centers, and trainers who work with these people use these exercises to improve balance, spasticity, and range of motion of MS patients. In addition, since these exercises were not different from each other, it is suggested that those can be used according to the time and place requirements.

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