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Research Article

THE EFFECTS OF MENTAL PRACTICE COMBINED WITH PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION ON MUSCLE STRENGTH OF UPPER LIMB AND HANDGRIP

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ABSTRACT

Purposes: Document the effects of mental practice (MP) when added to PNF on the strength of arm muscles and handgrip in healthy individuals. **Materials and Methods:** 30 female students were randomly assigned to the PNF group and PNFMP group. The mean age of PNF group = 18.53 ± 6.4 years, and BMI = 20.49 ± 3.42 kg/m^2. The age of PNFMP group = 19.27 ± 1.49 years, and BMI= 19.13 ± 1.96 kg/m^2. The training program has administered for five weeks with 3 x 30 min training sessions/week, with regular intervals of assessment. Electrical muscle activities of arm and handgrip force were examined by EMG and handheld dynamometer. **Results:** MANOVA revealed an improvement in muscle performance of the PNFMP group by, F= 6.2, p = <0.019, and F= 5.9, p = <0.022 for infraspinatus and anterior deltoid muscles respectively, for biceps brachii by F=4.9, p = <0.035, and F=4.8, p = <0.037, and brachioradialis muscle. Scores of handgrip force were higher by F= 5.3, p =0.03. **Conclusion:** This study confirmed the use of MP combined with PNF in healthy subjects, and it will be beneficial for neurological and orthopedic cases.

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INTRODUCTION

Self-generated cognitive operation using sensory and perceptual mechanisms by imagination without body movement is defined as motor imagery (MI) or mental practice (MP).[1] Studies clarified that imagination of MI contents improved the motor skills.[2]

Two types of imagery have documented; visual (external), and kinesthetic (internal). External type includes imagery of person, environment, or both. A person perspective consists of the first person (kinesthetic or visual), and third person (visual). The first person perspective involves the imagination of dynamic movement, including its contents and kinesthetic sensation, it needs the ability to experience somato-sensory feelings related to the motor action. Imagined scenes in mind outside the person are a third-person perspective, and it is a static process.[3,4] It was found that motor response and skill acquisition will be improved not only by motor execution but also need mental practice.[5]

Research on motor skill acquisition has demonstrated clearly that mental practice leads to improved performance.[6] Mental practice of distal hand muscles (abductor muscles of the little finger) has been conducted for 4 weeks and resulted in a 22% increase of maximal contraction.[7] So; one might ask whether the strength gain following mental training could be realized in a larger, more proximal muscle group, such as shoulders and the elbow flexor muscles.[8]

Proprioceptive neuromuscular facilitation (PNF) is an exercise technique in the form of pattern or mass movement and applied through the spiral and diagonal plane including series of joints

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and large groups of muscles. This approach stimulates the neuromuscular mechanism resulting in the desired muscle response.[9] Everyday tasks and skills, from picking up a bottle of water to throwing and kicking naturally utilize diagonal and spiral movements.[10]

Therapeutic effects of PNF have been documented in clinical settings for soft tissue injuries and also for athletic subjects. It has been found that PNF improves range of motion, in addition to its effect on muscle strength.[11]An isolated intervention of physical therapy was compared with the technique of combined physical and MI practice. A high significant effect of the motor performance was achieved with combined physical and MP, followed by physical practice alone.[12]

Most of the studies on MP have been conducted for neurological rehabilitation, particularly in stroke rehabilitation. Several review articles offer summaries of these studies.[2, 13] Studies of individuals who are healthy have shown the enhancement of the performance of various aspects of motor control because of MI practice. These enhancements of performance include gains in strength of selected muscle groups improved speed in arm pointing capacity, [14] increased range of motion of the hip joint when MP was added to PNF, [15] and improved postural control in elderly people.[16] The use of MP to facilitate the mastering of perceptual-motor professional skills such as nursing and surgery has been demonstrated.[17]

In the current study, training program that combined PNF and MP was performed under observation and supervision of physical therapists for learning effects**.** It has shown in the previous studies that the internal type of imagery (kinesthetic) of the first person perspective results in physiological improvement with a real physical movement.[4, 18]

Little attention was given to potential differences in muscle performance of upper extremity and handgrip, as most researchers investigated the effects of MP mainly on the active range, especially in the lower extremity. Hence, the main aim of this project is to study the influence of MP when added to PNF during 5 weeks on muscle voluntary activity of the dominant arm and hand grip force in nonathletic healthy female subjects.

MATERIALS AND METHODS

The conduction of this study was at the physical therapy department, Jazan University. The design of the study was pre and post-testing. Thirty healthy female students recruited with ages ranged from19 to 26 years old, and dominant right hand according to the following inclusion criteria: right-handed subjects, previously untrained, absence of a prior injury of the hand or arm.[19] Before beginning the study, all individuals have been informed about the potential danger and benefits and signed the consent form. The approval of the study was getting from the research unit of Jazan University. Any volunteer didn't admit into the study based on the following: a history of a neurological disease, a history of musculoskeletal injury of the upper limb, and unstable medical condition.[19]

Subjects assigned randomly to proprioceptive neuromuscular facilitation (PNF) group and proprioceptive neuromuscular facilitation with mental practice (PNFMP) group, all participants took their informed consent before participation. PNF group: 15 individuals, these subjects received only PNF training. PNFMP: 15 individuals received MP combined with PNF.

Instrumentation used for measurement

EMG (Model"Xltek XCalibur LT"; Natus Medical Incorporated, Germany): it is rated 115V/230V, 50/60 Hz, 2A or 110 W. it is XLTEK`s portable version of its XCalibur system. It was used to measure the electrical activity of the shoulder and elbow muscles. Hand dynamometer - Baseline hydraulic (Fabrication Enterprises Incorporated, USA) for measuring the handgrip strength and pinch strength as.[20]

Measurement Procedure

The study has consisted of 6 test procedures: pre-intervention - baseline, during the intervention (after session 1, 3, 7, 14), and post-intervention testing with 17 days. After baseline assessment subjects randomly assigned to either PNF group or PNFMP group.

EMG measurement: skin preparation- cleaning the skin areas using soapy water, or an alcohol swab. Electrodes placement: the active electrode (black-cathode), which is disposable self-adhesive electrodes with surface area is about 0.5-3 cm^2 were placed over the proximal1/3 of the muscle. The reference electrode (red-anode) with surface area 5 cm^2 was placed 2 cm to 3 cm distal to the active electrode. For normalization purposes; the EMG recorded during a standardized production of isometric MVC (maximum voluntary contraction). Isometric MVC is determined using MMT (manual muscle testing).[21] The manual muscle test performed with maximal resistance for 5 seconds and for 3 times. The rest period was 20 seconds between tests. EMG data collected for 5 seconds during three trials and the mean of average amplitude taken as EMGmax, which was used as a reference value for the normalization of EMG amplitudes.[18]

MMT for anterior fiber of deltoid

The patient was in supine; moving the shoulder in slight abduction, flexion, and medial rotation. The therapist grasped the patient's wrist; the other hand of the therapist applied pressure or isometric resistance over the proximal arm in the direction of adduction.

MMT for infraspinatus

The patient position was prone; the therapist`s hand stabilized the humerus distally to prevent rotation, and abduction or adduction. The patient moved the shoulder in lateral rotation with the elbow bent 90^o, while the therapist applied the isometric resistance toward medial rotation of the arm.

MMT for biceps brachii

The patient was in supine or sitting. One hand of the therapist was under the elbow; the patient flexed the elbow approximately to $90^o$with the forearm supinated. The therapist applied resistance against the movement of the patient`s forearm toward extension direction.

MMT for brachioradialis

The patient position was sitting or supine. The therapist placed one hand under the elbow, while it was flexed less than 90^o,

with a pronated forearm. The therapist applied pressure on distal forearm against more flexion.

Measuring of the hand grip strength

- The subject was in a sitting position with the hip joint flexed at 90°, and shoulder joint in a neutral position.
- The elbow fixed at 90° flexion, forearm in a neutral position, and wrist at 0° to 15° radial deviation.
- The test was repeated for two times, and the maximum value has selected. The rest period was allowed for 5 minutes after the first measurement to avoid physical fatigue.

PNF Training

PNF training was administered for 15 sessions over five weeks, with 3 x 30 min sessions per week (the first session was 60 min).

- Agonist pattern: Flexion / Adduction/ External rotation of shoulder with elbow flexion PNF pattern.
- Antagonist PNF pattern: Extension/ Abduction/ Internal rotation PNF pattern. We chose Flexion - Adduction- External rotation PNF pattern as agonist based on the assumption that the pattern is used more frequently during daily living and thus has a greater capacity for strength improvements.

Mental Training of PNF

- A brief orientation session about the study, its goals, and the training procedure provided to each participant. Then, consent documents were signed and obtained from all individuals. All subjects received the familiarization trials of the training. Two days after the trial session, the data recording was done by the same physiotherapist, in an identical setting.
- The mental imagery practiced for five weeks with 3 x 30 min sessions /week. Consecutively, all participants were requested to perform self-guided MP for 15 min/day, during which they mentally imagined the motor sequences of PNF pattern.
- The training program was following the standardized method of the Mental Gait Training procedure. The general process (Fig.1) consists of 6 levels to activate the inner concept of the chosen PNF pattern.[19, 23]

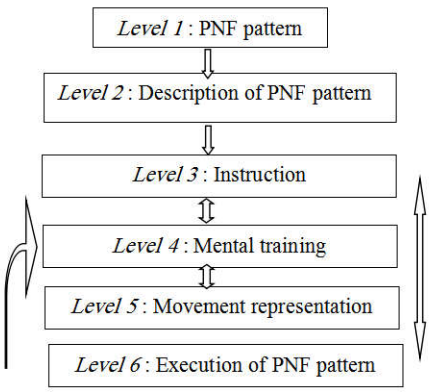

Figure 1 Flowchart of the mental practice procedure

STATISTICAL RESULTS

Data has tested by version 20.0 of SPSS. The significance of the study level was at 0.05. ANOVA (2 x 6 Mixed design) was used to detect "between-subject effect" for infraspinatus, deltoid, brachioradialis, biceps brachii, and handgrip strength in each of the three intervals of assessment the "pre" during and "post" between the groups. Also; it was used for comparison between the "pre" during and "post" of test intervals, and to test the "within-subject effect" in each group. Also; to compare the interaction effect between both two groups for these variables in each of the "pre-test" during and "post-test" conditions. The demographic data of the participants summarized in the table (1).

Table 1 Demographic data of the subjects

Item	$\bar{X}$±SD	Range	
		Minimum	Maximum
Age (yrs)	PNF Group I= 18.53 ± 6.4 PNFMP Group II= 19.27 ± 1.49	18.00 18.00	20.00 22.00
Weight (kg)	PNF Group I= 47.27 ± 8.51 PNFMP Group II= 44.87 ± 5.26	37.00 38.00	61.00 55.00
Height (cm)	PNF Group I= 151.8 ± 5.98 PNFMP Group II= 153.07 ± 3.95	142.00 145.00	160.00 160.00
BMI ($kg/m^{2)}$	PNF Group I= 20.49 ± 3.42 PNFMP Group II= 19.13 ± 1.96	16.02 16.23	28.54 21.76

PNF: proprioceptive neuromuscular facilitation PNFMP: proprioceptive neuromuscular facilitation with mental practice $\bar{X}$: mean
SD: Standard Deviation BMI: Body Mass Index

Data of MANOVA represented in table (2), showed that there was a high effect for measurement time for whether or not subjects trained with mental practice, F= 86.1, when p =< 001, and F= 66.2, when p =< 001, for both infraspinatus, and anterior deltoid respectively. It was obvious also a great interaction between the time of measurement and whether subjects trained with PNF or PNF with mental practice, F= 7.5, p = <0.001 for infraspinatus muscle, whereas no difference was detected for anterior deltoid muscle, by F= 3.7, when p = 0.730. There was significant improvement in muscles performance in PNFMP group by, F= 5.9, when p = <0.022, and F= 6.2, when p = <0.019, for anterior deltoid and infraspinatus respectively (Figs. 2, 3).

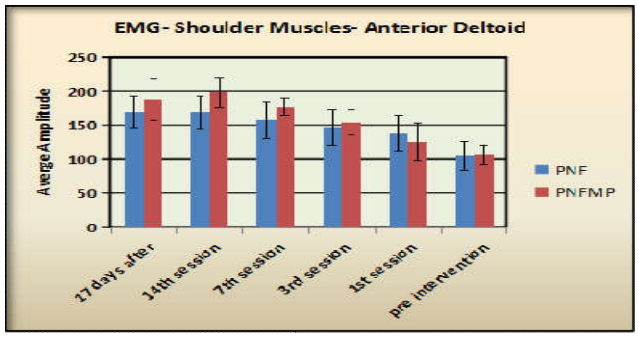

Figure 2 Means and standard deviations for EMG of shoulder muscles (anterior deltoid)

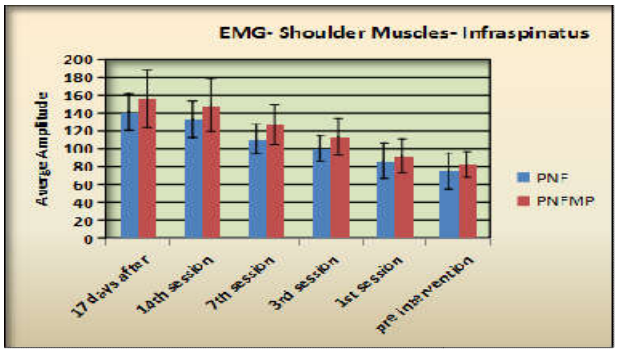

Figure 3 Means and standard deviations for EMG of shoulder muscles (Infraspinatus)

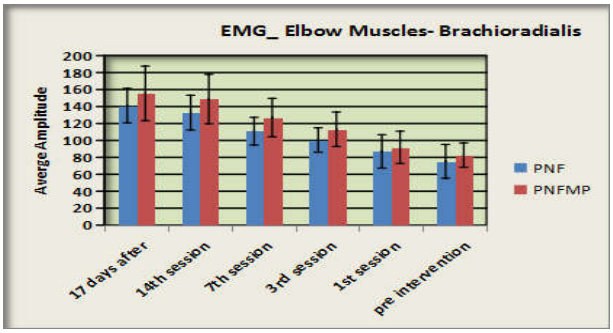

Figure 5 Means and standard deviations for EMG of elbow muscles (Brachioradialis).

Table 2 2x 6 Mixed ANOVA for EMG of shoulder joint

Test	Measured Effects	Infraspinatus muscle				Deltoid muscle			
		D.F	*F* value	*P. Value*	Sig.	*D.F*	*F* value	*P. Value*	Sig.
Within subjects effects	Main effect of measurement time within groups	(3.04)	86.1	0.000	HS	(3.7)	66.2	0.000	HS
	Interaction effect between measurement time and groups	(3.04)	7.5	0.000	HS	(3.7)	0.490	0.730	NS
Between subjects effects	PNF group & PNFMP group	(1)	6.2	0.019	S	(1)	5.9	0.022	S

D.F. Degree of freedom NS: not significant P: probability F value: F-test.

Data furnished in table (3) showed that there were significant increments in muscle strength which have been represented by EMG data in group PNF MP, for both biceps brachii and brachioradialis muscles regarding the main effect for the time of measurement with F=85, p = <0.001, and F=50, p = <0.001, respectively. Also, there was a significant interaction effect between the time of measurement and the subjects in the PNF group with F=3.2, p = <0.032, for biceps muscle. There was noticeable effect in PNFMP group by F=4.9, p = <0.035, for biceps brachii, and F=4.8, p = <0.037 for Brachioradialis muscle (Figs. 4, 5).

Means and standard deviations regarding handgrip strength in both groups indicated that handheld dynamometer scores of both PNF and PNFMP groups were very similar before the training program took place. However, the PNFMP scores were considerably higher by F= 5.3, p =0.03. Also in table (4), data of MANOVA cleared that there was obvious effect for measurement time F= 42.6, when p =< .001, for whether or not subjects were trained with mental practice or not, and also an increased interaction between measurement time and whether subjects trained with PNF or PNF with mental practice, F= 5.20, p = 0.0040 (Fig. 6).

Table 3 2x 6 Mixed ANOVA for EMG of elbow joint

Test	Measured Effects	Biceps muscle				Brachioradialis muscle			
		D.F	*F* .value	*P. Value*	Sig.	*D.F*	*F* .value	*P. Value*	Sig.
Within subjects effects	Main effect of measurement time within groups	(2.7)	85	0.000	HS	(2.8)	50	0.000	HS
	Interaction effect between measurement time and groups	(2.7)	3.2	0.032	S	(2.8)	1.8	0.154	NS
Between subjects effects	PNF group & PNFMP group	(1)	4.9	0.035	S	(1)	4.8	0.037	S

D.F. Degree of freedom NS: not significant P: probability F value: F-test.

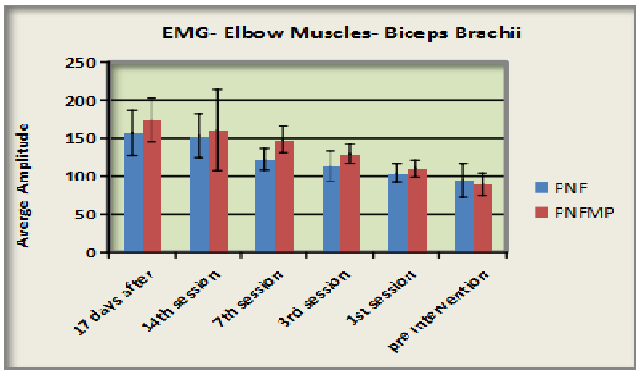

Figure 4 Means and standard deviations for EMG of elbow muscles (biceps brachii).

Table 4 2x 6 Mixed ANOVA for hand grip strength

Test	Measured Effects	Hand grip strength			
		D.F	*F* .value	*P. Value*	Sig.
Within subjects effects	Main effect of measurement time within groups	(2.7)	42.6	0.000	HS
	Interaction effect between measurement time and groups	(2.7)	5.2	0.004	HS
Between subjects effects	PNF group & PNFMP group	(1)	5.3	0.03	S

D.F: Degree of freedom. F value: F-test. P: probability HS: highly significant
S: Significant

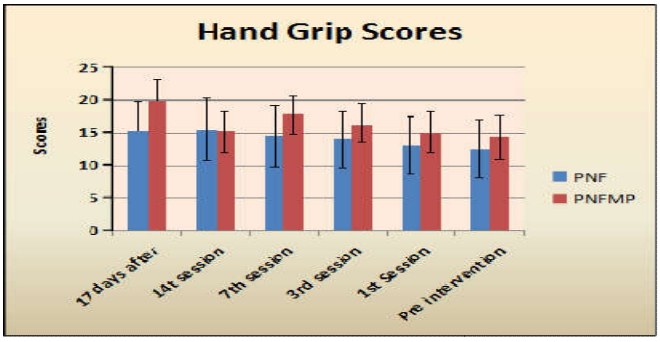

Figure 6 Means and standard deviations for hand grip strength

DISCUSSION

Enhancement of the performance of various aspects of motor control because of MI practice was investigated in healthy subjects including improved active movements of the hip joint when MI was added to PNF, [15] and improved postural control in elderly people,[16] with little attention to potential differences in muscle performance of upper extremity and handgrip. Previous studies have reported that patients with injuries of the spinal cord, and cerebellar disorders can be benefited by the MP as a therapeutic adjunct to PNF and physical practice.[24, 25]

The current study investigated and documented the effects of MP when added to PNF on muscle voluntary activity of the dominant arm and hand grip power in healthy nonathletic female subjects. The main findings of results indicated that there was a significant improvement in muscle performance of the shoulder joint in the PNFMP group for infraspinatus and anterior deltoid muscles. Also; it was evident a significant effect for the time of measurement for subjects were trained with MP or not. Regarding the interaction between the time of measurement and the groups; it was noteworthy a great significant effect for infraspinatus muscle, while there wasn't any significant difference of anterior deltoid muscle.

It has been found that there are significant increments in muscle strength of the elbow joint for both biceps brachii and brachioradialis muscles in subjects of the PNFMP group. Also; it was observed that handheld dynamometer scores of both PNF and PNFMP groups were very similar before the training program took place. However; the PNFMP scores were considerably higher with significant within-subjects effects.

These results are parallel with that of numerous clinical studies after stork, which compared the isolated physical therapy interventions with an approach that combined physical and MI practice. These studies consistently found that the greatest improvements in motor performance occurred with interventions that combined physical and MP.[12, 26, 27.]

Page and colleagues, 2001, 2005 demonstrated the effect of MP technique in 1 case report and 2 small controlled randomized trials (RCTs). In RCT, eleven stroke patients in the chronic phase who mentally practice ADL significantly improved in comparison with those who practiced only physical exercise. As well as; Liu and associates, 2004 investigated the relearning of functional tasks, such as household work, cooking, and shopping, using MI. After 15 practice sessions, significant gains were achieved in household and community tasks, gains that interestingly transferred to 5 unpracticed activities.

Results of this study revealed that there was retention of intervention gains in PNFMP group at 17 days follow- up compared with PNF group, this consistent with previous studies showing higher retention of performance level in the MI group after follow-up for one month.[26]

In this study, improvement in hand grip force in both groups was noted and recorded, with considerable increments in the PNFMP. These results have further been supported by reports of significant, long-standing improvement in wrist movements and object manipulation in chronic hemiplegic patients, and post-stroke hemiparesis.[28, 29]

Bedeschi et al., 2016 reported muscle strength gain of the flexor muscle of fingers by 42 % in two patients with cerebellar atrophy as a result of MP in isolation to a 10 % increase for practicing upper limbs PNF pattern. The training program was consisted of 10 sessions, over 5 weeks. The strength of fingers flexors was assessed by a dynamometer, prior to every session, and after 17 days of training.

It was concluded that motor imagery training might have value as an adjunct to restorative interventions targeting post-SCI deficits, with greatest improvements in motor performance occurred with interventions that combined physical and MP.[12] It was evident in this study and previous studies that, the neural events controlling the muscle parameters for performance (e.g., amplitude, timing) can be improved through MP. This is supported by evidence that neural activity of the brain will be changed and improved as level of motor skill increases.[30]

The study limitations are including sample size and profile; the same study may be conducted on a large number and on employees with different characteristics to study the influence of work-related activities on muscle strength. Also; this study was limited in using EMG to assess muscle strength, but it was due to the availability of types of equipment, isokinetic dynamometer system can be used to measure joints proprioception.

CONCLUSION

This study revealed a strong positive effect of the MP technique combined with PNF on strength of shoulder and elbow muscles and hand grip force. These results have implications for clinical practice, it apparently warrants the incorporation of MI into the rehabilitation program for both athletes and those undergoing physical therapy for motor relearning and strength including musculoskeletal disorders, and neurological disorders. Our research has been funded by future scientists program at Jazan University, The study protocol was approved by the research unit of Jazan University and registered in Clinical Trials.gov (ID: NCT03767413).

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Conflict of interest: None

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