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The Effect of Twelve-Week Neurofeedback Training on Pain, Proprioception, Strength and Postural Balance in Men with Patellofemoral Pain Syndrome: A Double-Blind Randomized Control Trial

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ABSTRACT

Background: Patellofemoral pain syndrome (PFPS) has been reported as one of the most common reasons for knee pain which accounts for about 30% of all injuries seen in sport medicine clinics. These group of patients have Postural Balance disorder that can cause pain, dysfunction in proprioception and decreased muscle strength. We aimed to study a twelve-week neurofeedback training (NFT) on pain, proprioception, strength and Postural Balance in PFPS patients.

Methods: This randomized controlled trial included 32 patients with PFPS who were randomly allocated into experimental (n=16) and control (n=16) groups. The variables measured included pain, knee proprioception 20 and 60 degrees, muscular strength quadriceps and hip abductors and Postural Balance that were evaluated before and after intervention. The experimental group performed NFT during twelve weeks, three times per week and 30 min per session, while the control group did not receive any treatment during this time. Covariance statistical method was used for data analysis.

Results: The results of data analysis showed that the experimental group had significant improvement in postural balance index anterior-posterior (P<0.004), overall stability (P<0.003), knee proprioception 20 degrees (P<0.004), knee proprioception 60 degrees (P<0.004), quadriceps muscle strength (P<0.007) and pain reduction (P<0.001). However, postural balance index medial-lateral (P>0.140) and hip abductor muscle strength (P>0.164) had no improvement after twelve weeks of NFT.

Conclusions: The NFT through thalamus inhibition led to reduced pain and improved sensory pathways, sensory integrity, increased attention and cognition. They also led to improved proprioception, Postural Balance, overall stability and quadriceps muscle strength. It is suggested that future studies examine the impact of long-term and short-term NFT on the variables of the present study.

Introduction

Patellofemoral pain syndrome (PFPS), which feels as a diffuse retropatellar or peripatellar pain aggravated by activities, is the most prevalent diagnosed orthopedic pathology in physically active individuals, So that accounts for about 30% of all injuries seen in sport medicine clinics and 9% of all injuries in young athletes and at the age of 16 to 25 years, it has a 70% higher prevalence [1, 2].

Postural Balance is a part of motor control that is maintained by central sensory-motor system and

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integrates information regarding the vestibular, visual and sensory - motor systems and leads to posture stability [3]. Postural Balance disorder has been reported in previous studies in patients with PFPS [4]; Negahban et al, reported the disorder in all directions, especially anterior-posterior direction [5], and Yalfani et al, reported disorder in all directions, especially medial – lateral direction [6]. However, based on the results of studies, oscillations in the medial - lateral direction are more than anterior-posterior oscillations, because of loading / unloading mechanism to reduce pain and the weakness of the hip muscles strength as controlling medial – lateral oscillations relative to quadriceps muscles as the controller of anterior-posterior oscillations [4, 6].

The main causes of Postural Balance disorder in these patients are pain, proprioception disorders, neuromuscular and hip abductor muscles weakness, especially the gluteus medius muscle, which have an important role in stabilizing posture and lower extremities by minimizing medial-lateral and anterior-posterior oscillations of the body's center of gravity during turbulence [6, 7]. In this regard, Akseki et al. reported knee joint proprioception disorder [8] and Carvalho et al. reported abductors and quadriceps muscle weakness [4].

Pain is the main symptom of PFPS, which can negatively affect the sensory-motor integrity and proprioception, so that the pain-related information for processing in the central nervous system is highlighted more than proprioception information. Subsequently, this causes muscle strength disorder, feedforward-feedback motor control, changes in muscle stiffness and sensory-motor system inefficiency and eventually posture oscillation [9, 10], In fact, Postural Balance requires the integration of sensory inputs and sensory inputs affect motor components such muscle strength, muscle activation and patterns co-contraction, the dysfunction of which eventually causes impaired Postural Balance [3, 9].

Neurofeedback training (NFT) is one of the newest non-invasive therapeutic method which has earned a special reputation in the field of neuroscience rehabilitation; In NFT, due to the intended treatment protocol, electrodes were placed on the specific areas of patient's scalp which shows the level of brain waves activity in the form of alpha, beta, theta, gamma [11]. This therapeutic, approach targets different waves to obtain the reduction in sensory information processing, increase of activity in brain areas that operate to sensory information control or the increase in relaxation levels. Regarding patients with chronic pain whose neurological activity in the brain waves changed, and in the context of such a new approach, Decharms et al. reported that subjects experienced a reduced perceived pain intensity after completing treatment sessions [12]. Kayıran et al. stated pain reduction [13] and Azarpaikan et al. noted an improvement in patient Postural Balance after receiving NFT [14]; however, no study was found on the effectiveness of NFT on proprioception and muscle strength. Despite the conducted studies on the effectiveness of NFT, about effect of this rehabilitation new approach has not been studied concerning pain, proprioception, muscle strength, and Postural Balance of patients with PFPS ; on the other hand, PFPS is a multifactorial musculoskeletal disease (anatomical, biomechanical, and psychological) that until now little attention has been paid to the its psychological aspect [15]. The aim of the present study was the effectiveness of twelve weeks of NFT on pain, proprioception, strength and Postural Balance in patients with PFPS.

Methods

Research Design

This study is a double blind randomized controlled clinical trial (rehabilitation laboratory specialists as both evaluators and patients). The subjects were randomly assigned to experimental (16 subjects) and control group (16 subjects). All evaluations were performed by laboratory experts during two stages before and after the intervention of twelve weeks of NFT in the rehabilitation laboratory of Bu Ali Sina University of Hamadan, Iran.

Participants

Sampling was performed from 10th April 2019 until 17th June of the same year from the patients aged between 18 to 35 with PFPS who referred to orthopedic clinics in Hamadan province. The stairs test (ICC: 0.94) was used to screen the patients [16]. To estimate sample size, G*Power software version 21 was used (Universität Kiel, Germany) and the values applied in software agreed with those in the previous study (0.80=power, 0.25=effect size, α=0.05) [17]. The sample size consisted of 32 patients (16 subjects for experimental group and 16 subjects for control group) who were allowed to participate in the study base on inclusion and exclusion criteria. Before intervention, the researcher informed the patients of the process of evaluation, and they signed the consent form. Inclusion criteria included the following: pain around patellofemoral joint more than 6 weeks, deeper pain intensity in anterior or posterior part of the patella at least by one of the activities as long-time sitting, kneeling, running, squatting, jumping and ascent and descent form of the stairs (3 out of 10 visual analog scales) [18]. Exclusion criteria included the following: injury and hip pain, lumbar spine, other knee joint structures such patella tendon, surgical history, neurological disorders, patellofemoral joint instability, knee joint effusion, physiotherapy in the previous year to treatment knee pain, lower limb deformity or weekly use of anti-inflammatory drugs [18]. After completing the assessments, all patients were homogenized based on age, height, weight, BMI index, pain, strength, and posture control, and were randomized by Random Number Generator software; they were then divided into experimental and control groups based on SNOSE method. During this time, patients were not informed of their allocation to the mentioned groups, but after the completion of the study, they were fully informed of their allocation in these groups (Figure 1).

Ethical Considerations

This project has been approved and registered by the national committee for ethics in biomedical research (IR.BASU.1398.001) and clinical trial center (IRCT

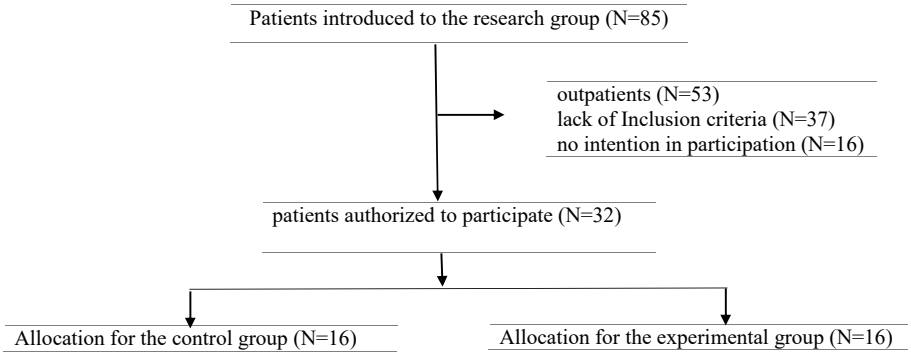

Figure 1: Patient selection process

20191209045669N1), and has been performed in accordance with 2008 Helsinki declaration.

Assessment

Step 1: it is associated with the demographic information (age, height, weight, BMI). The measurement demographics indexes of height, weight and BMI of patients was performed using digital scales and the values were recorded.

Step 2: it is associated with the measurement of the perceived pain intensity. The patient was asked to report the pain intensity during daily activities; to measure the pain intensity a 10-cm visual analog scale (VAS) was used (ICC=0.91) [19]. The reliability of this scale has been reported 77 % to 79 % for patients with PFPS [6].

Step 3: In this step, the knee proprioception was evaluated by angle error reconstruction method and with a goniometer made in Iran. The validity of this tool is reported 0.97, its reliability was 0.87 and its fixed time reliability was 0.82 [20]. Knee proprioception was measured at two angles of 20 and 60 degrees; these target angles were chosen for several reasons:

Firstly, at 20 degrees of knee flexion the distal patella contacts to proximal femoral trochlea so that any proprioceptive deficit at this angle may be related to patella mal-tracking, which is widely accepted to be a major causative factor in PFPS symptomology [21, 22].

Secondly, 60 degrees of knee flexion has been highlighted as a pertinent angle in PFPS pathology and significance of this angle was underlined by functional motion analysis [21, 22].

Thirdly, and eventually, most of daily activities are performed in the knee flexion angle between 20 and 60 degrees [21, 22].

The testing method was as follows; the patient sits on the examination table and the affected knee was in a 90-degree flexion (resting position); goniometer fixed arm was placed on the femoral axis and the mobile arm was placed on the tibia axis. The passively-affected limb was then moved by the tester by the target angle and the limb was held at that angle for 10 seconds. Subsequently, the patients were asked to see the target angle and memorize it, and then the limb inactively returned to 90-degree flexion position. After a 5-second pause, the patient with shut eyes and active manner moved the affected limb to the target angle. upon instruction, patients said "it arrived" when the limb reached the target angle to inform the tester. At that moment, the target angle was observed and recorded by another tester and no number was read. This test was performed 6 times and the average absolute error of these 6 attempts was calculated and recorded [21, 22].

Step 4: The static Postural Balance was measured. To measure Postural Balance, Biodex device with Balance System SD model manufactured in the united states was used (ICC=0.95) [23]. This device provided the result of the deviations of the center of pressure in three levels of medial-lateral, anterior-posterior and overall stability; thus, the higher values indicated weaker Postural Balance. Before the patient was placed upon the platform, the device was calibrated by a specialist. Then, with the guidance of tester, the patient stood barefoot on the marked area and his arms were placed crosswise on the chest. It is worth mentioning that the experiment was performed with the shut eyes and two legs standing upon hard surface, and the time of experiment was considered 30 seconds according to the previous study [24].

Step 5: measuring muscle strength. To prevent fatigue and its effect on the performance of other variables, strength assessment was performed in the last step. To measure strength, Nicholas Hand Held dynamometer (NHHD) model 01163 Lafayette instrument made in England was used (ICC=0.89–0.94) [25]. Dynamometer calibration was confirmed before the study by placing a specific weight upon dynamometer and comparing it with the specified amount on dynamometer [26]. Before performing examination and in order to familiarize patients with it, two submaximal contractions were performed [27]. The method for quadriceps muscle was as follow: the patient sat on examination table with the hip and knees at a 90-degree flexion (resting position) [4], and hands were held crosswise upon chest; then, tester placed the dynamometer in the front and between two malleolus and the patient performed the maximum isometric contraction [4]. To assess muscle strength, the patient's hip abductor was placed in side-lying position on treatment table with the testing limb on top. The examiner checked the limb to assure the lack of external rotations or extensions, and placed a pillow between the two legs to neutralize hip position [27]. The tester placed dynamometer on lateral femoral condyle and the patient performed the maximum isometric contraction [4]. Each contraction was carried out 5 seconds 3 times with the average recorded, and a 2-minute interval was considered between the trials [27]. It should be noted that in all muscle strength tests, verbal encouragement was provided by tester to the patient to maximize contraction

until pain threshold. After the completion, the visible values on the dynamometer screen was observed and recorded by another tester and no number was read.

Step 6: registration of baseline brain signals. It was implemented the next day, which was performed by a laboratory specialist in psychology laboratory of Bu Ali Sina university of Hamadan, Iran. To record brain signals and NFT in this study, 8-channel NF device model ProComp Infiniti was used with ProComp 2 hardware and Biograph Infiniti software (version 5) made by 'thought technology' company of Canada, with sampling rate of 256 Hz and 5-ohm electrode resistance. Before performing baseline and NFT, the clinical psychologist provided instructions for all patients about how NF works during treatment sessions. In sessions 1, 6, 12, 18, 24, 30, and 36, before the treatment session, baseline was performed to determine the level of brain waves in the Central Zone (CZ) area with both eyes open and closed. Before performing Baseline and treatment sessions, patients gave their rings, cell phones, watches and any accessories that caused noise and artifacts. Baseline's implementation method was as follows:

The patient sat on a chair in a comfortable position, then CZ region was identified based on 10-20 International system and marked and finally CZ area and earlobes cleaned with medical alcohol and Nuprep exfoliating gel made in USA. The active electrode was then impregnated to 'TEN 20 Conductive Gel' glue made in USA and was placed in the CZ area. The reference electrode was attached to the left ear and grand electrode was attached to the right ear. Before assessment began, to minimize artifacts, the patients were taught to avoid moving limbs, displacement, speech, and too much blinking. The duration of Baseline was 2 minutes and 10 seconds, which was set by default settings by biograph Infiniti software. Artifact and noise cancellation of signals were performed as visual exploration and selection of appropriate software domain. Then, the results of raw wave analysis were extracted and recorded by Biograph Infiniti software.

Neurofeedback Training Protocol

The treatment intervention of the present study was performed for twelve weeks, three sessions per week with each session lasting 30 minutes [28]. The executive protocol was selected based on previous studies [28], which included an increase in sensory-motor wave (12 – 15 Hz) and decrease in beta (15 – 20 Hz) and theta (4 – 7 Hz) in the CZ region which simultaneously affected the three cortex of sensory-motor, motor and signolite [29]. The electrodes placement was carried out at Baseline phase. Intervention execution was as follow: the patients sat facing monitor and animation was provided for them. when the process of sensory-motor waves, beta and theta did not agree with the purpose of the present study, the animation movement was stopped and when these waves were adjusted in the direction of the present intervention, the animation began moving. Patients received the necessary audio and visual feedback vision to regulate their brain waves with animation movement; a pleasant sound was played for positive scores and the animation halt meant a negayive score which was followed by an unpleasant sound . The control group did not undergo any treatment for twelve weeks and did not use painkillers.

Statistical Analysis

SPSS software version 21 was used for statistical analysis, and the significance and confidence level for analysis of all data were considered as 0.05 and 95%, respectively. Shapiro Wilk test was run in order to ensure normality of data related to variables and demographic features; independent T-test was run to compare two experimental and control groups for homogeneity of demographic characteristics and study variables. Levene's test was performed for homogeneity of variance and to investigate the effect of intervention (before and after intervention) on groups (experimental and control); statistical method of covariance was utilized by inserting pre-tests as a covariate.

Results

Patients who participated in this study were aged (25.13±2.14), with the mean height of (174.56±4.06), and mean weight of (75.65±5.61) and BMI index of (24.76±1.55). Examination results of the Shapiro Wilk test showed that demographic data of experimental and control group patients were statistically normal ($P<0.05$); also, the results of independent t-test showed that there is no significant difference between experimental and control groups, so the demographic characteristics and study variables were homogeneous between the two groups ($P<0.05$). Then, other main pre-assumptions of the covariance test were examined, including data normality distribution, homogeneity variances and regression slope ($P<0.05$). Thus, by observing test assumptions to examine statistical data, covariance parametric test was used. According to studies of Cohen et al, the effect size 0.01 to 0.059 was considered as a small effect size, 0.06 to 0.14 as a medium effect size and 0.14 as large effect size [30]. Also, according to the following formula [31, 32], the percentage of changes for the two groups in each variable is reported in Table 1.

$$\text{Percentage of changes} = \frac{\text{Post-test} - \text{Pre-test}}{\text{Pre-test}} \text{ X } 100$$

The results of covariance analysis showed that, after controlling pre-test effect (η^2=0.123, P=0.009, F (1,27)=3.785), main effect of the group (η^2=0.433, P=0.001, F (1,27)=20.598), had a significant effect on pain intensity (high effect size); this means that severity of pain in the experimental group has been reduced. In addition, the adjusted averages were reported in experimental group M=4.67 and control group M=7.06 (Tables 1-3).

The results of covariance analysis showed that, after controlling pre-test effect (η^2=0.211, P=0.012, F (1,27)=7.208), the main effect of the group (η^2=0.262, P=0.004, F (1,27)=9.581), had a significant effect on 20-degree proprioception angle (high effect size); this means that angle error in the experimental group has also decreased. Moreover, the adjusted averages were

Table 1: Covariance test results (Pre - test)

Variable	F	DF	Men Squares	Power	Eta	Sum of Squares	P value
Pain	3.785	1	7.737	0.467	0.123	7.737	0.009
Proprioception 20 degrees	7.208	1	40.456	0.735	0.211	40.456	0.012
Proprioception 60 degrees	1.079	1	6.845	0.171	0.038	6.845	0.002
Quadriceps muscle strength	253.345	1	1451.556	0.998	0.904	1451.556	0.001
Hip abductor muscle strength	209.127	1	801.914	0.999	0.886	801.914	0.003
Anterior-posterior index	183.034	1	1.319	0.999	0.871	1.319	0.002
Medial-lateral index	33.640	1	0.724	0.999	0.555	0.724	0.001
Overall stability	143.075	1	1.260	0.999	0.841	1.260	0.001

Table 2: Descriptive Statistics

Variable	Group	Pre - test	Post - test	Percentage of changes
Pain	Experimental	5.66±1.39	4.13±1.18	37.05 %
	control	7.00±1.85	6.53±1.35	-6.71 %
Proprioception 20 degrees	Experimental	1.60±4.76	0.80±3.32	-50 %
	control	3.53±2.58	5.60±1.63	58.64 %
Proprioception 60 degrees	Experimental	3.313±4.22	0.86±2.87	-72.52 %
	control	2.60±3.37	3.80±2.11	46.15 %
Quadriceps muscle strength	Experimental	36.91±5.69	36.98±6.17	0.19 %
	control	35.83±9.67	33.41±8.75	-6.75 %
Hip abductor muscle strength	Experimental	30.21±4.20	28.22±3.10	-6.59 %
	control	32.08±7.41	29.48±3.92	-8.10 %
Anterior-posterior index	Experimental	1.46±0.25	1.40±0.25	-4.11 %
	control	1.34±0.23	1.39±0.20	3.73 %
Medial-lateral index	Experimental	1.66±0.20	1.68±0.17	1.20 %
	control	1.41±0.17	1.52±0.22	7.80 %
Overall stability	Experimental	1.51±0.21	1.49±0.17	-1.32 %
	control	1.30±0.36	1.46±0.27	12.31 %

Table 3: Covariance test results (Post - test)

Variable	F	DF	Men Squares	Power	Eta	Sum of Squares	P value
Pain	20.598	1	42.109	0.990	0.433	42.109	0.001*
Proprioception 20 degrees	9.581	1	53.774	0.847	0.262	53.774	0.004*
Proprioception 60 degrees	9.649	1	61.215	0.849	0.263	61.215	0.004*
Quadriceps muscle strength	8.763	1	50.205	0.814	0.245	50.205	0.007*
Hip abductor muscle strength	2.046	1	7.845	0.281	0.031	7.845	0.164
Anterior-posterior index	9.703	1	0.070	0.851	0.264	0.070	0.004*
Medial-lateral index	2.314	1	0.050	0.79	0.049	0.050	0.140
Overall stability	10.435	1	0.092	0.876	0.279	0.092	0.003*

reported in experimental group M=2.26 and control group M=5.14 (Tables 1-3).

As can be seen in the results of covariance analysis, after controlling pre-test effect (η^2=0.038, P=0.002, F (1,27)=1.079), main effect of the group (η^2=0.263, P=0.004, F (1,27)=9.649), had a significant effect on 60-degree proprioception angle (high effect size); this means that angle error in the experimental group has been lowered. In addition, the adjusted averages were reported in experimental group M=0.90 and control group M=3.76 (Tables 1-3).

Evidently, after controlling pre-test effect (η^2=0.904, P=0.001, F (1,27)=253.345), main effect of the group (η^2=0.245, P=0.007, F (1,27)=8.763), had a significant effect on quadriceps muscle strength (high effect size),i.e., there was lower quadriceps muscle strength in the experimental group . Additionally, the adjusted averages were reported in experimental group M=36.49 and control group M=33.90 (Tables 1-3).

After controlling pre-test effect (η^2=0.871, P=0.002, F (1,27)=183.034), main effect of the group (η^2=0.264, P=0.004, F (1,27)=9.703) had a significant effect on anterior-posterior oscillations (high effect size); in other words, anterior-posterior oscillations in the experimental group were decreased. The adjusted averages were reported in experimental group M=1.35 and control group M=1.45 (Tables 1-3).

Moreover, after controlling pre-test effect (η^2=0.841, P=0.001, F (1,27)=143.075), the main effect of the group (η^2=0.279, P=0.003, F (1,27)=10.435) left a significant impact on overall stability (high effect size) representing a decrease in overall stability oscillations in the experimental group. In addition, the adjusted averages were reported in experimental group M=1.41 and control M=1.53 (Tables 1-3).

The main effect of the group (η^2=0.031, P=0.140, F (1,27)=2.046), did not have a significant effect on hip abductor muscle strength (small effect size) after controlling pre-test effect (η^2=0.886, P=0.003, F (1,27)=209.127) implying no increase in hip abductor muscle strength in the experimental group treatment interventions. The adjusted averages reported in

Table 4: Results of covariance test for brain waves

Brain Waves	F	Power	Eta	P value
Motor sensory waves	133.296	0.995	0.832	0.001*
Beta waves	114.818	0.991	0.810	0.001*
Teta waves	75.861	0.855	0.738	0.001*

experimental group were reported M=29.62 and control group M=30.68 (Tables 1-3).

Upon controlling pre-test effect (η^2=0.555, P=0.001, F (1,27)=33.640), the main effect of the group (η^2=0.049, P=0.140, F (1,27)=2.314) did not have a significant effect on medial-lateral oscillations (small effect size) showuing no decrease in medial-lateral oscillations in the experimental group treatment interventions . Furthermore, the adjusted averages were reported in experimental group as M=1.54 and control group as M=1.64 (Tables 1-3).

By Controlling the pre-test effect (η^2=0.427, P=0.001, F (1,27)=20.085), the main effect of the group (η^2=0.832, P=0.001, F (1,27)=133.296) had a significant effect on sensory-motor wave (high effect size), suggesting an increase in sensory – motor wave in the experimental group. Also, the adjusted averages reported in experimental group were M=14.175 and for the control group M=7.58 (Table 4).

By controlling the pre-test effect (η^2=0.550, P=0.000, F (1,27)=32.938), the main effect of the group (η^2=0.810, P=0.000, F (1,27)=114.818) had a significant effect on beta wave (high effect size) meaning that the beta wave in the experimental group decreased. The adjusted averages were reported in experimental group as M=15.003 and in the control group as M=24.570 (Table 4).

The results of covariance analysis demonstrated that after controlling pre-test effect (η^2=0.169, P=0.009, F (1,27)=5.500), the main effect of the group (η^2=0.738, P=0.000, F (1,27)=75.861) had a significant effect on theta wave (high effect size) implying it decrease intheta wave in the experimental group . Moreover, M=5.371 and M=10.362 are reported for the adjusted averages in experimental group and control respectively (Table 4).

Figures 2 and 3 show the rate of brain wave changes in both groups; the amount of sensory-motor waves in the normal state is 15 to 13 Hz, beta 20 to 15 Hz, and theta 8 to 4 Hz (32). According to the results of covariance test in Table 4 and adjusted mean of brain waves, significant improvement has been achieved in all three waves which is close to normal.

Discussion

In the present study, we aimed to investigate the effectiveness of twelve weeks of NFT on pain,

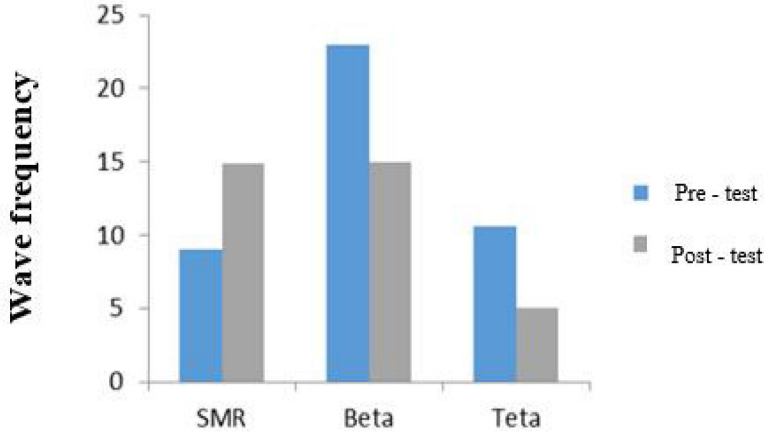

Figure 2: brain waves changes in the experimental group; after twelve weeks of NFT, the motor sensory waves increased and beta and theta waves diminished

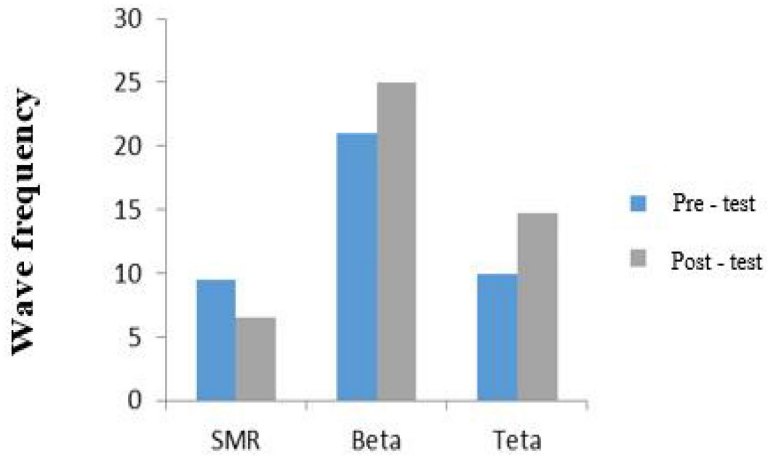

Figure 3: brain waves changes in the control group; after twelve weeks, the sensory motor waves decreased and beta and theta waves increased

proprioception, strength and Postural Balance in patients with PFPS. The results showed that twelve weeks of NFT led to pain reduction, proprioception improvement, quadriceps muscle strength and Postural Balance in anterior-posterior index and overall stability. No significance improvement was observed in hip abductor muscle strength and Postural Balance in medial-lateral index, which will be explained in the following discussion.

The results of data analysis showed that twelve weeks of NFT led to the pain reduction, which is in line with the following studies: Kayıran et al, examining the effect of NFT (8 weeks, 4 times a week and 30 minutes in each session) on pain reduction in patients with fibromyalgia syndrome [13]; and Jensen et al, investigating the effect of NFT (20 days and 30 minutes per session) on pain reduction patients with complex regional pain syndrome [33]. To understand the mechanism of efficacy, it is necessary to describe the mechanism of pain perception. Pain is triggered by the activation of an extensive network in certian areas in the brain including the motor sensory area, insular, syngolite, prefrontal cortex, thalamus, inferior cortex and brainstem [34]. Information is then processed in spinal cord and then transferred to thalamus and to primary sensory cortex; thus, it is argued that the initial pain perception occurs in thalamus and a more accurate perception occurs in the primary sensory cortex [28]. Accordingly, in the present study, pain is relieved by interventions applied in thalamus width and sensory cortex, which are the first spots for pain processing [28]. It seems that treatment intervention protocol facilitated the mechanisms of thalamus inhibition by focusing on sensory-motor cortex, [35] which is the primary and early effect of NF on subcortical structures, especially thalamus, and have an important role in central regulation and changes in central pain processing [21].

The results of data analysis showed that, twelve weeks of NFT led to improved Postural Balance in anterior-posterior index and overall stability, which was in line with the results of Azarpaikan et al. study, They investigated the effect of NFT (5 weeks, 3 times a week and 30 minutes per session) on Postural Balance [14]. However, this was not consistent with findings of the study conducted by Wenya et al, who examined the effect of NFT (5 daily workouts in a total of 25 sessions in 5 consecutive days) on Postural Balance [36]. The discrepancy in the results could be due to subjects' health conditions. In addition, the findings of present study revealed that there is no improvement in Postural Balance of the medial - lateral direction and also the effect size of treatment intervention on this variable is small, which can be explained by the weakness and delay in activating gluteus medius muscle, because its torque arm is longer than other lower limb muscles to control hip movements in frontal plane [37]. The results are in line with the findings of Carvalho et al. who reported a significant correlation between gluteus medius and medial-lateral index disorders in posture control [4].

Improving proprioception and Postural Balance caused by NFT can be achieved by regulating sensory processing in sensory processes and Postural Balance, where the relative dependence of central nervous system on vestibular, sensory-motor and visual systems is increased in sensory input integration [38]. The sensory integration approach creates conditions in which it involves most of the brain and body activities and it improves and strengthens nervous system and superior functions of the brain, such as motor skills by focusing on neurophysiological structures as, vestibular, vision, and proprioception systems; On the other hand, NFT can cause neuroplasticity efficiency and improve brain growth through the occurrence of neuroplasticity, all of which strengthen nervous system function, attention and cognition [14-39].

Attention and cognition are among factors that have a great impact on Postural Balance, so that maintaining posture stability requires the cognitive resources for processing somatosensory input [40]. They are involved in mental processing and strong behavior moderator and motor control, and make patients aware of movement experience and movement purpose, and to enable them to make decisions and organize responses; thus, having an appropriate control on posture stabilizing muscles can lead to better Postural Balance. In this regard, research shows that sensory-motor cortex helps to encode physical and cognitive tasks of cerebral cortex [41] and the increase sensory-motor wave. The protocol running in the present study is the reduction of the interference of unrelated stimulus processing, facilitating cognitive integration, and creating harmony between the environment and individual to regulate body movements [42]. As another protocol, we aimed to reduce theta wave to improve, focus and attention as emphasized by earlier studies, which can further establish Postural Balance [40, 42]. Therefore, NFT, which is based on biological feedback to central nervous system and wave regeneration to reach a desired state , can lead to precise control of individual's central nervous system in perceiving posture oscillations, which can ultimately lead to optimal Postural Balance [41].

According to figures 1and 2, the mean waves of experimental group have been changed compared to control group, which indicates effectiveness correctness of NFT. As a result, by affecting the subcortical structures and cerebral cortex, improvement in proprioception and Postural Balance will be obtained [43].

Based on the results, a significant improvement in quadriceps muscles strength is achieved. In general, weaker muscle is attributed to both psychological and neurological processes, and in the present to study the psychological processes gain more momentum. Accordingly, patients with musculoskeletal injuries are reluctant for muscle activation due to fear of pain, general weakness, and inability to successful and conscious movements. By the reduction of physical activity, the muscles eventually become atrophic due to lack of movement [10]. Therefore, it is inferred that the increase in quadriceps muscle strength can be due to a decrease in perceived pain intensity and psychological factors affected by pain [44]. The second mechanism can be the result of intervention applied in CZ area and its simultaneous effect on motor cortex to reorganize central movement which will result in muscle strength increase

due to voluntary contraction with motor units [10].

Lack of improvement in hip abductor muscle strength and a small effect of treatment intervention on this variable can be explained as the following.

NFT is a static state, with a non-physical movement of limbs that involves only sensory parts of sensory – motor system and there are no efferent activity or muscular firing, but on the contrary, during the active movements, all parts of sensory - motor system are involved and lead to neuromuscular adaptation resulting in an enhancement in strength and proper activation [10]. This is in line with the study conducted by Tadeu and colleagues, which stated that hip abductor muscle strength is not affected by psychological factors affected by pain [45]. Consequently, to improve strength and proper activation of this group of muscles, dynamic physical exercises were considered which aims at automating more complex synergies, including synergies that involve several joints, muscles and movement plane [46].

The limitations of this study included lack of control on participants' mental state, lack of evaluation posture control in dynamic and functional activities and lack of control over psychological factors related to pain and patient performance. Further research can focus on the effectiveness of NFT on dynamic posture control. It is also recommended that future studies examine the effect of immediate and long-term NF on the factors of the current study.

Conclusion

According to the present study, NFT reduces pain through thalamus inhibition and improves proprioception and Postural Balance in anterior-posterior index and overall stability through improvement in sensory pathways, sensory integrity, and enhanced attention and cognition; also, the strength of quadriceps muscles was increased. On the contrary, there is no significant improvement in hip abductor muscle strength and medial-lateral index of Postural Balance. Future studies can examine dynamic Postural Balance at stiff and soft surfaces or evaluate timing of activation quadriceps and hip abductor muscles. It is also recommended that in future studies, researchers use psychological questionnaires related to pain and performance.

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