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Changes in Functionality Induced by Conventional and Combined Electromyostimulation Knee Training, in Women with Patellofemoral Knee Syndrome

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Abstract

Background: Patellofemoral pain (PFP) is a chronic condition that usually results in long-term functional impairments both in adults and adolescents PFP has been found to decrease activity levels in individuals.

Purpose: The purpose of the present study was to investigate whether the additional use of electrical stimulation to an intervention program could result in greater improvements in the knee function and the level of pain compared with the intervention program itself.

Material and Methods: 22 women reported anterior knee pain symptoms clinically allocated in the patellofemoral region and confirmed through the patellar position, analyzed by magnetic resonance imaging (MRI). They randomly assigned into two groups with the same strengthening program. The experimental group used electrical stimulation combined with knee extensors and flexors strengthening exercises. The main outcome of the study was the visual analogue scale (VAS) in order to assess pain and the Anterior Knee Pain Scale (AKPS) to evaluate the functionality of the knee joint. All the outcomes were analyzed and compared pre and post a 6-weeks intervention period.

Results: Statistically significant differences were found between the two rehabilitation groups at the end of the intervention period both in VAS ($F_{1,20} = 44.083$, $p < 0.001$) and functional assessment ($F_{1,20} = 35.687$, $p < 0,001$), suggesting that the conventional intervention program with the use of electrical stimulation is more effective regarding the pain degrees and the knee function.

Conclusion: The use of electrical stimulation, combined with conventional strengthening program, could provide greater beneficial effects on PFP female individuals compared to the strengthening program itself.

Keywords: Anterior knee pain; conventional training; electromyostimulation; pain; functionality

Introduction

Patellofemoral pain (PFP) is one of the most common knee dysfunction, affecting both the adult (22.7%) and adolescent (28.9%) populations [1]. The etiology is multifactorial, usually related to conditions that involve proximal, local, and distal changes [2]. It affects sedentary, both physically active and non-active [1], many times leading to early patellofemoral osteoarthritis [3]. Furthermore, women were two times more likely to develop PFP compared with men [4]. Despite previous studies that have shown different kinetics and kinematics alterations in PFP patients [5], quadriceps muscle properties were considered an important risk factor affecting knee stress [6].

Recent studies demonstrated lower force capacity and rate of torque development (RTD) of the knee muscles in individuals with PFP [7, 8]. Furthermore, it is suggested that the core and lower limbs weakness in the women with PFP induce alterations in motor control, leading to a greater knee valgus during the eccentric phase of closed kinetic chain activities [9-11]. Moreover, pain alters the signal of the sensory, originating from receptors, leading to a different function of the neural system [12]. Therefore, it is highly recommended that dynamic and challenging multi-joint strengthening exercises should be used to stimulate proprioceptive receptors [13] since they were found to be more effective compared to the one-joint strengthening exercise [2, 14]. Previous studies have also shown that core and hip exercises combined with knee strengthening promote earlier and more effective alterations in individuals with PFP [15, 16]. However, it was recently demonstrated that single-joint exercises focused on hip rotators and abductors are not an essential element of a PFP intervention since they could replace with exercises in distal extremities without negative effects in benefits of the intervention program [17]. Despite several intervention treatments that have been proposed to eliminate these deficits, there are limited data regarding the optimal training stimulus to improve PFP individuals.

Several rehabilitation interventions are beneficial in PFP treatment. Traditionally, these programs consist of several exercises, such as squatting in different forms [18], hamstring flexibility, and core or hip-targeted strengthening exercises [16, 19]. All these exercises could be used or in combination to improve the intervention outcomes. It has been proposed that the combination of different methods or different muscle groups could result in superior improvements to those of a single treatment. Nevertheless, strengthening the knee extensor muscle seems to be a common strategy included in most intervention programs. As previously described, knee extensors muscle strength and activity are of great importance in PFP individuals and found to affect functional tasks such as squatting and step-down tasks [20]. The decreased force capacity and activity level of the knee extensors and vastus medialis oblique seems to be a determined factor regarding the pain levels and the functionality of PFP women, especially during squatting flexion-based tasks. These alterations were found to increase the patellas' frontal movement, leading to an increased pressure of the patella on the trochlear groove [21]. Given the above, quadriceps strengthening should consider of great importance during the rehabilitation and well-being programs for PFP individuals.

As a rehabilitation technique, Electrical Myo Stimulation (EMS) has been proposed to maintain or increase muscle mass, body function, and neural activation signal [22-24]. During EMS training, stimulus frequency, duration, and location are determined factors in reversing muscle atrophy and reducing fatigue. It has been showed that 100Hz with a 1-ms pulse is more effective compared with 200Hz with 0.5-0.25 ms to increase muscle strength [25]. Furthermore, EMS applied on the nerve could result in synchronous activation increases leading to better muscle recruitment with a relatively greater central contribution [26]. The applied EMS on the quadriceps muscles induced increases in hamstring strength, supporting the aspects of global neuromuscular adaptations [27]. A noteworthy outcome of EMS training at the lower limb leads to significant improvements in motor function tests. Multi-muscle EMS training induces increases in quadriceps, improvements in VO2 max, and the covered distance during the 6-min walking test [28]. Similarly, whole-body

EMS training was found to decrease the level of pain in adults with low back pain. These findings collectively indicate that EMS training applied to healthy and non-healthy individuals could result in neural and motor adaptations leading to improved motor function [29].

Previous studies supported that traditional intervention programs could increase force capacity and promote better patient functionality during daily life. There are limited data about the possible EMS with the conventional programs and their effect on PFP disease. It is possible that the combined use of EMS with traditional strengthening exercises would result in better improvements. Therefore, the present study aimed to determine the effects of EMS on pain levels and functionality in females with PFP.

Materials and Methods

Participants

All the participants signed informed consent forms and were randomly divided into one of two intervention groups, the Conventional group (CG) and the neuromuscular training group (EMS/CG). The randomization into the groups was performed using the Microsoft Excel RAND function and numbered envelopes. The intervention program started one week after.

The clinical examination was performed by an experienced sports medicine physician (orthopaedic specialist). All the patients reported anterior knee pain symptoms clinically located in the patellofemoral region. Furthermore, PFP was also confirmed through the patellar position analyzed by MRI. Patients with previous patellar dislocation, arthroscopic knee surgery or other knee surgical intervention, radiculopathy, disc hernias incidence, peripheral neuropathy, polyneuropathies, and previous history of thrombosis or neoplasia were excluded from the study.

The researchers responsible for the evaluation and the statistical analyses were not aware of any phases of the study. The physiotherapists who supervised the intervention were also unaware of the evaluation process. The participants were informed that they would receive treatment based on strengthening exercises, but did not know the study hypothesis or the differences between the two experimental groups. The participants were trained individually, using a different weekly schedule, so as the whole procedure to be considered blind.

The intervention program lasted six weeks. The participants performed four training sessions each week, completing 24 sessions. The CG and EMS/CG sessions lasted 60 and 80 min, respectively. The CG participants performed exercises that focused on both the flexibility and the strength of the core and lower limb muscles (lateral rotator, abductor, hip extensor, and quadriceps muscles). Similarly, the EMS/CG performed the same protocol, together with EMS training in a seated position on the optimal knee angle.

Electromyostimulation

The electrical neuromuscular stimulation was administered with the KneeHab XP (Theragen Inc, USA) in a seated position with the knee flexed at ~ 65°. The total duration of the EMS training was 20 min (P1 at the manual). The pulse waveform was a symmetrical bi-phasic square. The pulse frequency was set at 50 Hz with 300 - 400 μs width. The contraction time was five seconds, whereas the relaxation time was ten seconds. The ramp-up and down duration was 1 second and 0.5 second, respectively.

The pain intensity was assessed with the visual analog scale (VAS). A 10-cm line that listed "No Pain" and "Worst Pain Imaginable" was provided to the participants who were instructed to use a Likert arithmetic scale (0-10) to record the pain intensity pre and post-intervention programs. The straight line is separated in equal intervals of 1 cm where 0 represents "no pain" and 10 "worst imaginable pain". Pain level was compared to both groups (electric stimulation group and conventional group).

Anterior Knee Pain Scale (AKPS)

The AKPS was used to assess the severity of symptoms and physical limitations in the participants. It is a well-established patient-reported questionnaire which is used as a diagnostic tool, especially in individuals suffer from patellofemoral pain syndrome (PFP). A recent study indicated that the Greek KAKPS has good internal consistency, test-retest reliability and concurrent validity when correlated with the PFPS severity scale in adult patients [30].

Statistical Analysis

All data were analyzed using the Statistical Package for the Social Sciences (version 23.0, SPSS, Inc., Chicago, IL, USA). A two-way ANOVA 2x2 (intervention groups x time) was used to determine group differences (CG vs EMS/CG) before and after a six-week period intervention period for VAS and AKPS scores. Statistical significance was accepted at $P < 0.05$.

Results

Table 1 provides each group's descriptive characteristics. No statistical differences were found in the demographic between the two groups.

Responses relative to pain self-assessment showed (Table 2) that before the initiation of the treatment, the VAS median was 7 for the EMS/CG group and 6 for the CG. After the completion of the treatment the median was 2 for the EMS/CG and 3 for the CG (Table 2).

	CG (n=11)			***EMS/CG (n=11)***		
	Min	***Max***	***M±SD***	***Min***	***Max***	***M±SD***
Age (years)	16	41	27.64±7.749	13	52	23±10.412
Height (cm)	166	177	171±0.031	165	175	169±0.003
Weight (Kg)	55	1366	60.36±3.802	55	67	61.55±4.132

Table 1: Participant characteristics of control group (CG) and experimental group (EMS/CG).

		Pain assessment with VAS (n)				***Median***
CG (n=11)	Pre	5 (2)	6 (5)	7 (3)	8 (1)	6
	Post	3 (8)	4 (2)	5 (1)	-	3
EMS/CG (n=11)	Pre	5 (1)	6 (3)	7 (4)	8 (3)	7
	Post	1 (4)	2(5)	3 (2)	-	2

** The rating scale of Visual Analogue Scale (VAS) ranges from 0-10 and is separated in equal intervals of 1 cm where 0 represents "no pain" and 10 "worst imaginable pain".*

Table 2: Pre- and Post-treatment pain assessment with VAS for control group (CG) and experimental group (EMS/CG).

The analysis of variance for VAS and AKPS scores, confirmed a significant difference between groups (VAS: $F_{1,20} = 44.083$, $p < .001$; AKPS: $F_{1,20} = 337.776$, $p < 0,001$), and a significant interaction between groups and time (VAS: $F_{1,20} = 630.750$, $p < .001$; AKPS: $F_{1,20} = 35.687$, $p < .001$ respectively). EMS/CG group had lesser pain scores than CG group during the VAS and AKPS post-treatment pain assessment (Fig. 2) while there was no statistically significant difference between treatment groups before the initiation of the rehabilitation programs (Fig. 1).

Discussion

The main finding of the present study was that both intervention programs with or without EMS result in significant improvements both in pain levels and functionality in women with PFP, suggesting that both protocols could be used as effective protocols treatments. The novel finding of this study was that a conventional program for the PFP combined with the EMS of the quadriceps promotes more beneficial effects in female individuals with PFP, since it resulted in a greater the pain reduction (Table 2) accompanied with elevated levels of functionality (Figures 1 and 2).

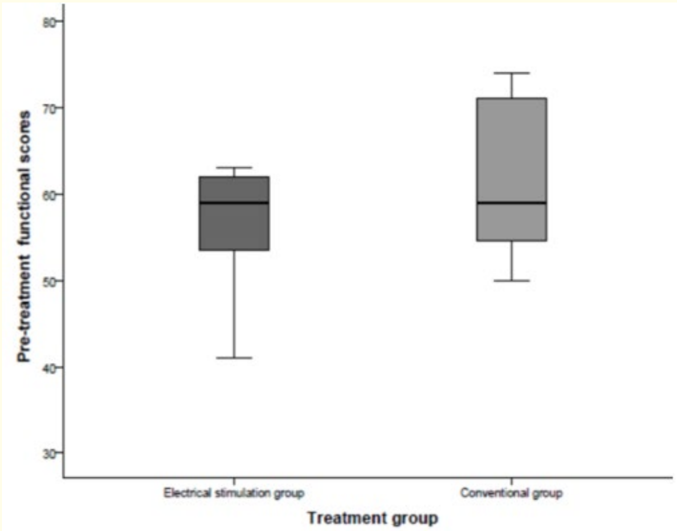

Figure 1: There was no statistically significant difference between treatment groups before the initiation of the rehabilitation programs.

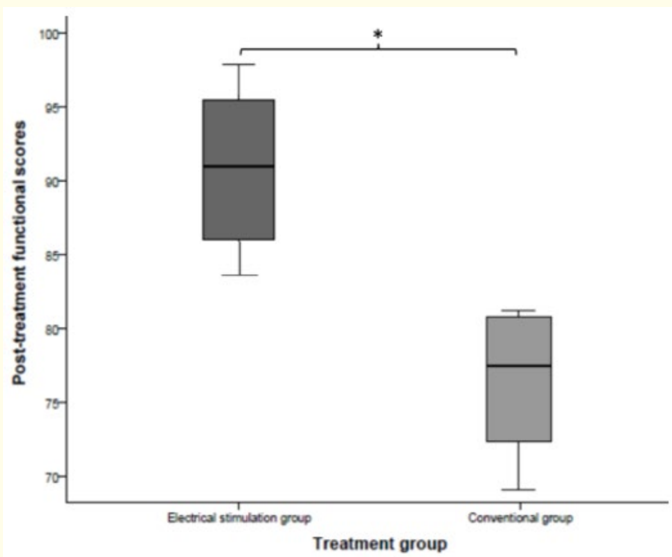

Figure 2: EMS/CG group had lesser pain scores than CG group during the VAS and AKPS post-treatment pain assessment.

Several intervention programs consisting of hip- and knee-targeted strengthening and flexibility exercises have been suggested to reduce pain and improve patient-reported functionality in PFP patients [2, 17]. Similarly, the present findings indicated that CG resulted in decreased pain and led to improved functionality after six weeks of intervention, adding to the existing knowledge about the PFP treatment. As the most of exercises were addressed to knee extensors and flexors, it is quite logical beneficial effects to be found, supporting previous results [31, 32] Moreover, a previous study [33] indicated that both strengthening the anteromedial or the posterolateral hip muscles could be equally effective in PFP patient treatment. Despite the variety of recommended exercises for PFP treatments, strengthening exercises focused on the quadriceps has been traditionally used, suggesting that these exercises are an important element of an intervention program.

Interestingly, our two intervention programs were effective after only a six-week intervention program. Our outcomes are in agreement with previous studies which demonstrated that a short-term (six-week) intervention could decrease the pain level and increase functionality during daily activities [16, 17]. Nevertheless, a previous meta-analysis study [15] suggested that the ideal intervention duration ranged from eight to twelve weeks. Given the above, two explanations could be proposed for our earlier adaptations: firstly, it seems that the increases in muscle strength could be achieved in a short intervention period, suggesting the adaptation at the neural level of strength training [34] Secondly, if these adaptations were not evident, it was found that a six-week intervention could result in decreased pain level and increased functionality without alterations in muscle strength, possibly due to motor control [20] While not evaluated in this study, better motor control could promote a better/ more efficient locomotion with decreased pain in daily activities and, thus it may be one method to reduce the long-term symptoms of PFP, leading to a better quality of life for these individuals [20]. A key-point of the present data was that a conventional intervention focused on knee strengthening and flexibility seems essential for the positive effects on PFP women, even in a short-term period.

Regarding EMS/CG group, the present study revealed that the combined intervention showed similar patterns of alteration after six weeks despite the additional stimulus of the EMS. Both groups have shown decreases in pain levels and increases in functionality, pointing out the effectiveness of similar intervention programs. These findings are consistent with previous results, leading to the conclusion that strengthening is an effective training stimulus to improve PFP individuals' daily activities [35] Our results also indicated the coactive interaction between conventional training and EMS training. Despite both groups leading to improve functionality with lower pain, EMS/CG resulted in better improvements compared to the CG, assuming the more beneficial effect of EMS training on PFP women. These results agree with previous studies and expand our knowledge about the effects of EMS training on PFP individuals, showing that EMS could provoke better results compared to the conventional alone [20] This finding is also consistent with previous studies, showing positive effects of EMS training both in healthy [36], non-healthy individuals [37] and in post-operation rehabilitation [27]. Besides the benefits in muscle strength, the use of EMS training in healthy older persons led to improved speed gait and walking endurance after the first six weeks of intervention, while the dynamic balance improved after the seventh week [36]. Similarly, it was previously found that people with multiple sclerosis increase gait velocity, and walking endurance with the use of EMS in their rehabilitation process [37], suggesting the global influence of EMS [29]. It has been reported a possible global effect of the EMS training applied to the quadriceps muscle, leading to increases in hamstrings strength as well [27]. Additionally, EMS training was found to cause better improvements in the functional tests, supporting the idea of global EMS adaptations. Given the above, EMS intervention could cause improvements in pain levels and performance during locomotion in women with PFP.

Limitations

This study had some limitations. Firstly, a non-athletic women sample was recruited, the extrapolation of the present results for male or trained individuals with PFP requires caution. Secondly, the present experimental procedure did not include a follow-up period, thus it could not provide any data about the PFP recur. The present interventions are highly applicable to small space requirements and should be considered the strength of this study.

Conclusion

Significant differences were found in the pain level and functionality in women with PFP, who received rehabilitation with and without EMS. The EMS in conjunction with knee strengthening-based intervention is clinically applicable and it could be helpful in PFP treatment. Taken together, our data support the potential beneficial effect of EMS on knee strength and functionality in PFP individuals, supporting its use during the rehabilitation process.

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