

# NEUROMUSCULAR ELECTRIC STIMULATION IN PATELLOFEMORAL DYSFUNCTION: LITERATURE REVIEW

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## ABSTRACT

Patellofemoral dysfunction is a fairly common deficiency among young individuals that primarily affects females and may be characterized by pain, swelling and retropatellar crepitation. The purpose of this review of literature from the period between 2005 and 2011 was to systematize knowledge in relation to the increase in quadriceps muscle strength and pain relief in patients with patellofemoral dysfunction, using neuromuscular electrical stimulation and resistance exercises. The inclusion criteria were intervention articles from the past six years, in English, Spanish and Portuguese, which used muscle strengthening and neuromuscular electrical stimulation

for rehabilitation obtained through searches in the electronic databases Medline and Lilacs and in the Bireme library. The bibliographic search yielded 28 references, of which nine were excluded in accordance with the aims and inclusion criteria while 16 articles were selected for reading of the abstracts and subsequent analysis. Medium-frequency Neuromuscular Electrical Stimulation (NMES) can be used in association with resistance exercises as an adjuvant in the treatment of patellofemoral dysfunction (PFD), both to achieve muscle rebalance and for pain relief.

**Keywords:** Chondromalacia patellae. Knee. Quadriceps muscle.

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## INTRODUCTION

Internal knee joint problems are numerous and their consequences compromise the function and the quality of life of individuals.<sup>1</sup> Chondromalacia patellae is characterized by pain, edema and retropatellar crepitation,<sup>2</sup> and is produced by repeated abnormal compressive action on the articular cartilage. This abnormal compression is derived from the non-congruence and from the decrease of the patellofemoral joint contact area (PFJ) when a patellar subluxation or dislocation is caused by a poor anatomical or biomechanical relationship.<sup>3</sup> Freire *et al.*<sup>4</sup> report that the incidence of patellofemoral dysfunction increases according to the age bracket, with greater frequency in female patients with associated obesity. Other factors such as instability, fracture, patellar subluxation, increase of the quadriceps angle (Q angle), inefficient vastus medialis muscle, poor post-traumatic alignment, excessive lateral pressure syndrome and posterior cruciate ligament injury can increase the incidence. Belchior *et al.*<sup>5</sup> report that this pathology constitutes 25% of the injuries that compromise the knee and 5% of all sports injuries, which represents a common

complaint, in 20% of the population and mainly affects young females between 15 and 25 years of age.

A study conducted by Fonseca *et al.*<sup>6</sup> reports that the main factor that provokes patellofemoral dysfunction is abnormal lateral traction of the patella, due to a neuromuscular imbalance between the vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles; accordingly, muscle strengthening based on VMO and VL rebalancing could reduce discomfort in patients with Patellofemoral Pain Syndrome (PFPS), which corroborates the results of Cabral *et al.*,<sup>7</sup> where they demonstrated that treatment based on quadriceps strengthening enables an improvement of the signs and symptoms exhibited by patients.

"Russian electrical stimulation" arose in 1976 with the goal of obtaining greater muscle performance, through the use of a medium-frequency alternating current, with 2,500Hz, on elite athletes with the objective of achieving muscle strength gains of 30 to 40%.<sup>8-10</sup> Brill *et al.*<sup>11</sup> in his study with 15 healthy patients of both sexes, achieved gains of muscle strength and trophism by associating "Russian stimulation" with resistance exercises. A study carried out by Pelizzari *et al.*<sup>12</sup> demonstrated that the

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use of medium-frequency neuromuscular electrical stimulation (NMES) produced an increase in muscle mass in a dog with induced muscular atrophy. In a study conducted by Modli *et al.*<sup>13</sup>, the author informs that neuromuscular electrical stimulation has been used for many years in rehabilitation, especially in the treatment of denervated muscles, muscular atrophies or to increase muscle strength.

This study is vital, since the work to increase muscle strength interferes in knee instability, probably leading to a decrease in patellofemoral pain. The aim of the present study is to systematize knowledge about the use of neuromuscular electrical stimulation on the quadriceps associated with resistance exercises, to increase muscle strength and to reduce pain in patients with patellofemoral dysfunction.

## MATERIALS AND METHODS

This study consists of a narrative review of the literature from the period from 2005 to 2011. The first step was a bibliographical survey using the keywords: chondromalacia patellae, knee, quadriceps muscle and their correlated versions in English and Spanish in the databases Medline and Lilacs and in the Bireme library. For the reading selection of the abstracts we included intervention articles from the last six years, which used muscle strengthening and neuromuscular electrical stimulation for rehabilitation. At this point we excluded the literature review articles, articles from outside the 2005-2011 period and articles that presented other pathologies associated with chondromalacia. After the selection of the included abstracts the articles were read in full for the analysis.

## RESULTS

The bibliographic search yielded 28 references, obtained through the keywords patellofemoral dysfunction, knee, quadriceps muscle, neuromuscular electrical stimulation and their respective correlated versions in English. Nine references were excluded from this total according to the inclusion objectives and criteria and 16 articles were selected for reading of the abstracts. No studies were found in Spanish and the predominant methodology was that of controlled intervention articles. The searches indicated a larger number of publications in the year 2008. The information on the results found in the articles is summarily described in Table 1.

Indexed articles written in English and Portuguese were included in the review, with those addressing the effects of NMES and of muscle strengthening on patients with Patellofemoral Dysfunction (PFD) prevailing.

## DISCUSSION

The use of "Russian electrical stimulation" associated with resistance exercises in patients with patellofemoral dysfunction (PFD), products strength gains and consequently pain relief. Augusto *et al.*<sup>14</sup> verified that the intensity of muscle activation increases with the use of neuromuscular electrical stimulation (NMES), which makes it suitable in cases of PFD, since the greater incidence of this dysfunction is related to muscular imbalance, which corroborates the study by Bevilaqua-Grossi *et al.*,<sup>15</sup> where a difference is observed in the reflex activation time between the Vastus Medialis Obliquus (VMO) and Vastus

Lateralis Obliquus (VLO) muscles, both in healthy individuals and in patients with PFD. Santos *et al.*<sup>16</sup> compare the vastus medialis obliquus (VMO), vastus lateralis longus (VLL) and vastus lateralis obliquus muscle activation time during a walk on the treadmill with 27 individuals, 15 of whom were healthy and 12 had PFD. At the end of the study they observed a difference between VMO and VLL, where in the individuals with PFD the activation order started with VLL followed by VLO and finally VMO, while in the individuals without PFD the order was inverted, starting with VMO, followed by VLO and lastly VLL. This study shows that the imbalance between the lateral and medial musculature will predispose to the appearance of PFD. Cabral *et al.*<sup>17</sup>, through a controlled study, with a total of eight sessions, verified that open kinetic chain (OKC) and closed kinetic chain (CKC) exercises bring about important improvements in the main signs and symptoms presented by patients with PFD. Nakagawa *et al.*<sup>18</sup> conducted a study on 14 patients of both sexes with PFD. The intervention group (G1) performed additional strengthening of the hip abductors and lateral rotators associated with reinforcement of the quadriceps and the control group (G2) performed only quadriceps reinforcement. At the end of the study they ascertained that (G1) had achieved improvement in torque during knee extension, in the electromyographic activity of the gluteus medius and in the symptomatology of the pain perceived, while (G2) only achieved an improvement in torque for knee extension. Therefore, these studies show us the considerable importance of muscle strengthening in obtaining better balance between patella and femur, diminishing the degenerative processes and consequently the pain symptomatology.

Jennifer *et al.*<sup>19</sup> conducted a study with 19 women with PFD and noted that the strengthening at eight weeks of the proximal hip muscles improves knee stability, reducing pain and improving functional capacity.

Belchior *et al.*<sup>20</sup>, when comparing the difference between the quadriceps angle in 20 female individuals allocated in two groups, one with 10 symptomatic individuals and the other with 10 asymptomatic individuals, at two different times, first with the quadriceps relaxed then in maximum voluntary isometric contraction (MVIC), verified that the mean values of the Q angle for the asymptomatic individuals were 17.15° in relaxation and 14.5° in MVIC, while the symptomatic individuals presented 21.45° and 15.8°, respectively. These results show that in a state of relaxation there is a significant difference in the value of the Q angle between symptomatic and asymptomatic individuals and that this difference is not present in a state of maximum isometric contraction of the quadriceps muscle; accordingly, it is believed that this procedure, associated with exercise performed with the straight leg raise (SLR) will be able to minimize patellar malalignment.

Muscle imbalance is considered one of the risk factors for patellar malalignment.<sup>1</sup> Bevilaqua-Grossi *et al.*<sup>21</sup> assessed the electrical activity of the vastus medialis obliquus, vastus lateralis and vastus lateralis longus muscles at 45° and 60° of isometric flexion in 30 female patients (15 clinically healthy and 15 with patellofemoral pain syndrome), and it was noted that there was no difference in the muscle activation. Thus, it is believed that squatting exercises at the angulations studied provide balance between the medial and lateral portions of the dynamic patellar

**Table 1.** Methodological characteristics and evidence observed for determining the use of Neuromuscular Electrical Stimulation to gain strength and reduce pain in patients with patellofemoral dysfunction.

| Authors<br>Year of<br>publication          | Study design            | Study population/<br>Place  | Identification  | Results   | Discussion   | Remarks   |
|--|-------------------------|---|---|---|--|---|
| Jennifer et al. <sup>19</sup> ,<br>in 2011 | Intervention            | Nineteen women with PFD.  | An 8-week muscle strengthening program on women with PFD.   | Strengthening of the hip muscles, improves knee stability reducing pain and improving functional capacity.  | An 8-week rehabilitation program improves the neuromuscular control of the hip muscles and reduces PFD symptoms.   | Muscle strengthening is associated with improvement of PFD.   |
| Santos et al. <sup>16</sup> ,<br>in 2011   | Controlled intervention | Twenty-seven female individuals students from UFSCAR  | Fifteen without PFD and 12 presented PFD.   | There is a difference in hip muscle activation order in individuals with and without PFD.   | In individuals with PFD the activation order started with VLL followed by VLO and VMO, while in individuals without PFD the order was inverted, starting with VMO, followed by VLO and ending with VLL.  | This study shows that the imbalance between the lateral and medial muscles will predispose to the onset of PFD.   |
| Billot et al. <sup>27</sup> ,<br>2010      | Controlled intervention | Twenty soccer players, allocated in 2 groups. (G1) performed only soccer training while (G2) had soccer training plus electrical stimulation 3 times a week for 12 minutes. | Soccer players from Faculdade de Ciências do Esporte French Football Federation.  | There was an increase in eccentric torque in the third week (+ 11.5 +- 10.4%, p <0.01) and in the fifth week (22.1 +- 16.4% p <0.001). There was an increase in isometric contraction in the third and fifth weeks (16.3 +- 21.3, p <0.01 and 27.1 + - 22.6% p <0.001, respectively). | The results of the present study showed a smaller increase in strength than that observed previously in ice hockey players in eccentric conditions (12 vs. 24% in soccer players and ice hockey players, respectively).  | A 3-5 week NMES training program appears to improve strength and the specific functions of soccer in the preseason and during the season, and to lessen or eliminate the effects of detraining in injured athletes. |
| Duarte et al. <sup>23</sup> , 2009         | Controlled intervention | Thirty female patients who presented shortening of the ischiotibial muscles.  | Female academics, from Universidade Estadual de Goiás   | In relation to hip flexion in MID, the control group had a relative gain of 0.25 %, manual passive stretching achieved a relative gain of 29.65 %, stretching associated with NMES had a relative gain of 61.89 %.  | It is evidenced that the increase in the range of motion of a joint is only possible by means of the application of a program of planned and regular exercises, and the muscle stretching method associated with electrical stimulation offers advantages over the other methods.  | Despite the interesting results, it is suggested that new surveys be conducted with a larger sample, over longer periods of time, with individuals of both sexes and from different age brackets.                   |
| Bily et al. <sup>25</sup> ,<br>2008        | Controlled intervention | Thirty-eight patients with PFD (14 men and 24 women), divided into 2 groups. (G1) performed only exercises and (G2) Exercises + NMES  | Supervised home based treatment   | Both groups achieved a decrease in pain and an increase in the quadriceps torque, with no statistical difference between G1 and G2.   | The improvements observed in isometric conditions corroborated the work of Gondin et al., who observed a 15% increase in isometric maximum voluntary contraction of the quadriceps muscles after 4 weeks of NMES training that can be explained by the fact that the angular position during the NMES sessions was the same as the isometric test position (i.e., 60°) | Further investigations should address different aspects of training exercises, including measures to discover potential neurophysiological effects of exercise and EMS.   |
| Cabral et al. <sup>17</sup> ,<br>2008      | Controlled intervention | Twenty female patients with PFD (10 performed hip MS in OKC and 10 in CKC).   | Study carried out at the Clinical Physiotherapy Investigation and Electromyography Laboratory of the Department of Physiotherapy, Speech and Language Therapy and Occupational Therapy of FMUSP | The analysis of the demographic data did not evidence a statistically significant difference between the groups. G1 and G2 had a statistically significant difference P<0.05 in most of the variables after treatment.  | Sacco et al studied the misalignments of patients with PFS, obtaining results similar to this study before the treatment, and observed a decrease in the alterations after the treatment.  | The strengthening of the quadriceps muscle enabled improvements in the main signs and symptoms. Yet in relation to realignment of the lower limb, the treatments did not prove efficient.                           |

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**Table 1.** Methodological characteristics and evidence observed for determining the use of Neuromuscular Electrical Stimulation to gain strength and reduce pain in patients with patellofemoral dysfunction.

| Authors<br>Year of<br>publication                   | Study<br>delineation             | Study population/<br>Place  | Identification   | Results  | Discussion  | Remarks  |
|---|----------------------------------|---|--|--|---|--|
| Nakagawa<br>et al. <sup>18</sup> , 2008             | Blind controlled<br>intervention | Fourteen patients<br>(10 women and 4<br>men) diagnosed with<br>patellofemoral pain<br>syndrome.   | During the week one<br>session was held<br>at the rehabilitation<br>clinic and four<br>sessions at home.   | The intervention<br>group achieved an<br>improvement in torque<br>during knee extension,<br>in the electromyographic<br>activity of the gluteus<br>medius during maximum<br>isometric contraction and<br>in the symptomatology<br>of the pain perceived,<br>while the control group<br>achieved improvement<br>only in torque for knee<br>extension. | Recent studies have reported<br>significant losses in hip<br>abduction and in lateral<br>rotation strength, and suggest<br>that strengthening exercises<br>for the hip muscles may be<br>an important factor in pain<br>management.   | New surveys should<br>be carried out with<br>a larger sample and<br>a longer follow-up<br>period.  |
| Augusto<br>et al. <sup>14</sup> , 2008              | Blind controlled<br>intervention | Eighteen healthy<br>female volunteers,<br>with an analysis<br>of VMO vs. VL<br>activation, before and<br>after neuromuscular<br>electrical stimulation.                           | The study was<br>carried out on healthy<br>subjects at UFRN in<br>the Physiotherapy<br>Department  | The results showed an<br>increase in activation of<br>the VMO muscle from<br>458uV to 580uV after the<br>use of NMES.  | The literature states that one<br>of the factors for PFD is poor<br>patellar alignment. Bohannon et<br>al showed that NMES prevented<br>lateral dislocation of the patella.   | EENM has proven<br>itself to be an<br>important technique<br>in the treatment of<br>PFPS, providing this is<br>secondary to muscle<br>imbalance.   |
| Avila et al. <sup>24</sup> ,<br>2008                | Controlled<br>intervention       | Twenty healthy<br>students of both<br>sexes   | Study carried out at<br>the Laboratory of<br>Muscle Plasticity in<br>the Physiotherapy<br>Department<br>(UFSCar) and in<br>the Physiotherapy<br>Department of<br>(UFRN). | Men and women<br>increased their peak<br>torque in both limbs with<br>no difference between<br>Ex and<br>Ex + NMES.  | The study showed that NMES<br>associated with concentric knee<br>exercises did not produce any<br>additional torque increase, in<br>comparison with only concentric<br>exercises in healthy men and<br>women.   | New studies should<br>be conducted with a<br>larger population and<br>different velocities.  |
| Pelizzari<br>et al. <sup>12</sup> , 2008            | Controlled<br>intervention       | Eight dogs with<br>induced muscular<br>atrophy  | Study carried out on<br>the dogs from the<br>Central Vivarium of<br>Universidade Federal<br>de Santa Maria   | As regards the<br>morphometry of the fibers<br>of the vastus lateralis<br>muscle, a higher value<br>was observed in the<br>treated group than in the<br>control group.   | It is suggested that the<br>presence of adipocytes on the<br>histology slides may explain<br>the increase in the perimeter,<br>when evaluated in this manner,<br>making this method subjective.   | Medium-frequency<br>NMES produces gain<br>of muscle mass in dog<br>with induced muscular<br>atrophy.   |
| Santos<br>et al. <sup>16</sup> , 2008               | Controlled<br>intervention       | Twenty sedentary<br>women, divided into 2<br>groups, where group<br>(A) received only<br>passive electrical<br>stimulation, while<br>group (B) performed<br>resistance exercises. | Voluntary, right-<br>handed, sedentary<br>women in Maceió, in<br>the state of Alagoas  | Group A did not<br>achieve a significant<br>increase in strength or<br>in the perimeter of the<br>quadriceps muscles,<br>while group B achieved a<br>significant increase in the<br>strength and perimeter of<br>the quadriceps.   | The study showed that the<br>resistance exercise of flexo-<br>extension of the knees is<br>effective in promoting an<br>improvement in muscle mass<br>and strength, contrary to<br>electrical stimulation using an<br>apparatus for domestic use,<br>which did not achieve the same<br>results. | The results suggest<br>that electrical<br>stimulation could<br>have been effective<br>in increasing muscle<br>strength measured by<br>the dynamometer if the<br>numbers of sessions<br>had been increased. |
| Bevilaqua-<br>Grossi<br>et al. <sup>15</sup> , 2008 | Controlled<br>intervention       | Twenty-four<br>sedentary female<br>patients, 12 healthy<br>(control) and 12 with<br>PFPS, where the<br>reflex response time<br>of VMO, VLO and<br>VLL was evaluated.              | Study carried out<br>at the FMRP-USP,<br>Campus Universitário.   | There was no difference<br>between healthy<br>individuals and those<br>with PFPS, yet there was<br>a significant difference<br>between VLO and VMO<br>activation times.  | In the discussion the authors<br>mention that in the individuals<br>with PFPS, the VL muscle<br>presents a shorter reflex<br>response time than the VMO<br>muscle.  | No decision can be<br>made on a basis of the<br>reflex response time,<br>since both healthy<br>individuals and those<br>with PFPS exhibit an<br>imbalance between<br>VMO and VLO.                          |

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**Table 1.** Methodological characteristics and evidence observed for determining the use of Neuromuscular Electrical Stimulation to gain strength and reduce pain in patients with patellofemoral dysfunction.

| Authors<br>Year of<br>publication            | Study<br>delineation    | Study population/<br>Place   | Identification   | Results  | Discussion   | Remarks   |
|--|-------------------------|--|--|--|--|---|
| Matheus et al. <sup>10</sup> , 2007          | Controlled intervention | Sixty female rats, divided into 6 groups. G1 – control, G2 – electrically stimulated, G3 – immobilized in shortened position, G4 – immobilized in stretched position, G5 – immobilized in shortened position and electrically stimulated G6 – immobilized in stretched position and electrically stimulated. | Carried out at the Vivarium of the Bioengineering Laboratory of FMRP-USP.  | Results of the ALP (stretching at the limit of proportionality) Significant differences were observed between G1 and the immobilized groups; in comparing G3 and G5, significant differences were also observed. Results of the CLP – carga no limite de proporcionalidade (load at the limit of proportionality) Significant differences were observed between groups G1 and G2 and the immobilized groups; in comparing groups G3 and G5 it was also possible to observe significant differences, which did not occur between G4 and G6. | In this study, just as in the study by Järvinen et al, the gastrocnemius muscles immobilized in shortened position (SP) had a greater reduction of the properties than those immobilized in a lengthened position (LP).  | The study suggests that the immobilization of the muscles in a stretched position delays the atrophy process and that electrical stimulation, carried out during immobilization, contributes to the prevention of mechanical properties during the immobilization period. |
| Silva et al. <sup>12</sup> , 2007            | Controlled intervention | Nine male individuals who had been practicing bodybuilding for more than 2 years, 5 of whom were from the Special Operations Battalion and 4 frequented a gym).  | Carried out at the Special Operations Battalion (BOE) of Passo Fundo, Rio Grande do Sul and at a fitness center from the south side of Porto Alegre. | The group that associated strength training with NMES achieved a significant increase in strength and in the thigh perimeter when compared with the group that performed only exercises.   | Grillo et al inform that many protocols used in electrical stimulation programs contain discrepancies. Alonso et al reports that the application of NMES on the thigh muscles produces an increase in muscle strength as well as an increase in the thigh perimeter. | It was verified that the application of neuromuscular electrical stimulation is an efficient method to assist in muscle strengthening. However, further studies are necessary.  |
| Belchior et al. <sup>20</sup> , 2006         | Controlled intervention | Twenty female individuals (10 symptomatic and 10 asymptomatic) where a difference was observed in the quadriceps angle of these 2 groups.  |  | The mean values of the Q angle for the asymptomatic subjects were 17.15° in relaxation and 14.5° in MVIC, while the symptomatic subjects presented 21.45° and 15.8° respectively.  | Keeping track of the analysis of results, it is possible to visualize the difference in magnitude of the Q angle between symptomatic and asymptomatic individuals, in a state of relaxation (p = 0.004).   | It is believed that Maximum Voluntary Isometric Contraction (MVIC), associated with exercise performed with Straight Leg Raise (SLR), might minimize poor patellar alignment.   |
| Bevilaqua-Grossi et al. <sup>21</sup> , 2005 | Controlled intervention | Thirty female patients (15 clinically normal and 15 with patellofemoral pain syndrome)   | The study was conducted at FMRP-USP, Campus Universitário  | The control group at 45° obtained greater electromyographic activity of the VLL muscle when compared with VMO and VLO. At 60° there was no difference. In the group with PFPS, during the exercises at 45° and 60° no difference was obtained between VMO, VLO and VL.   | Isometric exercises at an angle of 45° and 60° activate equally the musculature, vastus medialis obliquus, vastus lateralis and vastus lateralis obliquus.   | New studies should be carried out to compare the electrical activity of the VMO, VLL and VLO muscles so as to favour the preparation of physiotherapy protocols.  |

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stabilizers, particularly in patients with PFD, and that they can be indicated during the rehabilitation program.

The association of NMES with resistance exercise demonstrates significant results in the recovery of individuals with PFD. Silva *et al.*<sup>22</sup> conducted a study with nine male individuals for eight weeks, comparing the effects of the use of neuromuscular electrical stimulation associated with strength training with exercise for lower limbs with leg press and leg extension machine, verifying greater effectiveness with the strength training associated with electrical stimulation, making this method more efficient as a muscle strengthening aid, both for aesthetic purposes and for rehabilitation of the lower limbs.

Duarte *et al.*<sup>23</sup> conducted a study on the effect of stretching of the ischiotibial muscles associated with neuromuscular electrical stimulation for gain of hip flexion. At the end of the treatment they ascertained that there was no significant increase in the range of motion in the control group and in comparing the (G2) group that performed passive stretching with (G3) which performed passive stretching associated with Russian electrical stimulation, concluded that G3 contributed to a greater increase in the range of motion of hip flexion. This result suggests that in a patellofemoral dysfunction caused by muscle shortening, "Russian electrical stimulation" can be an adjuvant therapeutic resource in this treatment.

Avila *et al.*<sup>24</sup> verified the effect of neuromuscular electrical stimulation associated with an isokinetic training program (Ex) with a dynamometer in men and women. At the end of the study they noted that both genders increased their peak torque, with no difference between Ex and Ex + NMES, and asserted that NMES associated with eccentric quadriceps contraction does not obtain any additional advantage in torque over isolated eccentric contraction. While Bily *et al.*<sup>25</sup> conducted a study for a year with 38 patients diagnosed with PFD allocated in two groups. (G1) performed just exercises and (G2) exercises + NMES at 40 Hz. At the end they observed a decrease in pain and an increase in the quadriceps torque in both groups, with no statistically significant difference between G1 and G2. These results may be a result of the frequency used, since 50Hz could show a better result as it selects in a proportional manner both the phasic and tonic fibers and due to the longer follow-up, during which neural adaptation may have occurred. Santos *et al.*<sup>26</sup> with the intention of observing muscle conditioning, carried out a study comparing passive home based electrical

stimulation versus resistance exercises. However, their results showed that the group that performed passive electrical stimulation did not obtain a significant increase in strength or in the perimeter of the quadriceps muscles, while, on the other hand, the group that performed resistance exercises obtained a significant increase in the strength and in the perimeter of the quadriceps. It is believed that electrical stimulation only has its effects potentiated for gain of strength when associated with resistance exercises.

Pelizzari *et al.*<sup>12</sup> conducted a study with eight dogs where they proposed to observe the effect of NMES on induced atrophy of the quadriceps, and at the end of the study observed that NMES associated with activities provides an increase in muscle mass in dogs with induced muscular atrophy. In a study conducted with 20 soccer players, by Billot *et al.*,<sup>27</sup> they ascertained that the electrical stimulation of the quadriceps associated with training (isometric, concentric and eccentric), results in better muscle strength, a better concentric torque and a better kicking speed. These results also suggest that NMES can be used for injured athletes to decrease or eliminate the effects of detraining.

Matheus *et al.*,<sup>10</sup> aiming to verify the effects of NMES on muscular atrophy, conducted a study with 60 rats to analyze the effects of neuromuscular electrical stimulation during immobilization of the gastrocnemius muscle in lengthening and shortening positions and after analyzing the results of the study, noticed that the lengthened immobilization of the muscles delays the atrophy process and that the electrical stimulation performed during this period will contribute to the prevention of the mechanical properties. A possible explanation for the effects of NMES on muscular atrophy in humans lies in the presence of the distancing of the sarcomeres associated with stimulation of the motor units that lead to a delay in atrophy.

## FINAL CONSIDERATIONS

The result of this review allows us to observe that when PFD is caused by muscular imbalance, the use of medium-frequency NMES can be associated with resistance exercises as an adjuvant in the treatment; both to achieve muscle rebalance as for pain relief. Moreover, it can be used both for muscle strengthening and for aesthetics. Finally, it is necessary to conduct further intervention studies for a better understanding of this type of therapy.

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