RELATION BETWEEN FEMORAL NERVE CONDUCTION VELOCITY AND ITS MECHANOSENSITIVITY CHANGES AMONG INDIVIDUALS WITH PATELLOFEMORAL PAIN SYNDROME

Ramez fady fahim¹, Abdelrahman Chabara², Mohamed ezzat mohamed shalby³, Nabil abdo Abdellah mohamed⁴
¹Bsc.In physical therapy Cairo University
²Prof. Dr. of physical therapy for musculoskeletal Disorder and Its Surgery Faculty of Physical Therapy CairoUniversity
³⁴Lecturer of Physical Therapy for Musculoskeletal Disorder and Its Surgery Faculty of physical Therapy Cairo University

ABSTRACT

Background: Patellofemoral pain syndrome (PFPS) is the anterior or retro patellar painthat can be precipitated by some daily activities such as ascending and descending stairs, kneeling, squatting or performing everyday tasks and is a multifactorial condition.

Objective to investigate the relationship between nerve conduction velocity of femoral nerve and its mechanosensitivity changes such as (limited hip extension range of motion(ROM) & pain) in patients with PFPS

Methods: Thirty symptomatic individuals with PFPS and 30 healthy individuals as a control group were assessed through sensory surface nerve conduction velocity of femoral nerve and measuring the hip extension (ROM) with the level of pain on Numeric rating scale (NRS) during femoral slump test.

Main Outcome measures: All of the participants in both groups were underwent the sensory conduction test (Peak Latency and conduction velocity) and the femoral slump test (Hip extension ROM & pain level on NRS).

Results: There were no significant difference between groups regarding hip extension ROM during femoral nerve slump test (p =0.57), while the pain associated with femoral nerve was higher in PFPS group than control group (p =0.000), also, femoral nerve velocity measured using EMG was lowered in PFPS group in comparison with healthy individuals while the initial latency was delayed and prolonged in PFPS than their controlcounter partners , (p =0.000), (p =0.000) There was a significant moderate negative correlation between NRS during femoral nerve slump test and hip ROM (p=0.007, r = -0.48), and femoral nerve velocity using EMG study (p=0.005, r = -0.502). There was a significant moderate positive correlation between NRS during femoral nerve slump test and femoral nerve latency using EMG study (p=0.003, r = 0.523)

Conclusion: There is a significant difference in femoral nerve mechanosensitivity among individuals with PFPS. Also there was a significant difference in conduction velocity of the femoral neve among individuals with PFPS compared to control group and There wasas significant moderate negative correlation between NRS during femoral nerve slump test and hip ROM, and femoral nerve velocity using EMG study. As well rehabilitation programs for those with PFPS should include neurodynamic techniques for femoral nerveor (femoral nerve gliding). Finally femoral NCV may be used as a gold standard method for assessing femoral nerve mechano-sensitivity changes in those with resistant PFPS.

KEY WARDs: PFPS, Electromyography, mechanosensitivity, nerve conduction velocity studies, neurodynamic testing, Femoral slump test, Numeric rating scale, femoral nerve gliding.
I. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is considered one of the most common conditions affecting young active populations, it accounts for about 40% of individuals complaining of knee pain (Smith et al., 2018). Individuals with PFPS can experience a history of cracking or popping sounds when changing position or climbing stairs and also experience pain during repeated knee flexion (Crossley et al., 2016). People with PFPS have a height socioeconomic load as it is estimated to account 29% between adolescents and 23% between general populations each year. Also, it is estimated that PFPS is more common among females than males by double chance (Smith et al., 2018).

The current management of the patellofemoral pain support using open- and closed-chain exercises, strengthening, stretching, aerobic exercise, patellofemoral and tibiofemoral mobilizations, patellar taping, high-intensity NMES, neuromuscular training, and gait retraining as a multimodal treatment for PFPS (Capin et al., 2018). Despite these methods result in significant improvement, other few patients reported some residual symptoms (Mason et al., 2011 & Heintjes et al., 2003).

Previous study showed that 56% of the participants reported a significant pain reduction and an improvement after six session of femoral nerve mobilization which support the effect of altered mechanosensitivity of femoral nerve on Patellofemoral joint (Huang et al., 2015). Femoral slump test can be used in examining the neurodynamic responses in individuals with anterior knee pain which has a specificity of more than 75% in testing neural mechanosensitivity (Lai et al., 2012).

In summary, there are a lack of studies in the current literature regarding the important role of femoral nerve mechanosensitivity in the development of Symptomatic patellofemoral pain syndrome.

The purpose of the study was to investigate the relationship between NCV of femoral nerve and other dependent variables such as (pain & limited hip extension ROM in femoral slump test) in patients with PFPS and compare that with a control group also, to examine the NCV as a method for assessment femoral nerve mechanosensitivity changes in those with PFPS.

II. MATERIALS AND METHODS

2.1 The participants

The participants in this case control observational study were 60 subjects (30 patients with unilateral PFPS and 30 healthy active individuals as a control group) who were between 18 and 35 years old. All were recruited from outpatients clinic at faculty of physical therapy Cairo university. All participants were informed about the process that would be conducted during the study and signed an informed consent form following standards of the institutional ethical committee for research involving human subjects. The study protocol was approved by Research Ethical Committee of the Faculty of Physical Therapy (NO: P. T. REC/012/002959) and registered at American Clinical Trial Registry. (The clinical trials.gov ID NCT04624542).

An interview and clinical examination were used to confirm fulfillment of the inclusion criteria.

The inclusion criteria were pain during patellar palpation. In addition, subjects needed to fulfill all of the following requirements to be included in the PFPS group: participant reported symptoms of insidious onset and duration of at least 1 month (de Oliveira et al., 2016) and had Peri- or retropatellar pain during at least 2 of the following activities: squatting, prolonged sitting, kneeling, running, jumping, and climbing stairs (Vegstein et al., 2019). Also, the worst pain level in the previous month of up to 3 cm on a 10 cm (NRS) (de Oliveira et al., 2016). Participants BMI was within 25-30 kg/cm2 (Nouri F et al., 2019). To be included in the control group participants could not present any signs or symptoms of PFPS or other musculoskeletal conditions. Participants who had an inflammatory process of lower limb (Lin et al., 2014) or patellar tendon or meniscus tears (Hung et al., 2015) or bursitis and ligament tears (Hung et al., 2015) or undergone knee surgery, oral steroids and knee injection were excluded from this study (Vegstein et al., 2019). Also who complained of lower back dysfunction (Lin et al., 2014) or had undergone physiotherapy during the previous 6 months (de Oliveira et al., 2016) were excluded from the study.

2.2 Instruments:

2.2.1 Surface Neuro-EMG-Micro machine with a separate computer
The device consists of Screen, keyboard, printer, computer processing unit (CPU) as shown in figure (1). Assessment of the femoral nerve conduction velocity was performed by a two-channel digital electromyogram device (Neuro-EMG-Micro, Neurosoft, Ivanovo, Russia) applied to the cutaneous femoral nerve (Patel, Anup, 2015) Recording electrodes (one active and one reference) were positioned parallel to the thigh with a distance of 2-4 cm between them, and the ground electrode was wrapped around any distal joint like the ankle joints or between both electrodes (Blando A. V. 1998). The skin overlying the thigh and ankle joint was cleaned carefully with alcohol. Then, the active electrodes were placed 2 cm medial to the anterior superior iliac spine (ASIS) superior to inguinal ligament (Roy P. C. 2011). And fixed by self-adhesive plastic. The impedance was checked after the positioning of the electrode to confirm that it was at an acceptable level (<2 kΩ) (Lee., Bach., & DeLisa., 1995).

2.2.2 Universal Goniometer:
Is a standard method of measuring the ROM of body joints and it is a very common and valid tools used by clinicians (Behnoush et al., 2016) due to its relatively easy to use, low cost and portability (Roach et al., 2013).

2.2.3 Numeric Rating scale (NRS):
Is one of the most commonly used pain scale in medicine and is a horizontal line with an eleven point numeric range from zero to 10 as illustrated in figure (2) (Alghadir, A. H. et al., 2018).

Figure (1): Surface electromyography system: (A) Screen, (B) printer, (C) key board, (D) Computer Processing unit, (E) Foot presser, (F) Amplifier. (Patel, Anup, 2015)

Figure 2: Numeric rating scale
2.3 Procedures:

2.3.1 Assessment of femoral nerve sensory conduction velocity

Examiner started by cleaning the area to be tested by alcohol and asked the subjects to remove excess hair to avoid poor recording and all of the participants were instructed to wear the shorts of their choice or clothing that would allow access to the targeted region then examiner fixed the recording electrodes over the anterior aspect of the thigh along the course of femoral nerve (Patel, Anup, 2015) as illustrated in figure (3) by adhesive plastic and wrapped the ground electrode around the distal ankle joint and the stimulating electrode above the inguinal ligament 2 cm medial to ASIS then the subject was asked to relax as much as possible then the examiner pressed on the foot pedal of EMG unit as illustrated in figure (1) then the wave was recorded. (Lee, Bach, & DeLisa, 1995).

(Figure 3): femoral nerve conduction study

2.3.2. Assessment of femoral nerve mechano sensitivity by femoral slump test (FST):

All participants underwent assessment of femoral nerve sensory conduction velocity and then we used the femoral slump test (FST) in a side lying position to examine the mechanical sensitivity of femoral nerve and the two components of FST were registered: 1) the degree of pain on NRS, 2) degree of hip extension at the onset of pain or discomfort.

- the participant was positioned in side-lying in his non tested limb and his lower leg flexed at hip and knee about 90 degree and stabilized by participant hands and his trunk was flexed and neck was neutral alignment as illustrated in figure(4) then the investigator was standing close to the level of pelvis of participant and holding participant examined leg by one hand and the other hold the universal goniometer with fixed arm directed toward lower leg and movable arm parallel to tested thigh. After that the investigator extend hip till participant reported pain or discomfort then the participant was asked about degree of pain and the hip extension ROM was measured.
2.4 Statistical analysis

Unpaired T test was conducted for comparison of subject characteristics (age, weight and height) between groups (PFPS and healthy individuals). Unpaired t test was conducted for comparison of dependent variables (pain intensity, hip extension ROM, femoral nerve velocity and latency) between groups (PFPS and healthy individuals).

Pearson correlation coefficient was conducted to investigate the correlation between pain intensity and hip extension ROM, femoral nerve velocity and latency in individuals with PFPS.

The level of significance for all statistical tests was set at p < 0.05. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

III. RESULTS

Subject characteristics in both groups:

Table 1 showed the subject characteristics of both groups (PFPS (A) and healthy group (B). There was no significant difference between groups regarding age (p= 0.51) and height (p=0.18). however there was a significant increase in the weight of affected individuals (group A) than healthy individuals (group B). (p=0.008)

Comparison of the mean of the dependent variables between PFPS group (A) and healthy group (B).

There was no significant difference between groups regarding hip extension ROM during femoral nerve slump test (p =0.57), while the pain associated with femoral nerve was increased in PFPS group than control group (p =0.000), also, femoral nerve velocity measured using EMG was decreased in PFPS group in comparison with healthy individuals while the initial latency was delayed and prolonged in PFPS than their control counter partners, (p =0.000), (p =0.000) (Table 1. Figure 5).

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional (21)</td>
<td>Bodyblade (21)</td>
</tr>
<tr>
<td>NRS</td>
<td>6.83 ± 1.15</td>
</tr>
</tbody>
</table>

Table 1. Comparison of the mean of dependent variables between group A and B
8.87 ± 0.73  14.37±0.72  -5.5  -29.4  0.57
Velocity (M/sec)  35.92±8.35  62.8±3.5  -26.8  -16.3  0.000*
Latency (msec)  5.44 ± 1.3  2.2 ± 0.52  3.2  12.7  0.000*

Correlation between NRS and other dependent variables (Hip ROM, femoral nerve velocity and latency) in individuals with PFPS

There was a significant moderate negative correlation between NRS during femoral nerve slump test and hip ROM (p=0.007, r = -0.48), and femoral nerve velocity using EMG study (p=0.005, r = -0.502). There was a significant moderate positive correlation between NRS during femoral nerve slump test and femoral nerve latency using EMG study (p=0.003, r = 0.523) as illustrated in Table (2) and Figure (6).

Table 2. Correlation between NRS and other dependent variables (Hip ROM, femoral nerve velocity and latency) in individuals with PFPS
<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>Numeric Rating scale</th>
<th>Hip extension ROM</th>
<th>Velocity</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>1</td>
<td>.096</td>
<td>.205</td>
<td>.210</td>
<td>-.320</td>
<td>-.241</td>
<td>.319</td>
</tr>
<tr>
<td>Sig</td>
<td>.612</td>
<td>.277</td>
<td>.266</td>
<td>.084</td>
<td>.199</td>
<td>.085</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Pearson</td>
<td>.096</td>
<td>1</td>
<td>.502**</td>
<td>-.030</td>
<td>-.147</td>
<td>.232</td>
<td>-.125</td>
</tr>
<tr>
<td>Weight</td>
<td>.612</td>
<td>.005</td>
<td>.874</td>
<td>.438</td>
<td>.218</td>
<td>.511</td>
<td></td>
</tr>
<tr>
<td>Sig</td>
<td>.30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Height</td>
<td>.205</td>
<td>.502**</td>
<td>1</td>
<td>-.060</td>
<td>.028</td>
<td>.201</td>
<td>.230</td>
</tr>
<tr>
<td>Pearson</td>
<td>.277</td>
<td>.005</td>
<td>.754</td>
<td>882</td>
<td>.286</td>
<td>.221</td>
<td></td>
</tr>
<tr>
<td>Sig</td>
<td>.30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Numeric Rating scale</td>
<td>.210</td>
<td>-.030</td>
<td>-.060</td>
<td>1</td>
<td>-.480**</td>
<td>-.502**</td>
<td>.523**</td>
</tr>
<tr>
<td>Velocity</td>
<td>.199</td>
<td>.218</td>
<td>.286</td>
<td>.005</td>
<td>.004</td>
<td>.004</td>
<td>.000</td>
</tr>
<tr>
<td>Sig</td>
<td>.30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Latency</td>
<td>.319</td>
<td>-.125</td>
<td>.230</td>
<td>.523**</td>
<td>-.339</td>
<td>-.638**</td>
<td>1</td>
</tr>
<tr>
<td>Pearson</td>
<td>.085</td>
<td>.511</td>
<td>.221</td>
<td>.003</td>
<td>.067</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Sig</td>
<td>.30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
* . Correlation is significant at the 0.05 level (2-tailed).

Figure (6): Correlation between NRS and hip ROM during femoral slump test, femoral nerve velocity and latency using EMG in PFPS individuals
Velocity

Figure (7): Correlation between NRS during femoral slump test and femoral nerve velocity using EMG in PFPS individuals

Latency

Figure (8): Correlation between NRS during femoral slump test and femoral nerve latency using EMG in PFPS individuals

Hip ROM

Figure (9): Correlation between NRS and Hip ROM during femoral slump test and femoral nerve latency using EMG in PFPS individuals
IV. DISCUSSION:

The purpose of the current study was to investigate how much sensory nerve conduction studies can help in identification of the femoral nerve mechanosensitivity changes among those with PFPS and detect the role of altered femoral nerve mechanosensitivity in the development of neurogenic PFPS in 60 participants (30 PFPS and 30 control group) regarding the characteristics of participants of both groups (PFPS A) and healthy control group (B). There was no significant difference between groups regarding age (p = 0.51) and height (p=0.18).however there was a significant increase in the weight of affected individuals (group A) than healthy individuals (group B). (p=0.008) which support the hypothesis reported by Ferreira etal.,2021 considering the body weight as predisposing factor of developing PFPS.

Nowadays the Alteration of pain processing and sensitization using Neuro- dynamic mobilization become a new trend in management of most of the musclo-skeletal disorders like ankle sprain, lateral epicondylitis (Yilmaz etal.,2020 & Ramalingam etal.,2018)and recently the PFPS. Some of previous literatures that was conducted by Hung et al .,(2015) tested the effectiveness of femoral nerve gliding techniques in relieving symptoms of PFPS especially among those with resisted neurogenic patellofemoral pain and had a positive reaction toward the femoral slump test. Not only the neural gliding techniques but also the different ways of modulating pain mechanisms are advised to be used with those suffering from chronic patellofemoral pain (Scafoglieri etal.,2021, Bartholomew etal.,2020& Sigmund etal.,2020).

The results of the current study showed that there were a significant increasing in the femoral nerve mechanosensitivity among participants with PFPS compared to control group through applying the femoral slump test as the PFPS group reported increasing pain with test compared to healthy participants (p =0.000)which support the results of previous literature reported by Lai etal., 2012 that argued the presence of pain among individuals with PFPS with FST and recommend using the FST in examining anterior knee pain but on the other way the measurement of hip extension range of motion (ROM) showed no significant difference in PFPS group compared with control group(p =0.57) which is considered contradictory with Lai etal 2012 study may this variance was due to low sample size in the Lai’s pilot study.

Throughout this study the femoral nerve conduction velocity measured by using EMG machine was decreased in PFPS group and showed significant difference in participants with PFPS compared to control group (p =0.000), also the latency showed a significant difference in PFPS group in comparison with the control group as the initial latency was delayed and prolonged in PFPS than their control counter partners.

On the other way our study supported the presence of a significant moderate negative correlation between NRS during femoral nerve slump test and hip ROM(p=0.007, r = -0.48), and femoral nerve velocity using EMG study (p=0.005, r = -0.502).Altogether these findings can be explained as an evidence for increased mechanosensitivity of the femoral nerve in participants with PFPS that support some of previous researches regarding the femoral nerve mechanosensitivity changes among individual with PFPS which reported as a findings in neurogenic PFPS (Lin etal.,2014,Lai etal.,2012,Jensen etal.,2008&Vegstein etal.,2019).

Regarding the sensory latencies of the sensory conduction studies many of pervious literatures confirmed that sensory latency help the clinicians to confirm a lot of the clinical diagnosis of nerve injuries especially as it facilitate the controlling mechanism of the confounding variables like temperature, height, age, and other patient-specific variability.(Srikanteswara etal.,2016)within the current study we found that there was a significant moderate positive correlation between NRS during femoral nerve slump test and femoral nerve latency using EMG study (p=0.003, r = 0.523)which support the presence of alteration with the femoral nerve mechanosensitivity.

Throughout this study the presence of moderate negative correlation between NRS during femoral nerve slump test and hip ROM (p=0.007, r = -0.48), and femoral nerve velocity using EMG study (p=0.005, r = -0.502). along with a significant moderate positive correlation between NRS during femoral nerve slump test and femoral nerve latency using EMG study (p=0.003, r = 0.523) may facilitate the upgrading of the clinical setting for introducing femoral NCV as a gold standard method for detecting the femoral nerve mechanosensitivity changes in those with neurogenic PFPS and encourage future researches about the neurogenic issue of PFPS as our study and other previous studies have supported the presence of neurogenic factor aggravating the PFPS.(Jensen etal., 2008, Jensen etal .,2007 & Morganti etal.,2002).
To our knowledge this case control observational study is the first one in clinical setting that tested the mechanosensitivity changes of femoral nerve among individuals with PFPS by using sensory femoral NCV which make a great interest for adding the femoral NCV as assessment tool in those with resisted neurogenic PFPS in clinical practice because only two of neurodynamic tests (prone knee bend&femoral slump test) were reported to be valid to assess the neurogenic PFPS (Lin et al., 2014 & Lai et al., 2012).

We recommend adding the femoral slump test as an important test for clinically examining patients complaining of anterior knee pain also introducing the femoralnerve conduction studies as an objective method of investigating nerve mechanosensitivity changes within individual with PFPS and physical therapy program for PFPS should including femoral nerve neurodynamics glidding as an intervention for those with PFPS finally we also suggest more future researches concerning femoral nerve mechanosensitivity and its relationship with the femoralnerve conduction studies.

We should not neglect the great efforts of previous literature in developing a new vision regarding the treatment and assessment of the neurogenic issue of PFPS thatstarted by developing a prospective explanation about the nature of anterior knee pain if it may be neuropathic or not that help us to think out of box regarding assessment and treatment of PFPS (Sanchis-Alfonso et al., 2016, Lin et al., 2014, Sanchis-Alfonso V.2014, Jensen et al.,2008,Jensen et al.,2007, Sanchis-Alfonso et al.,2001)

Limitation of the study:
The limitations of the current study were: 1.small sample size which may be due to the firm exclusion criteria 2.possible influence of over weight of some of the participants 3.may be the way of measuring hip extension was not accurate as it were measured by closed kinetic chain assessment.

V. CONCLUSION:
There is a significant difference in femoral nerve mechanosensitivity among individuals with PFPS., Also there was a significant difference in conduction velocity of the femoral neve among individuals with PFPS compared to control group and There was a significant moderate negative correlation between NRS during femoral nerve slump test and hip ROM, and femoral nerve velocity using EMG study. This is in addition to having a significant moderate positive correlation between NRS during femoral nerve slump test and femoral nerve latency using EMG study finally rehabilitation programs for those with PFPS should include neuro-dynamitechniques for femoral nerve or (femoral nerve gliding) as a treatment protocol. Also, femoral NCV may be used as a gold standard method for assessing femoral nerve mechanosensitivity changes in those with resistant PFPS

Conflict of interest: The author declare that no conflicts of interest.

REFERENCES
5. Smartphone and Universal Goniometer for Measurement of Elbow Joint Motions: A Comparative Study. Asian journal of sports medicine, 7(2)
7. de Oliveira Silva, D., Magalhães, F. H., Faria, N. C., Pazzinatto, M. F., Ferrari, D., Pappas, E., & de Azevedo, F.
30. Sigmund, K. J., Hoeger Bennet, M. K., & Earl-Boehm, J.
33. Srikanthswara, P. K., Cheluvaiah, J. D., Agadi, J. B., & Nagaraj,