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

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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 femoralnerve 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 amongindividuals 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 wasa significant moderate negative correlation between NRS during femoral nerve slump testand 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, neurodynamictesting, Femoral slump test, Numeric rating scale, femoral nerve gliding.

I. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is considered one of the most commonconditions 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 orclimbing stairs and also experience pain during repeated knee flexion (**Crossley etal., 2016).** People with PFPS have a height socioeconomic load as it is estimated toaccount 29%between adolescents and 23% between general populations each year. Also, it is estimated that PFPS is more common among females than males bydouble chance **(Smith et al., 2018).**

The current management of the patellofemoral pain support usingopen- 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 etal., 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 thedevelopment 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 60subjects (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 signedan informed consent form following standards of the institutional ethical committee for researches 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 confirmfulfillment of the inclusion criteria

The inclusion criteria were pain during patellar palpation. In addition, subjects needed to fulfill all of the following requirementsto be included in the PFPS group: participant reported symptoms ofinsidious 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 worstpain level in the previous month of up to 3cm on a 10cm (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 (**Vegsteinet al., 2019)** Also who complained of lower back dysfunction **(Lin etal., 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 bothelectrodes **(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 medialto 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)**

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

2.2.2 Universal Goniometer:

Is a standard method of measuring the ROM of body joints and it isa 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 10asillustrated in figure (2) (**Alghadir, A .H.et al .,2018)**

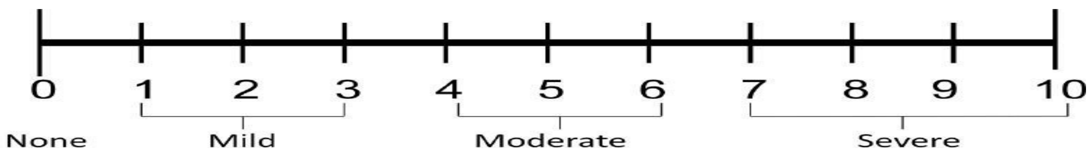

Figure 2: Numeric rating scale

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 subjectsto 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 toexamine 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 atthe onset of pain or discomfort.

- the participant was positioned in side-lying in his non tested limb and his lower legflexed 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.

Figure 4: femoral slump test

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 extensionROM, 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 latencyin individuals with PFPS.

The level of significance for all statistical tests was set at $p < 0.05$. All statisticalanalysis 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 ofaffected 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 extensionROM 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 1. Comparison of the mean of dependent variables between group Aand B

	Group A Traditional (21)	**Group B Bodyblade (21)**			
	x̄ ±SDx	̄ ±SD	**MD**	**t-value**	**p- value**
NRS	6.83 ± 1.15	0 ± 0	6.83	32.6	0.000*
Hip ROM(Degrees)					

	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*
Latencey (msec)	5.44 ± 1.3	2.2 ± 0.52	3.2	12.7	0.000*

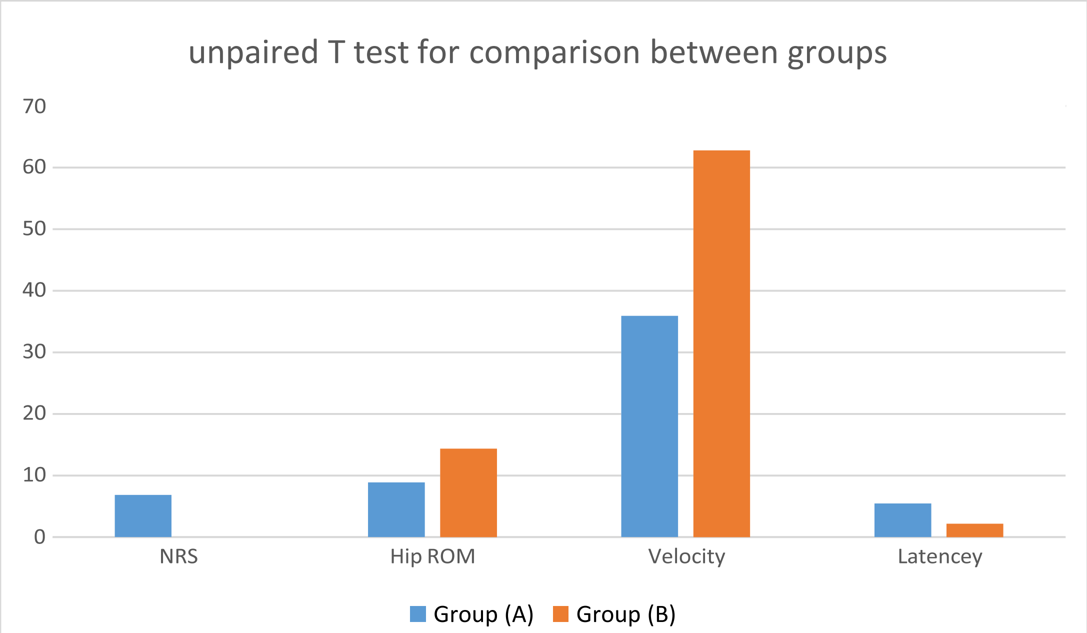

Figure (5): Comparison of dependent variables between groups

Correlation between NRS and other dependent variables (Hip ROM, femoralnerve 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) andFigure (6).**

Table 2. Correlation between NRS and other dependent variables (Hip ROM,femoral nerve velocity and latency) in individuals with PFPS

		Age	Weight	Height	Numeric Rating scale	Hip extension ROM	Velocity	Latency
	Pearson	1	.096	.205	.210	-.320	-.241	.319
Age	Sig		.612	.277	.266	.084	.199	.085
	N	30	30	30	30	30	30	30
	Pearson	.096	1	.502**	-.030	-.147	.232	-.125
Weight	Sig	.612		.005	.874	.438	.218	.511
	N	30	30	30	30	30	30	30
Height	Pearson	.205	.502**	1	-.060	.028	.201	.230
	Sig	.277	.005		.754	.882	.286	.221
	N	30	30	30	30	30	30	30
	Pearson	.210	-.030	-.060	1	-.480**	-.502**	.523**
Numeric Rating scale	Sig	.266	.874	.754		.007	.005	.003
	N	30	30	30	30	30	30	30
	Pearson	-.320	-.147	.028	-.480**	1	.506**	-.339
Hip extension ROM	Sig	.084	.438	.882	.007		.004	.067
	N	30	30	30	30	30	30	30
	Pearson	-.241	.232	.201	-.502**	.506**	1	-.638**
Velocity	Sig	.199	.218	.286	.005	.004		.000
	N	30	30	30	30	30	30	30
Latency	Pearson	.319	-.125	.230	.523**	-.339	-.638**	1
	Sig	.085	.511	.221	.003	.067	.000	
	N	30	30	30	30	30	30	30

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

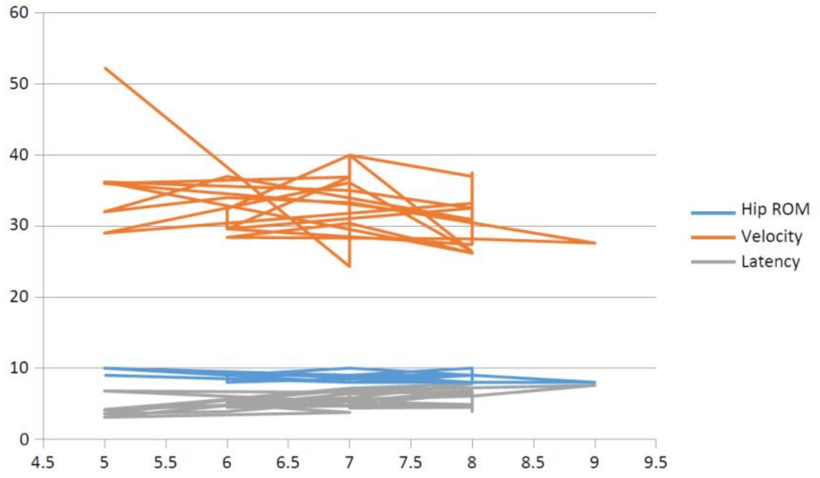

Figure (6): Correlation between NRS and hip ROM during femoral slump test, femoralnerve velocity and latency using EMG in PFPS individuals

Velocity

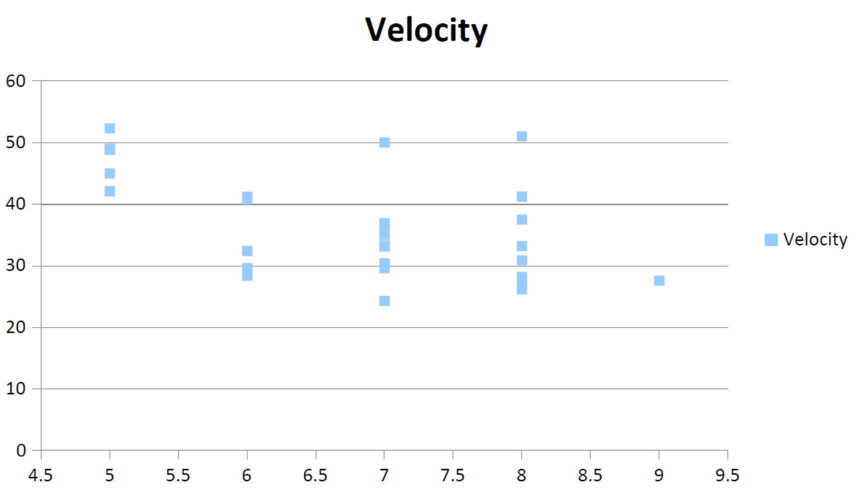

Figure (7): Correlation between NRS during femoral slump test and femoral nerve velocityusing EMG in PFPS individuals

Latency

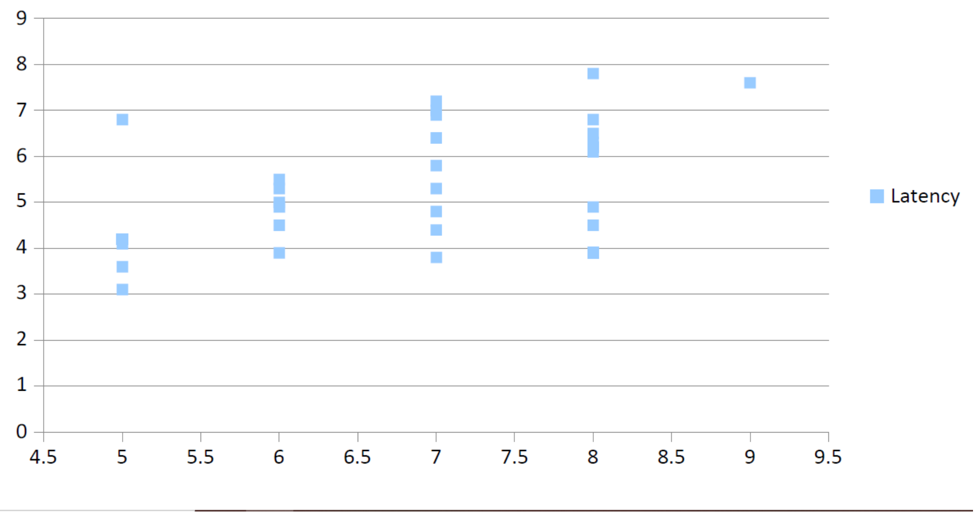

Figure (8): Correlation between NRS during femoral slump test and femoral nerve latencyusing EMG in PFPS individuals

Hip ROM

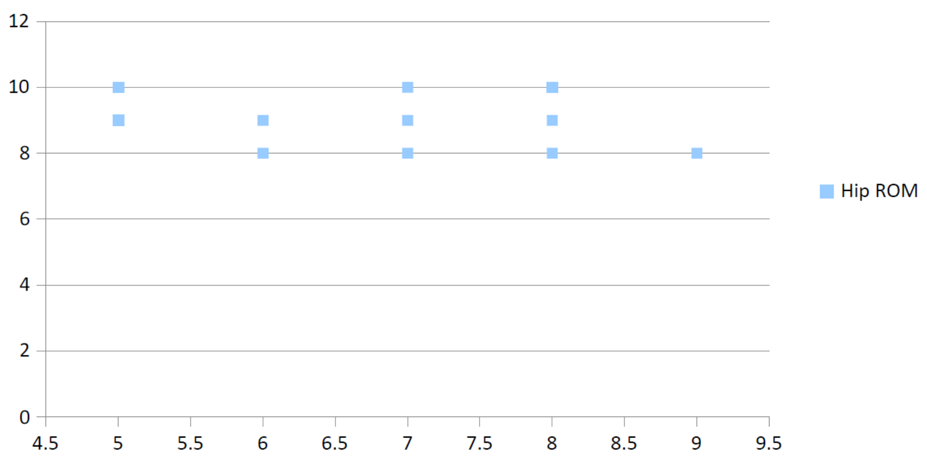

Figure (9): Correlation between NRS and Hip ROM during femoral slump test andfemoral nerve latency using EMG in PFPS individuals

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) thanhealthy 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 rtal.,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 et al., 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 inparticipants 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 injures especially as it facilitate the controllingmechanism 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 NRSduring 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 etal.,2016, Lin et al.,** 2014, Sanchis-Alfonso V.2014, Jensen etal.,2008,Jensen etal.,2007, Sanchis-Alfonso etal.,2001)

Limitation of the study:

The limitations of the current study were: 1.small sample size which may be due tothe 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 if wemeasured 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-dynamictechniques 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.

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