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The test-retest reliability of the onset of core and vasti electromyographic activity while ascending and descending stairs in healthy controls and patellofemoral pain patients

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Abstract

Background: Patellofemoral pain (PFP) is a common affliction and complex clinical entity. It is hypothesized to result from abnormal patellar tracking caused by altered motor control. Deficit in neuromotor control of the core may be a remote contributing factor to the development of PFP. Application of reliable EMG measures would be helpful to handle this theory. Therefore, the purpose of this study was to determine the test-retest reliability of the core and vasti EMG onsets, while ascending/descending stairs.

Methods: Ten males with PFP and ten healthy controls participated in this study. Vasti and Core EMG onsets during stair stepping were assessed two times a day. Intraclass correlation coefficients (ICCs) and standard errors of measurement (SEMs) were calculated.

Results: During both ascending/descending, high reliability was found for all EMG onsets of control cases (ICC 3,1 $\geq$ 0.70) except Quadratus Lumborum (QL) which showed a moderate reliability (ICC for ascending=0.59 and for descending = 0.61). In controls, Vasti in both tasks showed the highest absolute reliability. During ascending, high reliability (ICC $\geq$ 0.70) in PFP group was demonstrated for all EMG onsets except Gluteus maximus (GMAX) and QL which showed a moderate reliability (ICC = 0.69 and 0.63 respectively). In this group while descending stairs, all EMG onsets showed high relative reliability (ICC $\geq$ 0.70). Moderate to high absolute reliability was obtained for onset times while ascending/descending stairs in PFP group.

Conclusion: Most EMG onsets during stair ascending/descending had moderate to high reliability.

Keywords: Reliability, patellofemoral pain, core, EMG.

Introduction

Patellofemoral pain syndrome (PFPS) is a common affliction in both the athletic and general population especially where taking part in repetitive lower limb loading activities [1-3].

PFPS affects nearly one of four people in the general community and Dye et al. called this condition the ''Black Hole of Orthopedics'' because its etiology is not understood correctly [4,5].

Although, multiple factors affect the PEF development, maltracking of the patella is the most accepted hypothesis [6,7].

It is commonly accepted that patellar maltracking is related to deficit in the control of quadriceps muscle [8,9].

One proposed mechanism for decreased con-

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trol of this muscle is the delayed activity of vastus medialis obliquus (VMO) relative to the time of activation of vastus lateralis (VL) muscle [8-14].

Moreover, patellar tracking is the result of an interactive linkage between the local and remote passive structures, muscles and the neural control systems [2]. Recently, Donatelli and Wooden in their book emphasized on the role of neuromuscular training of lumbo-pelvic region and its effect on the lower quarter function[15].

Hence, it is of paramount importance that scientists and clinicians widen their attention to include the assessment of joints proximal and distal to the knee because of the closed chain nature of activities [16]. The pelvis and trunk stability is essential for movements of the extremities [17,18].

Pelvic obliquity or excessive anterior tilt may be a predisposing factor for knee injury or PFP [16,19-21].

Also it is demonstrated that excessive trunk displacement in frontal plane maybe a predictor of knee pathology or injury [22,23].

Significant reduction in PFP and improved lower extremity kinematics were reported after trainings which target hip, pelvis and trunk muscles [24].

Such findings put forward an idea that the knee may be a "victim of core instability"[16].

Maintenance of core stability is closely related to motor control mechanisms of the human nervous system.

Recent evidence indicates that poor neuromuscular control of trunk will affect other joints and predispose the subject to lower extremity injury [25].

Limited information exists regarding trunk motor control and neuromuscular activity of core muscles in the patellofemoral pain population.

Some researchers evaluated the activation timing of vasti and gluteals during stair stepping task in PFPS but their studies had conflicting results [2,26,27].

While Brindle et al. [28] and Cowan et al. [2] stated a greater delay in GM activation relative to the VMO and VL in subjects with PFPS, Boling et al. [29] did not confirm this finding.

Recently, Bolgla et al. [30] evaluated reproducibility of the EMG onset times of vasti and Gluteus medius muscles during stair descent, but reproducibility of onsets did not take into account while ascending stair.

Moreover, studies evaluated muscle activation timing focused more on vasti and gluteal muscles and less on other core (trunk) muscles.

During ascending and descending stairs, not only lower extremity muscles, but also core muscles are active and their role maybe very important for maintaining core stability and preventing lower extremity injury.

It is stated that PFP has a multifactorial nature and altered neuromotor control of the vasti (onset timing) may be only one of several components. Altered neuromotor control of the core muscles may be a remote contributing factor to the development of PFP. The evaluation of core muscle activation timing in PFP patients may help better understanding of its etiology and more effective treatment. Therefore, Electromyographic research in this field seems to be a necessity.

Validity is the extent to which an item actually measures and indicates the usefulness of research conclusions. If a test cannot provide reproducibility from trial to trial, then could never be considered valid. Because reliability is obviously a vital prerequisite for validity in any study reliability must be calculated. [31-33]

If EMG parameters are used for discriminative and evaluative purposes, then determining measurement error is a major concern.

Nonetheless, discern and systematic application of reliable EMG measures is vital for better understanding of core and knee neuromuscular activity in patients with PFPS.

Intrinsic and extrinsic factors along with variability of EMG signal are potential sources that may subject the EMG to measurement er-

rors [34].

Not only, technical and equipment errors but also learning and biological variance may lead to measurement error and these factors may influence EMG data between and within trials [35].

Assessment of intra-session reliability of muscles activation timing is of paramount importance for research settings and is helpful for clarification of changes over time in the same subject [36].

Even if electrodes replaced exactly at the previous position when EMG measurements of a same session are compared, the raised question is whether a subject muscle activation strategy remained persistent throughout a stair stepping task or not.

To our knowledge, no study has established measurement reliability of EMG onset timing of core muscles and vasti during stair stepping task, and there is a knowledge void in this field.

The purpose of this methodological study is to ascertain measurement reliability for assessment of vasti and core muscle onset times during stair stepping task.

Because the reliability is population dependent and not a fixed property [32], the results of each research can be generalized just to the same target population not other ones. Hence, we decided to evaluate reliability of onset times in both control and PFP groups in stair ascending and descending tasks.

Methods

Subjects: a sample of 10 males with PFPS and 10 healthy control subjects with identical age, sex, height, weight and body mass index (BMI) were recruited in this study. Demographic and functional characteristics of subjects are depicted in Table1. Participants in PFP group included if they had [29,37,38] retropatellar or anterior knee pain which exacerbated by at least two of the following provocative activities: prolonged sitting, stair stepping, squatting, running, kneeling, hopping and jumping. In addition they were to have a positive Zohler's and Clark's sign, patellar tenderness (symptoms for at least 1 month), Pain level of three or less on a 10-cm VAS, insidious onset of symptoms (none traumatic), at least grade 11 in FIQ (Functional Index Questionnaire), ability to do stair stepping task without touching hand rails, age≤40 (to reduce the likelihood of osteoarthritic changes), unilateral PFP, and BMI between 18.5 -24.9.

Subjects were excluded if they had [29,37] bilateral PFP, history of fracture, dislocation or surgery in lower extremity or trunk regions, history or clinical evidence of ligament sprain, meniscal defect, chondral lesion, apophysitis or pathology of patellar tendon, history or clinical evidence of low back pain (LBP) or sacroiliac joint (SIJ) dysfunction in last 6 months, osteoarthritis, significant faulty posture in lower extremity or trunk, systemic diseases such as diabetes and rheumatism, professional athletic activities, disc herniation or spinal referred pain and any other disorders which might interfere with the kinematics or kinetics of trunk, hip, knee and ankle motion.

The study was conducted in biomechanics laboratory of Rehabilitation Research Center, faculty of rehabilitation sciences of Tehran University of medical sciences (TUMS). All subjects signed an informed consent approved by Faculty of Rehabilitation Sciences Ethics Committee, TUMS.

Precedures: First, subjects completed the 10-cm VAS and FIQ describing their pain and knee function respectively.

Preparation of subjects' skin for electrode placement was done in a standard fashion [34,39].

EMG activity of vastus medialis obliqus (VMO), vastus lateralis (VL) , anterior gluteus medius (GM), gluteus maximus (GMAX), quadratus lumbarum (QL), erector spinae (ES) and internal oblique (IO) were recorded using surface (Ag-AgCl) electrodes with a center to

center distance of 20-mm .

The VMO electrode was placed over the muscle belly about 4 cm superior and 3 cm medial to the superomedial border of patella and oriented 55˚ to the vertical [40].

For the VL, electrode was placed nearly 10 cm superior and 6– 8 cm lateral to the superior patellar border and oriented 15˚ to the vertical [40].

The GM electrode was placed approximately 5 cm posterior to the anterior superior iliac spine and 3–4 cm below the iliac crest [1,2].

The GMAX electrode was placed at mid point of the line connecting greater trochanter to the inferior lateral angle of sacrum along muscle fibers (inferolaterally) [41].

The QL electrode was located 4cm lateral to the vertebral ridge or belly of the erector spinae muscle, and at a slightly oblique angle at half the distance between the 12th rib and the iliac crest [42].

The ES electrode was positioned on these muscles at the L4 level and parallel with spinal column plumb line [43].

The IO electrode was applied about 2 cm medial and inferior to the anterior superior iliac spine [44].

A ground electrode was also placed on the right wrist of the subjects.

Electrode placements were visually confirmed on monitor using manual muscle testing techniques.

An eight channel EMG system (MyoProbe, Kya L.t.d., Iran) recorded muscle activity during all tests.

A footswitch was connected to the EMG system to determine the time of foot-strike to the 1st step during stair stepping task. EMG onsets were determined relative to the foot contact [2].

The stairs had no hand rail with the following geometric specification:

I) The 1st stair (height = 20 cm, tread=30cm, width =80cm)

II) The 2nd stair [height = 20 cm, tread= 60cm, width =80cm)

Subjects were shown how to accomplish the stair-stepping task and allowed 3 practice trials for familiarization. Participants performed the stair stepping task as follows [2,4,45-47].

a) Stair stepping up: Participants stood facing a step, in quiet stance position, 20 cm away from the step edge, with their arms by their side and while their feet placed approximately shoulder width apart. They were instructed to step up (step over step) as quickly as possible in a self selected pace and in response to the alarm of X-note Stopwatch, version 1.5 (simple reaction-time task). The patients and control group were instructed to step up with involved leg and side matched leg respectively.

b) Stair stepping down: Participants stood on the top stair, in quiet stance position, 5 cm away from the step edge, with their arms by their side and while their feet placed approximately shoulder width apart. They were instructed to step down (step over step) as quickly as possible in self selected pace and in response to the alarm of X-note Stopwatch, version 1.5 (simple reaction-time task). The patients and control group were instructed to step down with involved leg and side matched leg respectively.

Data were collected for 3 steps up and down repetitions on the test leg. The mean of these three repetitions were used for the EMG onset analysis [1,48].

In order to prevent fatigue while repeating the test, a rest interval of 30 seconds was considered between trials [1,6,29,40].

In addition, to prevent systematic bias, the order of stepping up/down was determined randomly.

On the base of previous researches and articles related to fatigue which evaluated power spectrum of EMG, test -retest repeatability was assessed after 50 minutes for each subject [36, 48-50]

Retest was done with the same method as test session.

The EMG onset was determined visually as the point where EMG increased above the base-

line activity [2].

Finally, collected data were statistically analyzed to assess repeatability of trials.

Data processing: Electromyographic data, was sampled at 1000 Hz, and band-pass filtered between 25 and 500 Hz. The signals were low-pass filtered at 50 Hz (6th order butterworth filter) and then RMS smoothed with a time constant of 55 msec [11] and the onset times determined by Signapoint software (version 2008, Myosotic LLC).

Statistical analysis: The average of three trials of the EMG onsets measures in each condition (step up and step down) was applied for statistical analysis and assessment of reliability. Paired t-test on the difference of scores obtained at test and retest sessions, was used to determine the absence of systematic bias [51].

Based on the work of Shrout and Fleiss, we assessed relative reliability using two–way mixed model of interclass correlation coefficient, (ICC 3,1) [52].

On the basis of Munro's classification for reliability coefficients, we interpreted the degree of reliability. The ICC values were described as little if < 0.25 , low if ranging between 0.26 – 0.49, moderate if ranging between 0.50 – 0.69, high if ranging between 0.70 – 0.89 and very high if >0.90 [32].

Standard error of measurement (SEM) was calculated to assess absolute reliability [51] with Alpha set at 0.05 level. SPSS version 14 (SPSS Inc.) was used for statistical analysis.

Results

Because healthy and PFP groups were matched, hence were no significant differences ($p>0.05$) between both groups in age, weight, height and body mass index were found.

Table2 depicts the mean and S.D. of muscle activation timing variables obtained for test and retest sessions while ascending and descending stairs and Table 3 demonstrates ICC, its 95% CI and SEM values.

There was no significant difference between test and re-test mean scores for any onset timing measures, which indicates absence of any systematic bias ($p>0.05$).

In healthy controls, during stair ascending, high reliability was found for VMO, VL, GM, GMAX, IO and ES onset times with ICC levels of 0.73, 0.88, 0.85, 0.88, 0.89 and 0.87 respectively. Also, in this group, QL onset time showed a moderate reliability with ICC level of 0.59.

In the control group, during stair descending, high reliability was obtained for VMO, VL, GM, GMAX, IO and ES with ICC levels of 0.87, 0.83, 0.77, 0.84, 0.79 and 0.72 respectively. Consistent with ascending, QL showed a moderate reliability with the ICC level of 0.61.

The VMO and VL in both ascending and descending tasks showed the highest absolute reliability in healthy controls.

In PFP group during stair ascending, high reliability was demonstrated for VMO, VL, GM, IO and ES with ICC levels of 0.86, 0.73, 0.70, 0.74 and 0.86 respectively. The GMAX and QL showed a moderate reliability with ICC levels of 0.69 and 0.63 respectively in this task.

In this group while descending stairs, all muscle onset times showed high relative reliability with ICC levels of 0.84, 0.80, 0.78, 0.78, 0.76, 0.79 and 0.71 for VMO, VL, GM, GMAX, IO, ES and QL respectively.

Discussion

The results obtained show moderate to high relative reliability of EMG onset timing measures in stair stepping task in both control and PFP groups. This suggests that our measurement error was small and therefore there is a limited probability of type II error.

Many factors may affect reliability of EMG onset times. These include the statistical methods to establish reliability, the standardization of the task being tested and the methods of processing/analyzing the EMG data.

Table1. Demographic and functional characteristics of subjects.

	Control group(n=10)	PFP group(n=10)
	Mean(S.D)	Mean(S.D)
Age (year)	27.93 (6.90)	28.33(6.28)
Weight (kg)	69.66 (6.56)	69.13(6.20)
Height (m)	1.75 (0.05)	1.75(0.04)
Body Mass Index	22.55 (2.09)	22.37(2.25)
VAS	00. 00 (0.00)	2.06(0.79)
FIQ	16.00 (0.00)	12.86(1.30)

Some EMG studies did not describe the technique used to determine onset times [14,53], some used only computer based methods [28, 54,55] and some used only visual inspection to determine onset [2].

Nevertheless, it is stated that visual onset detection considered a reliable and is preferred method to mathematical algorithm since it is less affected by amplitude of background EMG [2].

The number of trials averaged and used for data analysis may affect reliability as well.

Greater number of trials may display less variability, but the factors affecting learning and fatigue must take into consideration.

It has been shown that both learning and fatigue can decrease the onset of anticipatory muscle activities [56,57].

It is difficult to compare the results of this study with previous investigations, because:

to our knowledge, this research is the first study which reported the reliability of EMG onset of core and vasti muscles in a stair stepping task.

Since, no other study evaluated the onset times of core muscles during stair stepping task, it is not possible to compare the current results to those of others.

Some previous studies which evaluated the onset times during stair stepping task did not report measurement reliability in their papers [1,28].

Most of these studies did not evaluate or report vasti and gluteus medius onset times and their reliability in both healthy and PFP groups in ascending/descending tasks.

Previous studies usually evaluated the reliability of relative differences of muscle onset times [6,8,30,37].

In one study, Cowan et al. [40], reported the between-day reliability of the onset of vasti in rock and rise tasks in healthy subjects. They reported an acceptable reliability in rock and rise tasks (ICC=0.30-0.84 and SEM=34.21-40.83). In our study, higher reliability of the onset of vasti was obtained in the healthy control group (ICC=0.73-0.88 and SEM=6.70-17.77).One of the reasons for differences in results might be the nature of tasks, (rock/rise task versus step up/down) and other differences maybe the interval between test and retest times. (Within day reliability versus between day reliability)

One study which considered the reliability of onset times, in both stair ascending/descending tasks in healthy and PFP group [29], just reported intra-rater reliability of onset times for PFP group.

Boling et al [29]reported intra-rater reliability of gluteus medius onset ± SEM for ascent and descent phase of stair stepping task as 0.41± 42.56 and 0.65±34.75 msec respectively.

In our study we obtained test-retest reliability of gluteus medius onset ± SEM for ascent and descent phase of stair stepping task in the con-

Table 2. Descriptive data for EMG measures of timing while ascending and descending stairs (n=20).

	Healthy controls				PFP group			
Onset	Stair ascending		Stair descending		Stair ascending		Stair descending	
	Test mean (S.D.)	Retest mean(S.D.)	Test mean (S.D.)	Retest mean(S.D.)	Test mean(S.D.)	Retest mean(S.D.)	Test mean (S.D.)	Retest mean(S.D.)
VMO	-114.700 (13.450)	-112.033(9.290)	-211.844(61.173)	-190.377(50.642)	-89.399(38.041)	-77.499(38.462)	-151.200(67.149)	-133.288(40.588)
VL	-102.166 (20.034)	-102.666(22.567)	-182.844(43.104)	-165.066(43.415)	-106.767(38.389)	-93.695(61.018)	-126.178(53.183)	-105.822(58.042)
GM	-87.266 (85.677)	-75.266(104.886)	-123.200(57.177)	-105.800(27.744)	15.600(35.890)	42.733(64.626)	-30.266(58.373)	-11.199(31.918)
GMAX	-90.600 (87.876)	-77.666(69.862)	-152.000(68.293)	-141.999(66.717)	4.133(32.039)	15.533(24.639)	-93.266(46.425)	-84.266(26.958)
IO	-236.200 (99.462)	-216.333(154.334)	-371.200(72.114)	-342.577(70.379)	-156.508(49.098)	-133.600(50.338)	-271.067(66.286)	-256.755(53.488)
ES	-128.533 (98.978)	-110.267(113.941)	-317.667(97.915)	-300.488(95.159)	-107.00(92.384)	-84.955(71.550)	-227.333(65.984)	-206.977(61.734)
QL	-142.933 (55.171)	-124.622(59.362)	-123.267(75.743)	-103.911(65.511)	-75.466(56.969)	-72.977(52.847)	-60.600(52.757)	-53.844(82.691)

trol group as 0.85±33.07 and 0.77± 27.30 msec respectively.

In PFP group test-retest reliability was 0.70±19.38 and 0.78±26.81 for ascending and descending stairs respectively.

One reason for differences between results may be due to variability of EMG signals. Standard deviations of EMG onsets in Boling et al. study were more than our study which may have decreased the ICC and increased their SEM.

Also, the ICC model used may be another factor affecting reliability of results. In our study we used (ICC 3,1) but Boling et al. used (ICC 2,1).

Various researchers used different step heights, different speed of task accomplishment, static or dynamic starting point which all may affect onset times.

Starting the stair stepping task from quite stance (static) or from a walking condition (dynamic) may also affect onset times. In our study, subjects started the stair stepping task from a static position rather than a dynamic position. In contrast to Cowan et al [1,2,6,8,37, 40,58-61] and our study, Boling et al [29] used a dynamic starting position that the subjects walked toward the step. This may be another cause of differences between our reliability measures and Boling's.

One of the advantages of our study is the fact that both normal and PFP subjects were participated in both stair ascending/descending tasks. This increases our ability to generalize the findings not only to both groups but also both tasks.

High reliability in this study may be due to several factors. Standardization of electrode placement in test and retest parts of this study may lead to increased probability of sampling from the same group or groups of motor units. This has been highlighted in previous studies [37,39,62].

To prevent signal cross talk, electrodes were placed over the center of muscle belly. It has been stated that when electrodes located over the center of muscle belly and in parallel with muscle fibers, EMG signal is more reliable [37,39,62,63].

The method of signaling the subject to start the stair stepping task must be the same across trials and conditions because it may effect on motor control and the response timing of the subjects [64] and can change reliability of the study.

In some studies a verbal command was used in order to signal the subject to start the task. For example the Brindle in his study [28] instructed the subjects to start the task after the verbal command, "ready, set, go."

The vocal characteristics (e.g. stress, loudness, etc.) of issuing a verbal command may be different between each record. This may be a source of variation in onset time measurements. To solve this problem, we used a software gen-

Table 3. Reliability analysis of EMG measures of timing while ascending and descending stairs (n=20).

Onset time	Healthy controls						PFP group					
	Stair ascending			Stair descending			Stair ascending			Stair descending		
	ICC(0.95%CI)	p	SEM	ICC(0.95%CI)	p	SEM	ICC(0.95%CI)	p	SEM	ICC(0.95%CI)	p	SEM
VMO onset	0.73(0.22 0.91)	0.025	6.94	0.87(0.54 0.96)	0.019	21.27	0.86(0.59 0.95)	0.037	13.92	0.84(0.53 0.94)	0.011	33.46
VL onset	0.88(0.66 0.96)	0.031	6.70	0.83(0.43 0.94)	0.025	17.77	0.73(0.22 0.90)	0.023	19.94	0.80(0.44 0.93)	0.022	23.39
GM onset	0.85(0.55 0.95)	0.017	33.07	0.77(0.33 0.92)	0.036	27.30	0.70(0.04 0.88)	0.035	19.38	0.78(0.36 0.92)	0.030	26.81
GMAX onset	0.88(0.67 0.96)	0.034	29.53	0.84(0.53 0.94)	0.018	27.31	0.69(0.13 0.89)	0.011	17.83	0.78(0.38 0.92)	0.041	21.47
IO onset	0.89(0.69 0.96)	0.043	32.82	0.79(0.41 0.93)	0.034	32.44	0.74(0.27 0.91)	0.026	24.54	0.76(0.33 0.92)	0.027	31.92
ES onset	0.87(0.63 0.95)	0.039	35.62	0.72(0.15 0.90)	0.040	50.91	0.86(0.59 0.95)	0.035	34.44	0.79(0.41 0.93)	0.044	29.69
QL onset	0.59(-0.17 0.86)	0.048	35.30	0.61(-0.16 0.87)	0.032	46.95	0.63(-0.13 0.88)	0.024	29.04	0.71(0.11 0.90)	0.036	27.95

erated sound that was the same across all tests and conditions.

Cowan et al [1,2] solved this problem by signaling the subjects using visual feedback (visual choice reaction time task).

In some studies which evaluated the EMG signals during stair stepping task, the subjects had to step up/down the stairs in a standardized rate of 96 step/min but some studies used a self selected pace.

Brindle et al [28] showed a delayed GM activity during stair descent for subjects with PFPS. Conversely, Boling et al [29] did not confirm this finding. Bolga et al. [30] reported delayed GM activation and stated that these conflicting results are due to different cadences.

Although, we used a self selected pace in methodology, our findings showed a delay in activation of gluteus medius in PFPS. Cowan et al [2] also used a self selected paced methodology and their findings supports our results. Therefore, other factors may be related to these conflicting results.

Because different methodologies were used in previous works and there is no standard method to perform the stair stepping task and signal analysis, complementary studies are necessary for this field in the future.

In fact, more control over the test conditions results in less generalizable findings.

Based on this study, the kinematics and pattern of motion in stair stepping may be a source of variability of onset times and affect reliability; for example some cases first contact their forefoot to the step and then their heels and some others vice versa. Future studies may answer this question.

Certainly, this study has its own limitations. In our study, only one examiner measured, processed and analyzed the EMG data; therefore, our findings may only be applicable to single examiner (intra-rater reliability) studies and is not suitable for studies evaluating reliability with more than one examiner (inter-rater reliability).

Another possible limitation associated with our study, may be the presence of cross talk, when recording EMG from QL muscle.

Because QL is a deep muscle, recording its signals by surface electrodes maybe contaminated with crosstalk from other muscles such as Paravertebral and Latissimus dorsi. This might explain the moderate reliability of QL onset time, while ascending/descending stairs (0.59 and 0.61 respectively) in control group.

Although, we applied surface electrodes for detecting QL signal based on the work of Cynn et al and McGill et al [42,65], our findings sug-

gest that application of surface electrodes may not be appropriate for recording QL signal.

Moreover, this confliction may be due to task dependent activity of QL, which acts differently during stair stepping task.

Future studies, using needle electrodes may provide higher reliability and help better understanding of the function and neural control of this muscle in a stair stepping task.

These findings have important applications for both clinicians and researchers. Reliable determination of the motor control of core and vasti muscles in a stair stepping task might help clinicians to realize abnormal or compensatory strategies that may be unique to individuals with PFP and increase the efficacy of rehabilitation.

Conclusion

Results of this study showed acceptable within-day reliability for most of the EMG onset times; therefore the onset time measurement maybe applicable in evaluation of motor control and treatment of PFPS. It is unknown if similar ICCs would be obtained using other methodologies. Application of more standardized techniques in future studies might provide higher reliability and more conclusive data, about core and knee muscle activation pattern during a stair stepping task.

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