Correlation between Proprioception Impairment and Onset of Muscle Activities in Knee Osteoarthritis

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ABSTRACT

**Background:** Muscle strength and proprioception deficits have been recognized in knee OA. Indirect evidence suggests that muscle strength and proprioception deficits may be interrelated. However, these relationships have never been clearly evaluated. **Purpose:** This study was conducted to investigate relationships between Proprioception deficits and onset of muscle activities during sit to stand in patients with unilateral knee osteoarthritis. **Material and methods:** 40 subjects from both genders of convenient sample were assigned into two equal groups; Group (A) consisted of 20 healthy control subjects, (8 males and 12 females) with mean age (47.4±2.28) and Group (B) consisted of 20 patients with UKOA (9 males and 11 females) with mean age (46.4±1.63). Proprioception measurement was recorded by taken three trials of active repositioning of knee joint. Onset of muscle activities of EMG signal recorded from vastus medialis and vastus lateralis muscles was measured by EMG during sit to stand. **Results:** Indicated that, there were significant differences between two groups in the onset of muscles activities of vastus medialis and vastus lateralis muscles, and proprioception where P-values were (0.03), (0.003) and (0.00) respectively. Also, there was significant positive correlation between proprioception and onset of muscles activities of vastus medialis where r\(^2\) value equals (0.592) and there was weak correlation between proprioception and onset of muscles activities of the vastus lateralis muscle where r\(^2\) value equals (0.381). **Conclusion:** Evidence was suggested that in the absence of adequate proprioceptive input, onset of muscle activities of quadriceps was greatly affected and the patient’s level of activities is also affected to a greater degree especially during sit to stand activities.

**Key words:** Proprioception, Onset of muscle activities, Knee osteoarthritis.

INTRODUCTION

Osteoarthritis (OA) is a common, chronic joint disease characterized by pain, disability, and progressive loss of function. It is the most common musculoskeletal complaint worldwide and is associated with significant health and welfare costs \(^1\). The knee is the most frequently affected joint of the lower limb and therefore essential activities which require considerable loading of the lower extremities are directly affected \(^15\), Compared with those without knee OA, those with knee OA demonstrate slower performance and increased need for functional modifications \(^26\). The proportions of people affected with symptomatic knee OA is likely to increase due to the aging of the population and the rate of obesity or overweight in the general population \(^46\). By definition, stability at the knee joint requires internal forces of sufficient magnitude to counteract external forces acting at the knee. The quadriceps muscle absorbs loads and provides dynamic stability. Weakness of the quadriceps may alter local contact
stress in a manner detrimental to articular cartilage. It may also lead to increased impulse loading, which has been associated with knee pain and may contribute to knee OA.

Several studies have been stated that proprioception, of which joint position sense (JPS) is a component, contributes to dynamic knee joint stability by coordinating the actions of the quadriceps, hamstrings, and associated muscles. Signals from muscle spindles are important for midrange perception of joint angle and joint mechanoreceptors, such as pacinian corpuscles, Ruffini end organs, and Golgi joint and tendon receptors in other knee joint components (tendons, joint capsule, cruciate and collateral ligaments, and meniscal attachments) are important for detecting stretch at extremes of joint range of motion.

Older adults with symptomatic knee OA have been reported to have impaired proprioception, strength, and balance, as well as fewer mechanoreceptors in ligaments, and a higher rate of falls compared with those without symptomatic knee OA.

Additional evidence for the contribution of impaired proprioception to the pathogenesis of knee OA are results of cross-sectional studies of individuals with unilateral knee OA that have shown proprioception is impaired in both the OA involved and uninvolved knee. Results from a recent longitudinal study did not demonstrate a relationship between greater error in knee joint reposition sense and development of knee structural damage.

Proprioception activates and modulates muscles in order to stabilize the joint and to produce controlled joint movements. Stable knees that do not give way are essential for executing daily activities. Studies have demonstrated that proprioception is poor in patients with knee OA compared with healthy controls. (Van der Esch et al) demonstrated that the association between muscle strength and activity limitations is stronger in knee OA patients with poor proprioception than in patients with accurate proprioception. They concluded that in the absence of adequate neuromuscular control through poor proprioceptive input, muscle strength affects a patient’s level of activities to a greater degree.

The influence of proprioception and varus-valgus laxity on the association between muscle strength and activity limitations might be explained by compensation mechanisms within the processes of joint stabilization and neuromuscular control. Muscle actions can compensate for lack of adequate passive stabilization and poor proprioception as long as there is sufficient muscle strength available. When there is insufficient muscle strength available, the muscles are unable to perform the dual task of stabilizing the joint and producing movements necessary to perform physical activities. This will result in increased activity limitations.

Alongside the changes in muscle activation changes are observed in the sensory system as well. In and surrounding the knee joint are thousands of sensory receptors that are responsible for detecting changes in joint positioning (proprioception) and transmitting the afferent information to the central nerve systems. Efferent information is transferred from the central nerve system to the peripheral system to create a motor response. This reflexive system prevents falls and injuries. In the event of damage to the proprioceptive system, a person is at a high risk to injury. In knee OA, almost 50% of patients report a sense of instability in their symptomatic knee, such as a feeling of “giving way”, an inability to trust the knee while carrying out daily activities and a feeling that the leg is “not cooperating”. This sensation of knee joint instability highly correlates with dysfunction and immobility. Moreover, it was reported that a five ms delay in vastius medialis (VM) activity onset relative to vastius lateralis (VL) resulted in a 26% increase in lateral patellofemoral joint loads which hypothetically may precipitate knee pain, and ultimately the development of knee OA. Similarly, it is possible that a delay in onset of quadriceps activity as a whole may lead to increased loading across the entire knee joint.

Assessment of onset of quadriceps activity has primarily occurred during stair stepping in individuals with symptomatic knee OA and also during gait. Whereas other ambulatory tasks have received little attention. Indeed sit to stand (STS) is a task with greater muscle demand than gait. So it is possible that any deficit in muscle activation patterns may be greater and more detectable than in gait and may contribute to the development and progression of knee OA. Also it was found that the knee extensors contribute 72% of the concentric force at the hip and the knee joint during STS.

Electromyography (EMG) is used to measure onset of muscle activities of quadriceps during STS. The reliability of the determination of EMG onset timing of the VM and VL was reported.

There is need for further research, to investigate if there is relationship between proprioception deficits and onset of muscle activities of quadriceps during STS. This would have implications for the content of, and expectations regarding, exercise therapy in the individual patient with knee OA. It is possible that tailored exercise interventions for patients with inaccurate proprioception or delayed of onset of muscle activities of quadriceps during STS lead to better outcomes. Therefore, the aim of the present study was to establish whether there is relationship between inaccurate proprioception and onset of muscle activities of quadriceps during STS in knee OA.
METHODS

Subjects

Forty patients of both gender (23 females, 17 males) participated in this study after signing institutionally approved consent form prior to data collection. The subjects were selected from the out clinic of faculty of physical therapy, Cairo University. Subject’s age ranged from 40 to 55 years, since KOA is more prevalent in this subject population (10) and their body mass index ranged from 25-29 kg/m². Patients with rheumatoid arthritis or other inflammatory joint diseases, Mal alignment of the knee (varus / valgus) deformities, Fracture of the lower extremities in the area of the joint to be treated and Patient with knee effusion were excluded from the study. Patients were randomly assigned into two groups with twenty patients in each group. Group A: subjects in this group are control healthy subjects with no injury or pain in either knee. Group B: Patients with grade 3 UKOA (moderate OA), these patients with moderate multiple osteophytes, definite joint space narrowing, some sclerosis, and possible deformity of bone ends (25). A sample of 40 subjects of both sexes participated in this study after approval of the Ethical Committee of the Faculty of Physical Therapy; Cairo University. All participants signed a written consent. The participants were randomly assigned to an experimental group (n=20) and the control group (n=20) by an independent person who took a sealed opaque envelope from a box following a numerical sequence; the envelope contained a letter indicating whether the patient would be allocated to an experimental group or the control group.

Instrumentation

A- Wireless Surface Kinesiological Electromyography Apparatus

Onset of Muscle Activity of the right and left vastus medialis (VM) and vastus lateralis (VL) were assessed by using Myomonitor Wireless EMG Systems (DE 2.3 SEMG Sensor, Delsys, Inc., USA) that had an inter-electrode distance of 1 cm. The Myomonitor is a portable EMG and physiological signal data acquisition system. The device operates in Wireless Mode: Data is transmitted to a receiving host computer for real-time viewing and storage. Myomonitor Systems are available in 8 channels and are designed to make the acquisition of signals comfortable and reliable (31).

B- Isokinetic System

Biodex system 3 pro Isokinetic dynamometer was used to perform proprioception assessment to knee joint. It provides an objective method for testing and rehabilitation for joints of the upper limb, lower limb and the trunk. Calibration of the Biodex System 3 was done by associated researcher of the lab every month by using reference weight, under the supervision of Manufacture Company (11).

C- Modified chair

The modified chair had an appropriate design and shape; the modified chair was used with backrest, adjustable at height, without armrest and its dimensions were (60x70 cm) for seat and its length was adjusted to (52cm) and made by the carpenter of physical therapy faculty. The height of the chair was adjusted according to height of lower leg of subjects. Each subject was instructed to stand in normal STS with natural way of trunk.

3. Procedures

Testing Procedures

A- Proprioception Measurement

- For testing, each subject was seated on the isokinetic bench with back support, with hip at an angle of (80°) and stabilized with a pelvic strap. The thigh of tested leg was stabilized proximal to the popliteal fossa on a knee piece.
- Every subject was allowed to move the tested limb at a steady rate from a starting angle of approximately (90°) knee flexion to criterion position in the mid-range of knee flexion (45°).
- Subjects rested in this position for few seconds and then attempted to replicate the criterion position actively while eyes closed.
- Three trials of active repositioning were recorded (33).

B- Onset of Muscle Activity Measurement

The following preparations were executed before the conduction of each trial:

- The subject was informed about the experimental process as well as the significance of the study.
- Before electrode placement, the skin was shaved, swabbed with alcohol, and gently abraded with sandpaper to reduce the electrical impedance to less than 5K.
- After skin preparation the motor points of vastus lateralis (VL) and vastus medialis (VM) of affected limbs were determined. Silver/silver chloride electrodes were placed over the muscle bellies of the VL and VM.
- The electrode for the VL was placed 10cm superior to the inferior border of the patella. The ground electrode was placed over the tibial tubercle.
The electrode for the VM was placed over the muscle belly approximately 4cm superior to and 3cm medial to the superomedial patella border.

The main unit of the Myomonitor wireless EMG system was charged before initiating it, and when it was turned on, it automatically configured itself for wireless network transmission(9).

C- Electromyography Normalization Procedure

In order to compare values of muscle activity across subjects it was necessary to normalize the EMG data before recording muscle activities. This required that all EMG values be expressed as a percentage of the maximum EMG activity that could be produced voluntarily by a muscle. Subjects performed two repetitions of two different maximal voluntary contractions (MVIC). The subjects were first required to perform a three second maximal isometric knee extension against an immovable resistance to maximally recruit VL and VM muscles from sitting position. The muscle activity during all subsequent experimental tasks was expressed as a percent of the peak activity found during the normalization procedure (MVIC exercises). Subjects were allowed to familiarize themselves with the movements before muscle activity was recorded (27).

-Then onset of muscle activity of the VM and VL of both affected and unaffected limbs were recorded by using surface electrodes during STS. Each participant was instructed to carry out 3 repetitions of STS task. Participants were instructed to sit on an armless chair with their arms across their chest and to position themselves initially so that their back is resting against the chair. They were then asked to stand, in their own time without using their arms to assist, and remain standing until a command to sit. The subjects remained standing for approximately 30 seconds before being asked to sit. After five seconds of sitting, they were asked to stand again, using the same instructions (12).

4-Statistical Analysis

All statistical analyses were carried out by using the statistical package for the social sciences (SPSS, version 19 for windows; SPSS Inc., Chicago, Illinois, USA). Kolmogorov-smirnov test and Shapiro-Wilk test was used, that reflect the data was normally distributed, so parametric statistical tests in the form of (Paired and unpaired t-test) were used to analyze the data of this work.

Spearman correlation analysis was used to test correlation between proprioception impairment and onset of muscle activity of EMG signals recorded from the right and left of the vastus medialis (VM) and vastus lateralis (VL) muscles, during STS in patient with UKOA. Level of significance was set at P > 0.05.

Sample Size

A preliminary statistical power analysis determined that a sample size of 40 for this study was adequate to achieve power 80% and probability 0.05.,Based on sample size estimations, also considering probable presence of dropouts (20%) and our available resources for conducting this study, we aimed to include 20 subjects in each group.

RESULTS

Subjects characteristics of both groups presented in table (1). There were no significant differences between both groups regarding age, body mass index (BMI) and duration after stroke onset as (P>0.05).

General Characteristics of the Subjects

Group (A) included healthy control subjects (8 males and 12 females) who received proprioception and onset of muscle activity assessment to matched limbs. Group (B) included twenty patients with chronic UKOA with grade 3 KOA (moderate OA) (9 males and 11 females) who received proprioception and onset of muscle activity assessment to osteoarthritic knees. There was no significant difference between both groups in their age, weight, height and BMI (table 1).
Table (1): Demographic data of subjects in both groups

<table>
<thead>
<tr>
<th>General characteristics</th>
<th>Age (yrs)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (Kg/m2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A Mean ±SD</td>
<td>47.4±2.28</td>
<td>74.85±2.7</td>
<td>161.9±2.63</td>
<td>28.57±1.51</td>
</tr>
<tr>
<td>Group B Mean ±SD</td>
<td>46.4±1.63</td>
<td>76.1±2.3</td>
<td>161.6±1.63</td>
<td>29.11±0.81</td>
</tr>
<tr>
<td>Comparison</td>
<td>t-value</td>
<td>-1.69</td>
<td>0.441</td>
<td>-1.43</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>0.165</td>
<td>0.114</td>
<td>0.664</td>
</tr>
</tbody>
</table>

SD: standard deviation, S= significance, P: probability

Figure (1): Demographic data of subjects in both groups

Proprioception and Onset of Muscles Activation of Vastus medialis and Vastus lateralis Muscles within Groups

There were significant differences between two groups in the onset of muscles activities of vastus medialis and vastus lateralis muscles, and proprioception where P-values were (0.03), (0.003) and (0.00) respectively (table 2).

Table (2): Comparison of means values within both groups

<table>
<thead>
<tr>
<th>Items</th>
<th>Vastus medialis (msec.)</th>
<th>Vastus lateralis (msec.)</th>
<th>Proprioception (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A Mean ±SD</td>
<td>6875±1180</td>
<td>7235±1539</td>
<td>6.93±2.7</td>
</tr>
<tr>
<td>Group B Mean ±SD</td>
<td>6180±745</td>
<td>5905±677</td>
<td>4.12±1.29</td>
</tr>
<tr>
<td>Comparison</td>
<td>t-value</td>
<td>2.339</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>0.03</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Sig.</td>
<td>s</td>
<td>s</td>
</tr>
</tbody>
</table>

SD: standard deviation, S= significance, P: probability
Correlation between Proprioception and Onset of Muscles Activities of Vastus Medialis and Vastus Lateralis Muscles

Spearman correlation coefficient ($r^2$) was used to find out the relationship between variables in both group (A and B). (For group A) there were significant positive strong correlation between proprioception and onset of muscles activities of vastus medialis and vastus lateralis muscles. (For group B) there was significant positive correlation between proprioception and onset of muscles activities of vastus medialis and there was non-significant positive weak correlation between proprioception and onset of muscles activities vastus lateralis muscle, as shown in table (3).

Table (3): Correlation between variables in both groups

<table>
<thead>
<tr>
<th></th>
<th>Proprioception</th>
<th>$r^2$</th>
<th>p-value</th>
<th>$r^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td></td>
<td>0.722</td>
<td>0.000</td>
<td>0.843</td>
<td>0.000</td>
</tr>
<tr>
<td>Group B</td>
<td></td>
<td>0.592</td>
<td>0.006</td>
<td>0.381</td>
<td>0.098</td>
</tr>
</tbody>
</table>

$r^2$: spearman correlation coefficient, P: probability
DISCUSSION

The aim of the present study was to establish whether there is relationship between proprioception deficit and onset of muscle activities of quadriceps during STS. Regarding the EMG results of the muscles analyzed and isokinetic results of proprioception accuracy, there was statistical significant delay in onset of muscles activities in participant with knee OA (group B) during STS when compared with control group (group A). Also, proprioception was impaired in participant with knee OA (group B) during STS when compared with control group (group A).

In an attempt to explain the previous results, Previous reports regarding STS and lower extremity muscle activities found that knee extensors are more involved than any other major lower extremity muscle (38,21). This suggests that the rectus femoris and VM are the principal muscles used to accomplish buttocks-off. However, it has been reported that knee OA patients have decreased quadriceps muscle force (36) and decreased joint proprioception (2), preventing them from using their knee extensors (20).

Several (large) cross-sectional studies, but not all, have shown a positive significant relationship between knee pain, activity limitations and impaired proprioceptive accuracy in knee OA patients. In the literature, two opposite hypotheses on the influence of knee pain on proprioceptive accuracy are mentioned. Firstly, nociceptive input may overrule proprioceptive input, thereby impairing proprioceptive accuracy. Secondly, long-lasting nociceptive input may lead to a lower threshold of the synapses transmitting pain signals and possibly other inputs as well (e.g., proprioceptive input), thereby improving proprioceptive accuracy (30).
Three explanations can be offered for the mixed results on the relationship between knee pain, activity limitations and impaired proprioceptive accuracy in knee OA patients. Firstly, it is possible that only severe proprioceptive impairments influence pain or activity limitations (13, 22, 3, 23, 16). Secondly, knee OA patients may compensate their impaired proprioceptive accuracy with other capacities, for instance greater muscle strength (13, 22, 17, 43). This may suggest that impaired proprioceptive accuracy would only affect pain or activity limitations if other (compensatory) factors are also impaired, as shown by (van der Esch et al) (43).

Because of these mixed results, a systematic review incorporating a meta-analysis is indicated. Longitudinal studies have shown that impaired proprioceptive accuracy could be a risk factor for progression of pain and activity limitations in knee OA patients. It is possible that impaired proprioceptive accuracy affects pain and activity limitations only when the disease is at an advanced stage (i.e., it may contribute to progression of pain and activity limitations), but not at an early stage of the disease (i.e., it may not contribute to onset of pain and activity limitations) (43).

Moreover, it was reported that a five ms delay in vastius medialis (VM) activity onset relative to vastiuer lateralis (VL) resulted in a 26% increase in lateral patellofemoral joint loads which hypothetically may precipitate knee pain, and ultimately the development of knee OA. Similarly, it is possible that a delay in onset of quadriceps activity as a whole may lead to increased loading across the entire knee joint (34).

The results of this study showed that the association between onset of muscle activities of vastus medialis muscle was stronger in participants with poor proprioception than in participants with accurate proprioception, but there was weak correlation between proprioception and onset of muscles activities vastus lateralis muscle. This finding confirms the results of a previous study of (Van der Esch et al), Who reported that in the absence of adequate proprioceptive input, lower muscle strength affects a patient’s level of activities to a greater degree (43).

There are several mechanisms that could explain the interaction between muscles strength and proprioception. First, patients with weaker muscles may have less muscle mass and fewer proprioceptors, and consequently impaired proprioceptive input (47). Secondly, reduced sensitivity of the muscle spindles may play a role (5, 26). During activities, patients with weaker muscles use a relatively high percentage of their maximum force, resulting in higher contraction levels, and thereby reduced sensitivity of the muscle spindles, leading to impaired proprioceptive input (5). A third possible mechanism is fatigue. Patients with weaker muscles will fatigue faster, leading to impaired proprioceptive input (5).

Proprioception was found to be directly positively associated with activity limitations. This finding indicates that participants with poor proprioception have a higher degree of activity limitations than participants with accurate proprioception. This is in agreement with 3 earlier studies in established OA, in which proprioception was measured using the same method (42, 35, 6). Also, in the majority of studies that measured proprioception with another method (i.e. a joint repositioning task), a direct association between poor proprioception and a higher degree of activity limitations was found (26, 23, 13). Proprioception apparently affects activity limitations in two ways: (i) poor proprioception is directly associated with a higher degree of activity limitations; and (ii) poor proprioception strengthens the association between muscle strength and activity limitations.

In conclusion, evidence was obtained for the theory that in the absence of adequate proprioceptive input, onset of muscle activities of quadriceps affects a patient’s level of activities to a greater degree than in the presence of adequate proprioceptive input.

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Declaration of Conflicting Interests
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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