Evaluation of Dynamic Posturography in Anterior Cruciate Ligament Injury Patients

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Abstract

Background: The incidence of the anterior cruciate ligament is high in the general population.

Aim: To identify quantitative postural sway assessed by unilateral stance test using computerized dynamic posturography in unilateral anterior cruciate ligament injury patients and healthy individuals.

Subjects and Methods: We studied 30 knees in 30 male patients suffering from chronic ACL injury and twenty-five healthy individuals. They were selected from Al-Razi Orthopedics Hospital and Physical Medicine and Rehabilitation Hospital, Ministry of Health, Kuwait. All subjects were evaluated clinically and submitted to computerized dynamic posturography for the unilateral stance test. Mean COG (centre of gravity) sway velocity which displays COG stability was computerized assessed.

Results: A significantly increase of means (± SD) of COG sway velocity on left or right leg standing with eyes open and eye closed in ACL group as compared to control group. Also, there was a significantly increase of means (± SD) of the percentage difference score of COG sway velocity during standing on left and right foot with eyes open and eyes closed in ACL group as compared to control group.

Conclusion: The patients with chronic ACL injury had impairment in postural control and balance which can be quantitatively evaluated by using computerized dynamic posturography.

Introduction

The anterior cruciate ligament is one of the most frequently torn ligaments of the knee [1]. Complete tear of the ACL is one of the most common injuries in active people [2]. The incidence of knee ligament ruptures, primarily involving the anterior cruciate ligament and the medial collateral ligament, is estimated to be 2 per 1,000 people per year in the general Population [3]. ACL rupture is a disabling knee injury which frequently occurs in young athletes [4]. Anterior cruciate ligaments are frequently injured due to repetition and overuse as well as quick cutting motions that involve acceleration and deceleration. These injuries often upset this balance between mobility and stability of the joint which causes damage to other soft tissues manifested as pain and other morbidity, such as osteoarthritis [5].

Partial or complete ACL tears can sometimes heal and regain continuity via the formation of scar tissue in the absence of ACL graft reconstruction [6]. ACL injury results in mechanical and functional instability leading to...
loss of mechanoreceptor feedback with loss of reflex muscle contractions. Furthermore, ACL injury often results in perceived instability of the knee joint and leads to decreased static stability [7, 8]. A deficit in proprioception has been proposed as one factor associated with poor postural control in ACL deficient patients [9].

ACL not only plays an important role on the passive stability of the knee joint but also provides proprioceptive feedback. ACL injury may cause the mechanical and neuromuscular changes of the knee joint and affect the balance function of these patients. Moreover, sensory disorders associated with damage of receptors in the anterior cruciate ligament may produce abnormalities in the posture control and balance [10]. The neuromuscular control system sensors (mechanoreceptors), found in joints, skin and muscle inform the central nervous system of changes in position, motion perception and joint tension [11]. The ACL’s proprioceptive neurophysiologic function has been considered to be as important as its biomechanical role in maintaining joint stability [12].

Anterior cruciate ligament lesions cause a remarkable deficit of body balance and movement mostly due to knee instability [13]. Dynamic posturography has become an important tool for understanding standing balance in clinical settings. The use of force platforms has provided a sensitive method for measuring postural stability. The unilateral stance test quantifies postural sway velocity with the patient standing independently on either the right or left foot on the forceplate with eyes open and with eyes closed [14]. Thus, our objective was to identify quantitative postural sway and balance deficits assessed by unilateral stance test using computerized dynamic posturography in unilateral anterior cruciate ligament injury patients and healthy individuals.

Materials and Methods

Between March 2007 and January 2010, we studied 30 knees in 30 male patients suffering from chronic ACL injury (ACL group). All patients with suffering from chronic ACL injury and twenty five healthy individuals as a control group matched by age and sex were admitted to sports and balance clinics, physical medicine and rehabilitation hospital, Kuwait were recruited for this study. Information from medical chart reviews was linked with survey data to create the database for the analyses. Medical charts review variables included sex, date of birth and other clinical data. X-rays were done to rule out fracture. All patients & healthy individuals were evaluated clinically with brief neurological examination.

All of the patients were diagnosed for the torn ACL by manual examination and magnetic resonance imaging. None of them presented with obvious dysfunction in the lower limbs, central nervous system, or vestibular functioning during the interview or on informal questionnaires. Their mean (± SD) age at the time of injury was 22.0 ± 3.2 years (range 15– 40 years), the mean (± SD) height was 166.9 ± 6.1 cm (range 152–183 cm), the mean (± SD) body weight was 64.4 ±7.8 kg (range 50–97 kg), and the mean( ± SD) body mass index was 21.0 ± 2.37 kg/m² (range 19.7–24.7 kg/m²). The mean (± SD) period from the injury to the assessment was 4.2 ± 1.8 months (range 2–11 months).

Inclusion criterion for the trial was ability to ambulate 25 feet independently. Those with cognitive deficit, peripheral neuropathy, significant visual field, cerebella or brain stem lesions were excluded. Exclusions also were serious cardiac conditions, severe weight-bearing pain, and other serious organ system disease. After patients passed the screening criteria, an informed consent was taken from subjects to participate in this study.

Figure 1: Represents normal unilateral stance test of dynamic posturography.
The Unilateral Stance Test by Computerized dynamic posturography (balancing while standing on one leg): The SMART Balance Master (NeuroCom International, Inc., Clackamas, OR, USA) was used for balance function assessment [14]. All subjects were evaluated clinically and submitted to computerized dynamic posturography for the unilateral stance test. The unilateral stance test quantifies postural sway velocity with the patient standing independently on either the right or left foot on the forceplate, with eyes open and with eyes closed. The length of each trial is ten seconds.

Mean (± SD) of COG sway velocity (degree/second) displays COG stability while the patient stood independently on each leg with eyes open and with eyes closed. The center bar graph displays the percentage difference score of COG sway velocity with the bar pointing in the direction of the limb with the better performance. The shaded area on each graphic represents performance outside of the normative data range. Gray (or green) bars indicate performance within the normal range; dark (or red) bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

Fig. 1 represents normal unilateral stance test of dynamic posturography. Fig. 2 represents abnormal unilateral stance test of dynamic posturography.

Statistical analysis

Study data were analyzed using the SPSS (version 11.0) statistical package. The Student’s t test indicates the magnitudes of the differences of means (± SD). A p value of ≤ 0.05 was used as significance. Linear regression (r-) correlation was also used to assess correlation between mean (± SD) of the percentage difference score of COG sway velocity during standing on left and right foot with eyes open and mean (± SD) of the percentage difference score of COG sway velocity during standing on left and right foot with eyes closed of unilateral stance test in cases with unilateral anterior cruciate ligament injury [15].

Results

Table 1 showed demographic and clinical data of 30 male patients with ACL tear and 25 male healthy controls. Of the 30 patients with ACL tear, the most frequently clinical findings of ACL tear were pain of knee (80%), tenderness (66.7%), swelling (83.8%) and limp (63.3%).

Table 1: Demographic and clinical data of 30 patients with ACL injury and 25 healthy individuals.

<table>
<thead>
<tr>
<th></th>
<th>ACL group (n=30)</th>
<th>Healthy group (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>23.1 ± 3.4</td>
<td>22.0 ± 2.8</td>
</tr>
<tr>
<td>Sex (all males)</td>
<td>all</td>
<td>all</td>
</tr>
<tr>
<td>Duration (months)</td>
<td>6.6 ± 2.2</td>
<td>-</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.8 ± 6.1</td>
<td>-</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>67.4 ± 19.2</td>
<td>-</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>20.1 ± 9.1</td>
<td>-</td>
</tr>
<tr>
<td>Site of lesion</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>• Right knee, n (%)</td>
<td>18 (60%)</td>
<td>-</td>
</tr>
<tr>
<td>• Left knee, n (%)</td>
<td>12 (40%)</td>
<td>-</td>
</tr>
<tr>
<td>Causes</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>• Non-contact ACL injuries</td>
<td>21 (70%)</td>
<td>-</td>
</tr>
<tr>
<td>• Contact ACL injuries</td>
<td>7 (30%)</td>
<td>-</td>
</tr>
<tr>
<td>Pain of knee, n (%)</td>
<td>24 (80%)</td>
<td>-</td>
</tr>
<tr>
<td>Tenderness of knee, n (%)</td>
<td>26 (86.7%)</td>
<td>-</td>
</tr>
<tr>
<td>Swelling of knee, n (%)</td>
<td>25 (83.8%)</td>
<td>-</td>
</tr>
<tr>
<td>Limping, n (%)</td>
<td>19 (63.3%)</td>
<td>-</td>
</tr>
</tbody>
</table>

Contact ACL injuries occur when a player is hit from behind or the outside of the knee. Non-contact ACL injuries result from sudden changes in direction on knee.

Table 2 and Figure 3 represent of mean (± SD) OF parameters of the unilateral stance test of CDP of 30 male patients with ACL tear and 25 controls. The unilateral stance test showed that we observed a significantly increase of means (± SD) of COG sway velocity on left or right leg standing with eyes open and eye closed in ACL group as compared to control group (p< 0.05). Also,
there was a significantly increase of means (± SD) of the percentage difference score of COG sway velocity during standing on left and right foot with eyes open and eyes closed in ACL group as compared to control group (p< 0.001).

Table 2: Means (± SD) of COG sway velocity (degree/sec) by unilateral stance test in ACL injury and control groups.

<table>
<thead>
<tr>
<th>Unilateral stance test with eye open</th>
<th>ACL group</th>
<th>Healthy group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>• while standing on left leg</td>
<td>2.1 ± 0.6</td>
<td>0.6 ± 0.2</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>• while standing on right leg</td>
<td>3.3 ± 2.4</td>
<td>1.3 ± 0.4</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>• the percentage difference score of both legs</td>
<td>25.7 ± 9.02</td>
<td>1.5 ± 1.8</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unilateral stance test with eye closed</th>
<th>ACL group</th>
<th>Healthy group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>• while standing on left leg</td>
<td>3.6 ± 2.3</td>
<td>1.5 ± 0.2</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>• while standing on right leg</td>
<td>4.4 ± 2.8</td>
<td>1.4 ± 0.2</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>• the percentage difference score of both legs</td>
<td>29.7 ± 10.4</td>
<td>3.8 ± 1.6</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table 3: Linear regression (r-) correlation between mean (± SD) of the percentage difference score of both legs with eyes open and mean ± SD of the percentage difference score of both legs with eyes closed of unilateral stance test in ACL group (r = 0.844, P< 0.001).

Discussion

Anterior cruciate ligament (ACL) rupture is a common injury [16]. However, subjects reduced their activity levels on average by 21% following injury. Injury to ACL results in mechanical and functional instability [17]. ACL is a critical component of the knee joint. ACL injury can lead to an impairment of postural control during upright stance in both double- and single-leg stance and on either the injured or uninjured-leg [18].

It has been theorized that when ACL is torn, kinesthesia of the knee joint will be decreased [19]. It may contribute to disability and result in progressive degeneration of the knee and balance deficits when receptors are damaged or destroyed [20]. Rupture of ACL results in increased tibio-femoral laxity in the knee, thereby ultimately resulting in knee instability and dysfunction [21]. Loss of neurophysiologic function in an ACL deficient of knee leads to deterioration in postural control and irregularities in neuromuscular coordination [22].
In the present study, incidence of non-contact ACL injury was 70% of our cases. There was a significantly increase of means (± SD) of COG sway velocity on left or right leg standing with eyes open and eye closed in ACL tear group as compared to control group (p<0.05). Also, there was a significantly increase of means (± SD) of the percentage difference score of COG sway velocity during standing on left and right foot with eyes open and eyes closed in ACL tear group as compared to control group (p< 0.001).

Our results are in agreement or consistent with other studies that incidence of non-contact ACL injury was high and poor postural stability is associated ACL group. Griffin et al. [23] reported that approximately 70% of ACL injuries occur through non-contact mechanisms. The mechanism of ACL injury often involves deceleration coupled with cutting, pivoting, or awkward landings.

Katayama et al. [24] reported that the amount of postural sway increased significantly on injured leg standing with eyes closed, and that vision in the ACL-injured knee. In other study of 19 patients with untreated ACL injuries, an increase in postural sway in the frontal plane was found for both the injured and non-injured legs when compared with a control group [25].

Lysholm et al. [26] reported that patients with a continuing chronic ACL insufficiency several years after injury have an impaired postural control in the antero-posterior direction in single-limb stance on their injured leg. They also demonstrated statistically significant deficits of the postural control in the patient group with chronic ACL insufficiency compared to the control group. There was a significantly higher body sway within the patient group when standing on a stable support surface on the injured limb than standing on the uninjured limb with the eyes open, but no difference with the eyes closed. When standing on a stable support surface, there was a significantly higher body sway in the patient group standing on the injured leg than in the control group, both with eyes open and closed.

Moezy et al. [27] suggested that postural sway may be increased by proprioception loss in ACL injuries. ACL injuries not only cause instability and disability in a high percentage of ACL-deficient athletes but also reduce proprioceptive ability and postural stability. In other study, postural sway had been significantly increased on the ACL-injured leg in the ACL injured group. They concluded that an ACL deficiency or dysfunction was present, which resulted in increased need for proprioceptive input [21]. Other authors reported that impaired postural stability has been demonstrated in ACL deficient patients and the persistence of poor stability control may be correlated to impairment in proprioception [28].

However, our results are in contrast to some previous studies. Katayama et al. [24] reported that in healthy young women who are in their twenties no significant differences were observed in any parameter of sway they measured in eyes-open tests in the ACL-injured knee. They could not show a significant relation between postural sway and the lower extremity muscle power strength they measured. However, their studies could not measure the contribution of vision to postural sway while standing. Other study found no significant difference between the operated and uninjured knees of patients or between patients and healthy controls in the ACL-injured knee (p>or=0.05) [29].

In addition, other authors also found that there was no significant difference between the injured and uninjured legs regarding postural sway during one-leg standing with eyes open, but the amount of postural sway increased significantly with eyes closed. However, there were no significant differences with respect to sex or general joint laxity and no correlation with the anterior translation of the tibia or the knee muscle strength [9]. Other study found no differences in postural sway during single-leg standing between dominant and non-dominant legs between the non-ACL-injured group and ACL-injured group [21].

The potential explanation for the deficits in postural control after ACL tear may be due to several biomechanical factors. ACL has both mechanical and proprioceptive (sensory) functions [29], but, the variability of postural sway generally increased in ACL tear because of the lack of proprioceptive information resulting from the ACL lesion [30]. Injury of ACL is associated not only with mechanical joint destabilization but also damage of receptors in the ligament responsible for joint proprioception. Sensory disorders associated with damage of receptors in the ligaments may produce abnormalities in the posture control [31]. Joint position sense was impaired in ACL deficient knees and osteoarthritis of knees [32].

One possible explanation with ACL injury is that sensory stimuli from the injured leg signaling position and movement of this leg are reduced and as a result larger body sway is exhibited [31]. Sensory and motor behavior changes were still observed resulting from the ACL lesion. This may be because of the lack of proprio-
ceptive information resulting from the ACL lesion [31]. Bilateral deficits in knee joint proprioception were documented after unilateral ACL injury [33]. Some authors suggest that reduction in postural control performance in individuals with ACL injury would be due to the reduction of sensory information provided by the ACL, but when sensory information is enhanced, postural control performance improves. These results have implications for novel approaches to improve stability in individuals with ACL injury [34].

Finally, Okuda et al. [30] reported that the balance of dynamic tension in the ligament is destroyed at the time of an ACL injury, and the peripheral muscular coordination around the knee is reduced when the information transfer from the mechanoreceptors in the ACL is disrupted. The net result is a reduction in proprioception related to the sense of position, motion, and gravitational stability [30]. Sensory information is reduced in the injured leg due to ACL lesion and the motor control system would have difficulties in controlling two limbs with different properties [35].

**Conclusion:** This study represents the first attempt in use of the computerized dynamic posturography equipment as diagnostic tool in assessment of postural control and balance deficit in chronic ACL injury patient in Kuwait. The unilateral stance test may be used to identify quantitatively postural sway and balance deficits on each leg standing patients with chronic ACL injury. Chronic ACL injury patients have high COG sway velocity and impaired balance than normal subjects.

Our study identifies quantifiably how much of impairment in postural control and balance that may help to predict which patients are predisposed to developing long-standing functional knee instability. The ligamentous damage, knee muscle strength deficits and proprioception deficits at the knee joint may explain poor balance in ACL injury.

Future research should include the effect of surgical intervention and various rehabilitation exercises by using the posturography equipment among patients with chronic ACL injury. Clinicians should focus on promoting rapid and appropriate test during rehabilitation.

**Acknowledgments**

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**References**


