The relationship between pelvic cross syndrome and chronic low back pain

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Abstract. Objective: Specific patterns of muscle impairments, known as Pelvic Cross Syndrome (PCS), in the lumbo-pelvic region have been attributed to causing chronic Low Back Pain (LBP). In PCS, based on their primary functions, muscles are categorized as “postural” or “phasic”, and it has been assumed that phasic (abdominal and gluteal muscle weakness) or postural (decreased flexibility in the hip flexor and back extensor) muscle impairments could lead to an exaggerated Lumbar Lordosis (LL), which in turn might cause chronic low back pain. PCS theory also indicates that exaggerated lordosis in impaired subjects is controlled by hamstring muscle shortening. The purpose of this study was to examine the relationship among Pelvic Cross Syndrome, degree of lumbar lordosis and chronic low back pain.

Design: A total of 600 subjects between the ages of 20 and 65 were selected. Subjects were categorized into four groups of males and females with and without low back pain. The degree of LL, the strength of abdominal and gluteal muscles and the extensibility of iliopsoas, erector spine, and hamstring muscles were measured in each group. The cut-off values obtained from Receiver Operating Characteristic (ROC) curve analysis were used to categorize subjects as having weak or short muscles in accordance with the PCS assumptions. The degree of lumbar lordosis in subjects with and without patterns of muscle impairments, and the association between lumbar lordosis and low back pain and the effects of hamstring muscle length on lordosis were assessed.

Results: The results of this study showed no significant difference in the degree of LL in subjects with and without patterns of muscle impairment, or in subjects with and without LBP, or in those with and without short hamstring muscles. However, a significant difference in the strength of abdominal and gluteal; and in the length of hip flexor and hamstring muscles was found between subjects with and without LBP.

Conclusions: The findings of this study did not support the assumptions of the PCS theory that certain patterns of muscle impairment would lead to exaggerated LL and LBP. Our data indicated that certain muscle impairments could contribute to chronic LBP, but probably not via changing the degree of lumbar lordosis as has been proposed in PCS theory.

Keywords: Low back pain, lumbar lordosis, muscle, flexibility, strength

1. Introduction

Low back pain (LBP) is one of the most frequent medical problems reported in western societies [57]. Despite its detrimental effects on individuals’ social and work-related activities, the exact causes of mechanical LBP have not yet been fully understood. Some investigators have identified changes in the size of lumbar lordosis [31,35,53–55] due to sedentary lifestyle [43, 64] or induced by individual muscle impairments such as decreased abdominal muscle strength [3,25,26,39, 40,44,47] decreased hip extensor muscle strength [40] decreased flexibility of back extensor [6,27,32,34,38, 61] and hip flexor muscles [4,39,46], as contributing factors to chronic LBP. Exaggerated lumbar lordosis is assumed to cause extra mechanical stress to the joints and soft tissue of the lumbar spine, resulting in LBP [8, 12,35,37,54]. Others, however, have questioned the association between the degree of lumbar lordosis and
the stated individual muscle impairments [5,59,60,63,65].

Considering the controversial effects of individual muscle impairments on lumbar lordosis, Jull and Janda have hypothesized that certain patterns of combined muscle impairments in the lumbo-pelvic area could result in exaggerated lumbar lordosis and could cause chronic low back pain [28,29,31,33,55]. These investigators categorized muscles, based on their primary functions, as “phasic” or “postural” [9,31,33,48], and indicated that in response to dysfunction or overuse, the phasic muscles tend to be inhibited or weakened; while the postural muscles tend to develop higher tone and ultimately shorten [9,48]. In the lumbo-pelvic area, the abdominal and gluteal muscles are categorized as phasic; and hip flexors, back extensors and hamstring muscles are categorized as postural muscles [9]. Jull and Janda [31,33] defined a certain pattern of muscle impairment, characterized by decreased extensibility of hip flexor and back extensor; and weakness of abdominal and hip extensor muscles [28,29,31,33,55] (Fig. 1), as “Pelvic Cross Syndrome” (PCS). They indicated that these muscle impairments in the lumbo-pelvic area would lead to an exaggerated lumbar lordosis, which in turn might cause chronic low back pain [33]. Additionally, in PCS it is assumed that the exaggerated lumbar lordosis is controlled by decreased extensibility of the hamstring muscles [33]. This theory has been adopted by some authors as a cause of chronic back pain. Chaitow [9] described two patterns of muscle impairments, one for the lower (lower crossed syndrome) and one for upper (upper crossed syndrome) quadrant. The lower crossed syndrome proposes similar patterns of muscle impairment to those described in the PCS theory [9]. Clinicians, based on these assumptions, have advocated strengthening of weak and stretching of short muscles in the lumbo-pelvic area to correct the changes in the degree of lumbar lordosis and to treat patients with low back pain [2,12,13,15,36,37,41,43]. Considering the controversial effects of muscle impairments on the degree of lumbar lordosis and questioned relationship between the degree of lumbar lordosis [14,16–18,20–22,49–51] or pelvic tilt [14,17,10] and LBP, the purpose of this study was to evaluated the validity of the PCS theory. This study tried to answer the following questions related to the assumptions of the PCS theory:

1. Is there any significant difference in the degree of lumbar lordosis in subjects with and without PCS patterns of muscle impairments?

2. Is there any significant difference in the degree of lumbar lordosis, muscle strength and muscle shortness between subjects with and without chronic low back pain?

3. Is there any significant difference in hamstring muscle length between subjects with and without PCS-patterns of muscle impairment? Is the degree of lumbar lordosis affected by hamstring muscle shortness?

2. Methods

2.1. Subjects

A total of 600 subjects between the ages of 20 and 65 were selected from five different hospitals. Subjects with LBP were selected among the patients in the orthopedic and physical therapy departments. Subjects without LBP, matched in age and gender, were selected among those who either accompanied a patient or were referred to the hospital for non-musculoskeletal problems. These subjects were evaluated and found to have no complains of pain and dysfunction in their lower extremities, low back, thoracic and cervical areas. Equal number of males and females with and without LBP were recruited. One hundred and fifty subjects were allocated to each group. All the subjects signed an informed consent form approved by the human subjects committee at the university of Social Welfare and Rehabilitation Sciences before participating in the study.

2.2. Selection criteria

The PCS theory relates to chronic mechanical LBP. Therefore, subjects with chronic LBP were selected. Subjects with LBP had a history of LBP for more than six weeks prior to the study or had at least three episodes of intermittent low back pain, each one lasting more than one week, during the year prior to the time of the study. Subjects without LBP had no spinal pain and had no radicular pain in their lower extremities during one year prior to their participation in the study. Subjects with history of spinal surgery, spinal or pelvic fracture, hospitalization for severe trauma or car accident, fracture of the lower extremities or any systemic disease, such as arthritis or tuberculosis were excluded.

2.3. Procedures

The measurement procedure for each variable was as follows.
2.3.1. Size of lumbar lordosis

We used a standard flexible ruler to measure the size of lumbar lordosis in the standing position based on the method explained by others [49,50,65,66]. In relaxed standing subjects, the base of sacrum and spinus process of L1 was located by palpation. A standard flexible ruler was fitted in subject’s lumbar curve, over the lumbar spinus processes of L1–S1. The curve of the flexible ruler, resembling the size of subject’s lumbar lordosis, was graphed on a paper. The method explained by others [6,65,66] was used to quantify the degree of lumbar lordosis. In a previous study we established the reliability of flexible ruler for measuring lumbar lordosis [50]. We found a very high correlation ($r = 0.92$) between degrees of lumbar lordosis measured indirectly by a flexible ruler and those obtained directly from lumbar X-rays [50].

2.3.2. Extensibility of back extensor muscles

The extensibility of back extensor muscles was assessed indirectly by measuring the degree of maximum lumbar flexion [6,49,58,65,66]. Besides the length of back extensor muscles some other factors such as joint and soft tissue stiffness can affect the range of lumbar flexion. It has been suggested that muscle length and soft tissue extensibility would adapt to available joint range of motion [11]. In this study, due to muscle length adaptation to the available range of motion, the maximum degree of lumbar flexion was assumed to represent the length of back extensor muscles.

We used a flexible ruler and followed the procedure described by Youdas [65,66] to measure the subject’s maximum lumbar flexion in the sitting position. The quantitative method described by others [6,65,66] was used to obtain the amount of maximum lumbar flexion in degrees.
2.3.3. Extensibility of hip flexor muscles

Using the Thomas test [35,42,49] the extensibility of hip flexor muscles was indirectly assessed. Subjects, positioned supine, were instructed to bring and hold one leg into full hip and knee flexion inducing a posterior pelvic tilt. Controlling for the hip abduction and adduction, the angle between the longitudinal axis of the trunk and the thigh of the subject (hip flexion angle) on the opposite leg was measured (in degree) by a standard goniometer [65]. Any difference between full extension ($180^\circ$) and the measured angle was considered as the level of inextensibility in the hip flexor muscles (Fig. 2). Using measurements for each lower extremity was impractical and too complex for analysis, therefore, the average of the measurements obtained from both legs was used in this study as the indicator of hip flexor muscle extensibility [49].

2.3.4. Extensibility of hamstring muscles

Active knee extension (AKE) method [19] was used to assess hamstring muscle length. Subjects, positioned in supine, were instructed to assume and maintain a $90^\circ$ hip flexion in the testing leg. Subjects were then instructed, while maintaining the degree of hip flexion constant, to actively extend the knee joint. Using a goniometer the hip range of motion was monitored by a therapist to make sure it remained constant during the test. The degree of achieved active knee extension was then measured. We used the average knee extension range, measured in both legs, as the indicator of hamstring muscle length (extensibility) for each subject (Fig. 3).

2.3.5. Testing muscle strength

Muscle strength was quantitatively measured by a pressure meter similar to the one described by Helewa et al. [23]. The reliability and validity of this procedure has previously been established [24]. The unit used in this study was calibrated and had 99% measurement accuracy. To measure muscle strength, subjects assumed the standard positions for testing the abdominal and gluteal muscle strength as described by Kendall et al. [36]. The inflated bag of the pressure meter was placed between the examiner’s hand and the specified contact point for each test on the subject’s limb or trunk [24]. The pressure meter used in this study provided measurements in kPa units, which is defined as force per unit area. All measurements of muscle strength were performed by one therapist and the same size inflated bag was used during all measurements. Intra-class correlation analysis ICC (3,1) [56] revealed 0.90 and 0.96 intra-rater reliability for abdominal and
A: Full knee extension indicates normal muscle length (flexibility).

B: The degree of knee flexion represents the level of hamstring muscle shortness.

Degree of Hamstring Shortness

Fig. 3. Hamstring Muscle Length Assessment. A: Full knee extension indicates normal muscle length (flexibility). B: The degree of knee flexion represents the level of hamstring muscle shortness.

gluteal muscle strength measurements. The procedure for inter-rater reliability assessment has been explained elsewhere [49].

2.4. Data analysis

2.4.1. Identification of subjects with and without muscle impairments

Subjects with and without muscle impairments were identified based on the cut-off values obtained from the Receiver Operating Characteristic (ROC) curve analysis [52] performed by MedCalc® statistical software [45]. Cut-off values were determined for abdominal and gluteal muscle strength and for hip flexor, back extensor and hamstring muscle length. Due to inherent gender differences in muscle strength and extensibility, separate cut-off values were obtained for males and females.

The ROC curve is a plot of sensitivity versus 1-specificity of a variable assessed against an external criterion [45]. Having or not having LBP was used as the external criterion for constructing the ROC curves in this study. MedCalc® statistical software [45] provides a value of the independent variable, with the highest sensitivity and specificity, as a cut-off value, which best can discriminate between subjects with and without a condition (chronic LBP in this study) using the tested variable as a diagnostic tool [52].

Upon identifying males and females with and without muscle impairments, subjects were then coded as having weak abdominal and gluteal, or having short hip flexor and back extensor or having both weak abdominal and gluteal along with short hip flexor and back extensor muscle impairments. Subjects with no muscle impairments were used as the control group.

3. Results

3.1. Subjects

As suggested by Table 1, there was no significant difference in subjects’ age, height and weight across all the groups. Among all the subjects with LBP ($N = 300$), sixty eight percent ($N = 204$) of the patients had LBP for more than six months and complained of pain and stiffness in the lower back at the time of the study.
Table 1: Mean Age, Height and Weight of Non-impaired Subjects and Those with Low Back Pain

<table>
<thead>
<tr>
<th>Variables</th>
<th>Males Without LBP</th>
<th>Males With LBP</th>
<th>Females Without LBP</th>
<th>Females With LBP</th>
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<td>Mean 43.3</td>
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<td>SD 11</td>
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<td>SD 11</td>
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LBP = Low Back Pain.

3.2. Cut-off values

The cut-off value, sensitivity, specificity and area under the ROC curve for the tested variable in males and females are presented in Table 2. The presented cut-off values were used to determine subjects with and without muscle impairment in correspondence with PCS theory. For example male and female subjects with abdominal strength less than 26 and 20 kPa respectively were considered positive for having weak abdominal muscle strength.

3.3. Difference in the degree of lumbar lordosis in subjects with and without PCS-patterns of muscle impairments

Using pooled data, the overall effects of impairment on lordosis was assessed. Independent t-test showed no significant difference ($P = 0.45$) in the degree of lumbar lordosis between subjects without (Mean = 35.9 ± 13.7) and those with any patterns of muscle impairment (Mean = 34.7 ± 14.3). Detailed descriptive statistics are presented in Table 3. A follow up analysis of variance determined the individual effect of each pattern of muscle impairment on the degree of lumbar lordosis in groups of subjects with and without chronic LBP. The results, presented in Table 4, showed that the degree of lumbar lordosis was not significantly different between any of the groups.

3.4. Difference in the degree of lumbar lordosis, muscle strength and muscle shortness between subjects with and without LBP

Table 5 presents degree of lumbar lordosis, strength of abdominal and gluteal, length of hip flexor, back extensor and hamstring muscles in subjects with and without LBP. Independent t-test showed no significant difference in the degree of lumbar lordosis ($P = 0.25$) and in the length of hip flexor muscles ($P = 0.63$) between subjects with and without LBP. The strength of abdominal and gluteal muscles, the length of back extensor and hamstring muscles were, however, significantly different ($P = 0.000$) between the two groups.

3.5. Difference in hamstring muscle length between groups of subjects with and without patterns of muscle impairment

In subjects with and without LBP, analysis of variance showed no significant difference in hamstring muscle length between groups of subjects with weak abdominal and gluteal ($P > 0.05$) or with short hip flexor and back extensor muscles ($P > 0.05$). In subjects without LBP, however, a significant difference ($P = 0.01$) in hamstring muscle length was found between subjects with all four muscle impairments ($N = 220$) and those without any impairments ($N = 8$).

Using pooled data, the degree of lumbar lordosis between groups of subjects with and without short hamstring muscles were compared. Independent t-test showed no significant difference ($P = 0.06$) in the degree of lumbar lordosis between subjects with short hamstring (Mean = 34.3, SD = 13.7, $N = 390$) compared to those without (Mean = 36.7, SD = 14.5, $N = 210$).

4. Discussion

4.1. Patterns of muscle impairment and degree of lumbar lordosis

The PCS theory has two premises, one is assuming that certain patterns of muscle impairments cause exaggerated lumbar lordosis, and the other is that exaggerated lumbar lordosis leads to chronic low back pain. If these assumptions were true, one would expect a significant difference in the degree of lumbar lordosis between subjects without and with either one or both patterns of muscle impairments. The theory, however, does not explain whether the exaggerated lumbar lordosis is due to presence of the both patterns of muscle weakness (abdominal and gluteal) and muscle shortness (hip flexor and back extensors) or either one
of the patterns of muscle impairment could also cause increased lordosis.

In this study the effects of both patterns collectively and the effect of each pattern individually in the degree of lumbar lordosis were examined.

The results of this study did not show any significant difference in the degree of lumbar lordosis between subjects with no impairment and those with phasic (abdominal and gluteal weakness), or postural (hip flexor and back extensor shortness) or with both patterns of muscle impairments (Table 3).

Our data, however, showed a significant difference in abdominal and gluteal muscle strength and in back extensor and hamstring muscle length between subjects with and without chronic LBP. These findings indicate that muscle impairment could be related to the presence of chronic LBP, but not probably via changing the degree of lumbar lordosis as it has been assumed in the PCS theory. It is speculated that although muscle impairments do not affect the degree of lumbar lordosis, but could affect the magnitude or direction of forces acting on the lumbar spine, causing microtrauma and pain in the region.

4.2. Lumbar lordosis and low back pain

This study tested the second assumption of the PCS theory, which presumes a direct relationship between increased degree of lumbar lordosis and low back pain. In contrast to PCS theory, our findings indicate that presence of low back pain is not related to the degree of lumbar lordosis.

Previous studies have identified changes in the size of lumbar lordosis, due to sedentary lifestyle [43, 64] or induced by muscle impairment in the lumbopelvic area [28–31,33,53–55], as a contributing factor to chronic LBP. It is assumed that exaggerated lumbar lordosis would cause extra mechanical stress to the joints and soft tissue of the lumbar spine, resulting in LBP [12,33,55]. Others, however, have questioned the association between the degree of lumbar lordosis [14, 16–18,20–22,49–51] or pelvic tilt [10,14,15] and LBP.

In this study, we found no association between the degree of lumbar lordosis and LBP, and found no significant difference in the degree of lumbar lordosis between subjects with and without LBP (see results section). Contrary to the PCS assumption, we found that subjects with LBP, although not statistically significant, have a lower degree of lumbar lordosis compared with those without LBP (Table 4). This finding is in accordance with the results reported by Adams and coworkers [1]. They defined a shock absorbing role for lumbar lordosis and explained reduced lumbar lordosis could be an important risk factor for occurrence of first time low back pain.

4.3. Lumbar lordosis and hamstring muscle length

Jull and Janda [31,33] believe that hamstring shortness in patients with low back pain is a compensatory...
5. Conclusion

In PCS theory, it is assumed that the patterns of phasic (abdominal and gluteal weakness) and postural (hip flexor and back extensor shortness) muscle impairments might lead to exaggerated lumbar lordosis and chronic LBP. We, however, found no difference in the degree of lumbar lordosis in subjects with different pattern of muscle impairments; and found no association between degree of lumbar lordosis and low back pain. Although there is a significant difference in the length and strength of some of the muscles in the lumbo-pelvic area between the subjects with and without LBP, such muscle impairments, do not seem to be related to LBP by causing exaggerated lumbar lordosis. Cross-sectional studies, including this one, cannot determine the pathophysiology of such association. Longitudinal investigations are needed to identify whether LBP is the cause or the effect of muscular impairments.

Acknowledgement

This research was reviewed and was approved by the Human Subject Committee at University of Social Welfare and Rehabilitation Sciences.

References


