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# Postural Control and Plantar Pressure Symmetry in Male and Female Athletes With Chronic Low Back Pain When Performing Overhead Squat

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## Abstract

**Background:** Low Back Pain (LBP) is one of the most prevalent problems associated with sport activities. The present study aimed to investigate the relationship between pain and plantar pressure variables. In addition, we compared these variables in male and female athletes with LBP.
**Methods:** In this study, 47 participants with the age range of 18 to 25 years were selected (22 males and 25 females). Visual Analogue Scale (VAS) was used to evaluate the LBP severity. The plantar pressure variables were recorded using a plantar pressure measurement device (model: Foot pressing FDM-S) made by Zebris Company.
**Results:** Length of minor axis ($p_{male}$= 0.020, $p_{female}$= 0.227), length of major axis ($p_{male}$= 0.041, $p_{female}$= 0.011), area of sway ($p_{male}$= 0.0001, $p_{female}$= 0.007), path length ($p_{male}$= 0.053, $p_{female}$= 0.001), velocity of sway ($p_{male}$= 0.023, $p_{female}$= 0.008), and standard deviation X ($p_{male}$= 0.048, $p_{female}$= 0.147) of the COP variables had a positive and significant relationship with the pain. The symmetry of plantar pressure variables did not show strong correlation with the pain intensity ($p>0.05$). The COP variables also showed a significant difference in area of sway ($p=0.042$), path length ($p=0.044$), and standard deviation X ($p=0.043$) between the males and females. Females had more oscillations than males, but there was no difference in the symmetry of plantar pressure variables between the males and females ($p>0.05$).
**Conclusion:** LBP is a factor that can impair the postural control, resulting in increased risk of injury among the athletes with LBP, especially in females.

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## Introduction

Low Back Pain (LBP) is one of the most prevalent problems associated with sports activities (1). The presence of LBP in contact and noncontact sports is a common complaint (2). One of the causes of the LBP is the change in neuromuscular control and the loss of normal spinal motion patterns, which ultimately threatens postural control (3). People with LBP lose the ability to use multi-sectional control (4). In contrast, their balance and postural control are maintained using a harsh strategy, including ankle strategy, resulting in increased oscillations in the ankle and foot (5). The mechanisms of this disorder have not yet been identified in the people with LBP.

Putative mechanisms include pain (6), changes in coordination, muscle fatigue and impaired ability of proprioceptive system (7). Ruhe et al. compared postural control in people with LBP and healthy subjects and concluded that people with LBP had more instability in postural control and this instability was associated with pain (8). Moreover, it was found that enhanced pain leads to a linear increase in postural oscillations (8). The study of postural control in people with LBP is very important; one of the reasons is the possible disadvantages of defects in whole body balance control in LBP patients (9). Another reason is the development of defects in the coordination of trunk muscles that are necessary to activate and control the function of the lower limb muscles and act as a feedforward mechanism (9). An accepted method for evaluating the control of whole body balance is to record and analyze plantar pressure data during an activity that creates disturbances. It is necessary to examine these variables in activities with the most frequent and most risk of LBP (10). In recent years, research on the overhead squat has increased. Overhead squat indicates imbalances and asymmetries in the body. In addition some researchers have applied overhead squat or single-leg squat to examine the performance of athletes (11). These tests were introduced by the National Academy of Sports Medicine (NASM) as an appropriate indicator for the examination of transitional movements (11). The overhead squat is an accurate assessment for the musculoskeletal disorders (12).

Taking into account the presented theoretical foundations and studies, it can be concluded that people with LBP have defects in postural control and weight distribution. These defects can increase the likelihood of injury in the joints by exacerbating LBP in athletes exercising with weights and other athletes through changes in postural control and proprioception mechanisms in the lumbar and other joints in the kinetic chain, especially the ankle joint. Therefore, the present study was conducted to determine the relationship between the pain intensity and plantar pressure variables, including indices related to COP sway and plantar pressure symmetry. Besides, our research aimed to detect the difference between plantar pressure variables in male and female athletes with chronic non-specific low back pain (CNLBP).

## Materials and Methods

### Participants

Participants of this study were weightlifting and powerlifting athletes in Hamadan, Iran. Athletes who had more than three months of low back pain with an unknown etiology were selected as the subjects with CNLBP. The total number of statistical population was 791 people.With calculations done by G*power software (Franz Faul, University of Kiel, Germany), 47 people were selected as the statistical sample in accordance with the inclusion criteria (13). Of 47 participants in this study, 22 cases with CNLBP were in the male group and 25 cases with CNLBP were in the female group (Figure 1). Participants did not have any physical or psychological diseases. Written consent was granted from participants. All stages of the tests were explained to participants. This study was approved and registered at the Ethical Committee of Hamedan University of Medical Sciences (IR.UMSHA.REC.1396.844).

### Assessments

In this study, the Visual Analogue Scale (VAS) was used to evaluate the LBP severity. The pain measurement tool was a 10-cm (100-mm) ruler. In this method, the number zero indicates the absence of pain and the number 10 means the maximum pain intensity (14, 15).

The plantar pressure variables were recorded using a plantar pressure measurement device (model Foot pressing FDM-S) made by Zebris Company in Germany (16, 17). Before the test, the athletes performed warming up for 6 minutes, including 3 minutes of warming up with an ergometer at a constant speed and resistance, and 3 minutes of full-body stretching. In performing the test, the subjects stood with feet shoulder width apart and straight to the front. Participants held their hands up and extended the elbows and placed the arms symmetrically beside the head. The patient performed overhead squat position (the knee angle was 90 degrees), the feet were forward and the knees were aligned with the feet (second and third toes). The legs and arms were aligned with the trunk (11, 12). Time of the test was 30 seconds. The Acumar ACU001 digital dual inclinometer gauge was used to measure knee joint angle (18, 19). The Win FDM-S stance (version 01.02.09) software was used to analyze plantar pressure variables (16, 17). The symmetry index of plantar pressure between the two feet was calculated by the equation of $SI = \frac{right\ force}{right\ force + left\ force}$. The symmetry index of plantar pressure between back and forefoot was calculated by the equation of $SI = \frac{forward\ force}{forward\ force + backward\ force}$. The amount of force in all items was in terms of body weight percentage (16, 17). (Figure 2)

## Statistical Analysis

Shapiro-Wilk test was used to determine the normal distribution of data. The Pearson correlation coefficient was used to examine the relationship between pain and plantar pressure variables, and Independent t-test was used to compare these variables between men and women. Data were analyzed by SPSS version 20 software and the significance level was $\alpha = 0.05$.

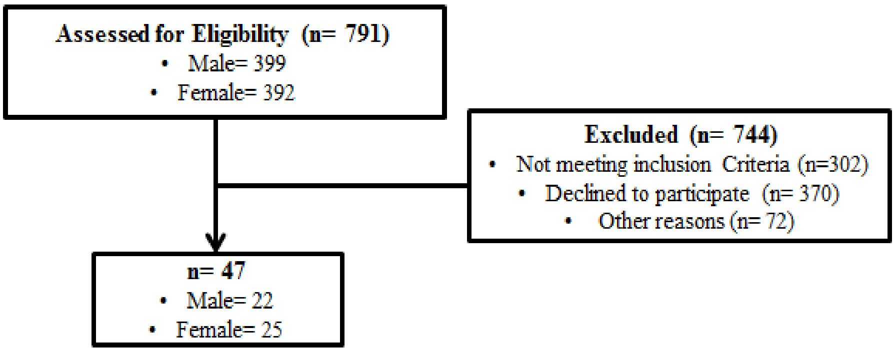


**Figure 1.** Sample selection diagram

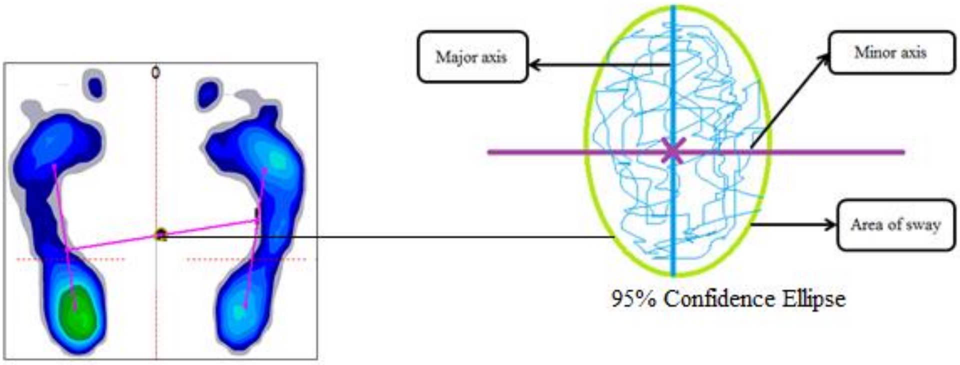


**Figure 2.** Average force distribution and COP sway

## Results

Demographic information including: age, height, weight, VAS (Visual Analogue Scale) Index, BMI, Lumbar Arch Index and pain index are listed in Table 1. Results of independent t-test and correlation of COP variables with VAS are listed in Table 2.

Results of independent t-test showed that in length of minor axis, length of major axis, velocity of sway and standard deviation of Y, there was no significant difference between males and females. Also, results of independent t-test showed a significant difference in the area of sway, path length and standard deviation X between males and females.

Results of Pearson correlation coefficient showed that the length of minor axis in the males had a significant correlation with the pain intensity, but no significant relationship was observed among females. The length of major axis and the area of sway showed a significant correlation with the pain intensity in males and females. Also relationship of path length and the pain intensity in the males was not significant, but there was a significant relationship in the females. The velocity of sway index had a significant relationship with the pain in males and females. The relationship between pain intensity and standard deviation X was significant in males, but there was no significant relationship in the females. Also, there was no significant relationship between pain intensity and standard deviation Y in males and females.

Results of independent t-test and correlation of plantar pressure symmetry with pain intensity are listed in Table3. Results indicated that no significant difference was observed between males and females. Results showed that the relationship of all symmetry indices with pain severity was not significant in males and females except the symmetry of fore and back of left foot with pain severity in males.

**Table 1.**Demographic information (mean ± standard deviation)

| Group | n | Age (years) | Height (cm) | Weight (kg) | VAS | BMI | LAI (deg) |
|---|---|---|---|---|---|---|---|
| **Male** | 22 | 21±1.73 | 175.45±7.84 | 68.96±9.03 | 4.70±1.85 | 22.41±2.31 | 29.91±4.32 |
| **Female** | 25 | 22.35±1.94 | 161.79±6.09 | 56.73±8.65 | 5.87±1.45 | 21.62±3.09 | 30.85±5.15 |

LAI: Lumbar Arch Index. VAS: Visual Analogue Scale of pain

**Table 2.** Correlation of COP variables with VAS in results of 95% confidence Ellipse and Center of Pressure (COP) sway

Results of 95% Confidence Ellipse

| Variable | GROUP | M±SD | t | Sig | r | Sig |
|---|---|---|---|---|---|---|
| **Length of minor axis (mm)** | Male | 18.10±10.36 | 0.657 | 0.517 | 0.685 | 0.020* |
| | Female | 22.29±15.34 | | | 0.345 | 0.227 |
| **Length of major axis (mm)** | Male | 38.28±17.46 | 0.567 | 0.576 | 0.621 | 0.041* |
| | Female | 46.97±28.82 | | | 0.655 | 0.011* |
| **Area (mm^2)** | Male | 398.84±56.91 | 2.18 | 0.042* | 0.978 | 0.0001* |
| | Female | 979.34±286.92 | | | 0.681 | 0.007* |
| **Results of Center of Pressure (COP) sway** | | | | | | |
| **Path Length (mm)** | Male | 522.48±96.71 | 2.15 | 0.044* | 0.596 | 0.053 |
| | Female | 947.53±202.58 | | | 0.802 | 0.001* |
| **Velocity (mm/sec)** | Male | 23.63±18.38 | 1.29 | 0.208 | 0.673 | 0.023* |
| | Female | 35.23±16.25 | | | 0.677 | 0.008* |
| **Standard Deviation X (mm)** | Male | 10.40±8.06 | 2.16 | 0.043* | 0.607 | 0.048* |
| | Female | 29.14±18.30 | | | 0.408 | 0.147 |
| **Standard Deviation Y (mm)** | Male | 54.55±21.56 | 0.503 | 0.620 | 0.408 | 0.213 |
| | Female | 47.88±33.87 | | | 0.122 | 0.677 |

*: Indicates significant difference ($p < 0.05$).

**Table 3.** Correlation variables of Symmetry with VAS in results of symmetry of plantar pressure (% pressure) Abbreviations: S was used for Symmetry; F&B were used for Fore & Back of foot.

| Variable | GROUP | M±SD | t | Sig | r | Sig |
|---|---|---|---|---|---|---|
| **S of Left & Right** | Male | 0.525±0.038 | 1.98 | 0.063 | 0.451 | 0.163 |
| | Female | 0.464±0.126 | | | -0.371 | 0.191 |
| **S of F & B (Right)** | Male | 0.544±0.195 | 0.215 | 0.832 | 0.207 | 0.542 |
| | Female | 0.566±0.209 | | | 0.431 | 0.124 |
| **S of F & B (Left)** | Male | 0.682±0.177 | 1.15 | 0.262 | 0.603 | 0.049* |
| | Female | 0.559±0.244 | | | 0.313 | 0.275 |

*: Indicates significant difference ($p < 0.05$).

## Discussion

The aim of this study was to evaluate the relationship of pain with plantar pressure variables and also to compare these variables among male and female athletes with CNLBP. Concerning the correlation between the pain intensity and the COP variables, results showed that the length of minor axis in males had a positive and significant correlation with the pain intensity, but there was no significant relationship in females. The length of major axis and the area of sway showed a significant and positive correlation in the pain intensity between males and females. In addition, the relationship between path length and the pain intensity in the males was not significant, but there was a positive and significant relationship in the females. The velocity of sway index had a positive and significant relationship with the pain between the males and the females. The relationship between the pain and the standard deviation X in males was significant and positive, but it was not significant in the females. There was also no significant relationship between the standard deviation Y and pain. The results showed that most of the COP variables had a positive and significant relationship with the pain, which means increased pain intensity and elevated postural oscillations. Concerning the symmetry of plantar pressure variables, the results showed that only the symmetry of forefoot and backfoot of left foot index in the males had a significant correlation with the pain intensity. The results of this study are consistent with some previous studies regarding the correlations of the pain and the postural oscillations (8,20-22). Oyarzo et al. compared the postural control in elite athletes with and without LBP (20). The results of their research showed that people with LBP used more energy to maintain the balance and had a greater displacement of the COP than healthy subjects, and collectively stated that the elite athletes with LBP are impaired in their balance indices (20). Sung et al. showed that the postural control of people with LBP is faced with more problem compared with healthy people (21). Mazaheri et al. argued that the postural sway is associated with the pain, and the LBP causes an increase in oscillation (22). Other studies did not show a strong correlation between the pain and the postural control (23, 24). Maribo et al. showed a poor relationship between the COP variables and the pain. Among the COP indices, only velocity and anterior-posterior displacement were studied in this study (23). Golbakhsh et al. concluded that there was no difference in the control of the lumbar and pelvic regions between individuals with and without LBP (24). Ainscough-Potts et al. stated that in people with LBP, transverse abdominis and other core muscles are weakened, as this dysfunction in the core region disturbs the postural control (25). The pain causes dysfunction in contractions of these muscles and thus overcomes postural control (26). Eventually, the postural oscillations increase with raising the pain severity. Butowicz et al. also argued that the postural defects are associated with poor deep muscles (27). In people with LBP, the use of ankle proprioception is predominant in the postural control and the lumbar proprioception is used less, and is associated with the development and recurrence of the LBP (28).

Results showed no significant difference in minor axis and major axis indices between the male and female athletes with chronic LBP, but there was a significant difference in the area of sway between males and females as well as the area of sway in the females was more than males. Also, results revealed a significant difference in path length and standard deviation X indices between the males and females and the values of these indices were higher in females than in males, but no significant difference was found in the velocity of sway and standard deviation Y indices.

The independent t-test results in the symmetry of plantar pressure showed no significant difference between the males and females. As a result, it can be concluded that there is a significant difference in some of the COP variables between the males and females and the rate of oscillation in most COP sway variables in females is larger than in males. Larivière et al. examined the effect of gender and LBP on trunk postural control and concluded that the males had better postural control (29).

This study has its own limitations. First, lack of a healthy group for comparing variables with the group suffering from the LBP as the main objective of this study was to examine the relationship between the LBP and the level of plantar pressure variables. In this regard, the need for a healthy group was not felt. As well as the presence of postural sway in people with LBP had been indicated in previous studies, as this study compared the males and the females to express sex differences in these variables.

## Conclusion

According to the results obtained in this study, it can be concluded that many of the COP variables in the males and females had a positive and significant relationship with the pain. Also, results of COP variables showed that the females had more sway than males. As a result, it can be stated that the LBP is a factor that can impair the postural control, resulting in increased risk of injury among the athletes with LBP, especially in the females.

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## Conflict of interest statement

The authors declare that there is no conflict of interest.

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