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Core Muscle Endurance and Its Association with Factors Contributing to Low Back Pain Development

Abbasi Saeedeh[1], Minoonejad Hooman[1*], Mousavi Seyed Hamed[1]

1. Department of Sports Injury and Biomechanics, Faculty of Sport Sciences and Health, University of Tehran, Tehran, Iran.

Corresponding Author's Email: h.minoonejad@ut.ac.ir

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Abstract

Background: Low back pain (LBP) is common, especially among individuals known as pain developers (PDs), who experience discomfort during prolonged standing without a prior LBP history. Lumbar lordosis and hip abductor strength are linked to LBP development, while core muscle endurance is vital for spinal stability and could prevent LBP.

Aim: This study aimed to assess the relationship between core muscle endurance, pain onset during prolonged standing, hip abductor strength, and lumbar lordosis in PDs.

Materials and Methods: Twenty-four female PDs participated, with core endurance measured via the McGill test battery, hip abductor strength assessed through the Active Hip Abduction (AHAbd) test, and lumbar curvature analyzed using photographic imaging.

Results: A significant positive correlation was identified between core muscle endurance and pain onset time (r = 0.46, p = 0.04). Participants with lower core endurance experienced earlier pain onset. However, no significant relationships were found between lumbar lordosis, AHAbd scores, and McGill test results, suggesting core endurance plays a crucial role in LBP prevention.

Conclusion: This study underscores the importance of core muscle endurance in reducing the risk of LBP development. Strengthening core muscles may serve as a viable preventive strategy for individuals prone to LBP.

Keywords: Low back pain, Pain Developers, Core Endurance, McGill Test, Hip abduction, Pain, Lumbar Lordosis.

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1. Introduction

Low Back Pain (LBP) is a prevalent and debilitating condition worldwide, affecting individuals under 45 years old (1,2). Its prevalence varies significantly, with risk factors including anthropometric characteristics, reduced spinal mobility, and psychological factors (3,4). The results suggest that standing in more lumbar lordosis may be a risk factor for low back pain development during prolonged periods of standing (5) and it is mentioned that the first experience of back pain can be a significant predictor of chronic low back pain (CLBP) later in life. Identifying factors that influence the early onset of back pain in younger individuals is crucial for preventing the progression to LBP (4). Prolonged standing is one of the factors that often leading to pain after 30 to 45 minutes (3,6). Studies have reported a prevalence of 31% to 80% of LBP due to prolonged standing, primarily among individuals aged 18 to 35 years (7–15).

The Visual Analog Score (VAS) during prolonged standing protocol is used to identify Pain Developers (PDs) (7,13–18), but results are not always conclusive (16,19), so the Active Hip Abduction (AHAbd) test can help with this screening (16,17,19). It evaluates the ability to maintain pelvic and lumbar alignment in an unstable position, which can be challenging for those with poor trunk control (17). A positive test score strongly predicts LBP during prolonged standing, with reported accuracy of 0.83 and sensitivity of 0.41 (20)(17). A meta-analysis study highlights the importance of considering various anthropometric, structural, psychological, postural, and muscular dimensions in identifying PD and designing preventive measures (11,14,18,20–25).

Previous researches showed that a decrease in the endurance of the trunk muscles can be related to an increase in the risk of back pain (26–28). It showed that a decrease in the endurance of the core muscles may be related to an increase in lumbar lordosis and, as a result, back pain (29). Various tests have been developed to evaluate this endurance, the McGill tests being particularly reliable for assessing core endurance and trunk stability (30).

This study aims to evaluate core muscle endurance in PD using the McGill tests. Additionally, it explores the relationship between core endurance, lumbar lordosis, AHAbd score , and the onset of LBP during prolonged standing. The findings from this research could inform the development of targeted preventive measures for individuals at risk of LBP during prolonged standing especially in individuals who are required to stand for prolonged periods due to their occupation.

2. Methods and Materials

2.1. Participation

A total of 24 female PDs (selected from an initial pool of 60) participated in this study. The Baecke questionnaire was utilized to assess habitual physical activity and exclude individuals classified as active or elite, with scores exceeding 13 (31) . Participants were eligible for the prolonged standing protocol if they had no lifetime history of low back pain (LBP) episodes that resulted in seeking any form of health intervention (e.g., from a physician, physical therapist, or chiropractor), missing three or more consecutive days of work or school, or altering daily living activities for three or more consecutive days. Participants were excluded if they had employment involving standing in one place for more than 1 hour per day in the past 12 months, were unable to stand for more than 4 hours, had a body mass index (BMI) greater than 30, or reported any symptoms of LBP at the start of the standing task. Those reporting any symptoms of LBP, defined as a score above 0 mm on the Visual Analog Scale (VAS) at the beginning of the standing protocol, were excluded from the study (5,32). All participants read and signed an informed consent form that was approved by the Ethical Committee of the University of Tehran.

2.2. Instrument

2.2.1. The Baecke questionnaire

The Baeck Physical Activity Questionnaire is a 16-item Likert-scale tool developed to evaluate physical activity levels comprehensively. It captures information in two primary domains: workplace activity and leisure-time activity, focusing on both the type and the frequency of physical exercise. The questionnaire assesses consistent physical activities over the past 12 months, providing a meaningful index of activity levels. Scores higher than 13 indicate individuals who are physically active, while scores below 13 classify individuals as less active. Scores above 15 represent individuals with high or excessive levels of physical activity, which may warrant further evaluation for potential health risks. The Baeck Questionnaire has demonstrated high validity and reliability, with a reported reliability coefficient of 0.8, making it a trusted tool for assessing long-term physical activity patterns in diverse populations (33).

2.2.2. Camera

The lumbar lordosis angle was assessed using photogrammetry with a Panasonic digital camera. Three retro-reflective markers were placed on the participant's skin overlying the spinous processes of the relevant vertebrae (5). The positions of these markers, recorded before the start of the 2-hour standing protocol, were used to calculate the baseline lumbar lordosis angle.

2.2.3. Kinovea Software

Lumbar lordosis was measured using Kinovea software through lateral-view photographs taken while participants stood in a natural posture. Infrared markers were positioned at specific anatomical landmarks, and the photographs were analyzed using the software. Kinovea's tools, including the virtual goniometer, were employed to draw lines between the markers, allowing for precise calculation of the lumbar curvature angle (34).

2.2.4. *Prolonged Standing Protocol*

participants were positioned in front of a work table in a (50 cm x 40 cm) confined workspace. The table was adjusted to 5 cm below the participant's wrist while his or her elbows were flexed to 90° . Participants then stood for 2 hours performing simulated light work tasks such as solving puzzles, assembling parts, etc. The work tasks and quiet standing were completed in 15-minute blocks of time with the order of tasks randomized prior to the start of standing. Participants were allowed to shift their weight as often as desired but were told to keep both feet on the ground the majority of the time, and were not allowed to rest their feet on the legs of the table or arms on the surface of the table (5,17,20,35). Subjects reported their level of perception of their back pain in 100 mm VAS every 15 minutes (17).

2.2.5. *Visual Analog Score (VAS)*

Pain intensity during the prolonged standing protocol was assessed using a VAS ruler. This scale consists of a 100 mm line, with "no pain" written on the left end and "most severe pain" on the right end. Participants were instructed to mark a point along the line corresponding to their perceived pain level, with the distance in millimeters from the left end representing the pain intensity score(36).

2.2.6. *The Active Hip Abduction (AHAbd) test*

The individuals were positioned in a supine lying posture, with both lower limbs fully extended and aligned with the trunk. The pelvis was positioned in the frontal plane, ensuring it was perpendicular to the support surface. Participants were then instructed to perform a single active hip abduction, keeping the knee extended and the lower limb aligned with the trunk, while maintaining the frontal plane alignment of the pelvis. The specific instruction provided was: "Please keep your knee straight, raise your top thigh and leg towards the ceiling, ensuring they remain in line with your body, and avoid tipping your pelvis forward or backward." (17). The scoring for this test ranges from 0 to 3, with 0 indicating complete control of the pelvis in the frontal plane and 3 indicating severe instability in maintaining pelvic alignment (S1.Table). This test was designed to assess the individual's ability to stabilize the pelvis, a key factor in preventing LBP (17,20,37).

2.2.7. *McGill core endurance tests*

The study employed several standardized tests to assess core muscle endurance (38):

1. Sorensen Test: Assessed the endurance of the back muscles (Figure 1.a).

2. Flexor Trunk Test: Evaluated the endurance of the trunk flexor muscles, primarily the abdominal muscles and hip flexors (Figure 1.b).

3. Lateral Plank: Measured the endurance of the oblique muscles on both sides of the abdomen (Figure 1.c).

4. Front Plank: Assessed the endurance of the abdominal muscles (Figure 1.d).

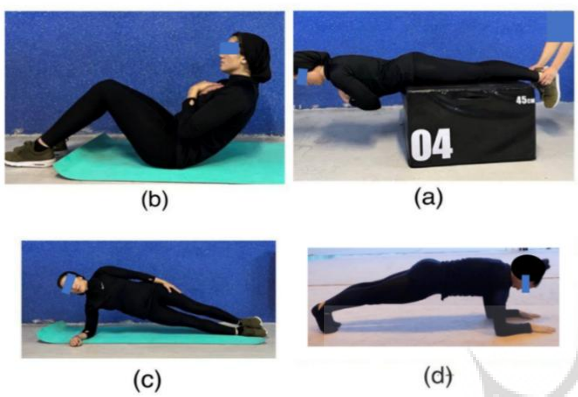

Figure 1. (a): Sorensen; (b): flexor trunk; (c): right or left plank; (d): front plank.

2.3. Procedure

All participants meeting the inclusion criteria were invited to the laboratory. At baseline, prior to the 2-hour standing period, retro-reflective markers were placed on the participant's skin, superficial to the spinous processes of the first (L1), third (L3), and fifth (L5) lumbar vertebrae (5). Participants then stood naturally in the center of the capture volume, and marker positions were captured using a camera. These marker positions, recorded prior to the 2-hour standing period, were used to calculate baseline lumbar lordosis using Kinovea software (5,10). Following the collection of the marker positions, markers were removed, and participants then proceeded with the prolonged standing protocol, which was used to classify individuals as either PD or NPD (17,20,35). A subject was classified as PD if their VAS pain score exceeded 10 mm during the standing procedure (39–41). At baseline and every 15 minutes during the standing test, participants reported the intensity of their LBP symptoms using the VAS (17). As shown in Table 1, participants often experienced their first pain at minute twenty of standing. After the rest, the AHAbd test for both legs were performed. One day later, to prevent muscle fatigue, participants completed the McGill core endurance tests in the laboratory, which included the front plank, Sorensen test, and lateral plank. Each test was conducted under standardized conditions, with participants holding each position for as long as possible. The time was recorded until participants could no longer maintain the correct form.

2.4. Statistic

All statistical analyses were conducted using SPSS Version 24.0 for Windows 10. The normality of the distribution of variables was assessed using the one-sample Shapiro-Wilk test. Correlations between core endurance, lumbar lordosis, AHAbd scores, and the pain onset during standing were analyzed using Pearson's correlation coefficients. The level of significance was set at 0.05.

3. Results

3.1. Demographic Data

The demographic data of the participants are presented in Table 1.

Table 1. Demographic Information. Means ($\bar{x}$) and Standard Deviations (SD) of Age, Height, Weight, BMI, and Written Outcome Measure Scores. Outcome Measures Include: Beck Questionnaire.

Index	$\bar{x}$ ±SD
Age(year)	29.15±3.68
Height(cm)	164.35±4.76
Weight (kg):	60.14±8.50
BMI (kg/m²)	22.28±3.26
Beck Q	9.36±1.80

3.2. Correlations

3.2.1. Core Endurance and Lumbar Lordosis

No significant correlations were found between lumbar lordosis and core endurance test scores (r = - 0.109, p = 0.64), including the Sorensen test (r = - 0.05, p = 0.83) and the flexor trunk test (r = - 0.02, p = 0.92).

3.2.2. Core Endurance and Pain Onset

There was a significant positive correlation between the total McGill endurance time and the onset of pain during standing (r = 0.46, p = 0.04), indicating that lower core endurance is associated with an earlier onset of pain. Specifically, the Sorensen test also showed a significant positive correlation with pain onset (r = 0.44, p = 0.05). The flexor trunk test exhibited the strongest significant positive correlation with pain onset (r = 0.48, p = 0.02). The front plank test, however, had a non-significant correlation with pain onset (r = 0.31, p = 0.17).

3.2.3. Core Endurance and Hip Abduction

No significant correlations were found between core endurance test scores and abduction tests (r = - 0.195, p = 0.40), including the right plank test with the right abduction test (r = - 0.154, p = 0.51) and the left side (r = 0.098, p = 0.68).

Table 2. Descriptive Statistics and Normality Testing for Core Endurance and Lumbar Parameters

$\bar{x}$ ±SD	Normality (Shapiro-wilk)	Index
195.54±151.41	0.00	McGill tests time (s)
41.17±27.20	0.01	Front plank (s)
39.45±24.40	0.01	Sorensen's test(s)
66.88±84.17	0.00	Flexor trunk (s)
26.02±17.63	0.006	Lateral plank (Right) (s)
22.02±11.40	0.05*	Lateral plank (Left) (s)
20.6±10.55	0.23*	Pain Onset (min)
23.95±5.03	0.51*	Lumbar Lordosis (˚)
2.2±0.69	0.001	AHAbd test (Right)(score)
1.85±0.36	0.00	AHAbd test (Left) (score)

*P>0.05

Table 3. Correlations Between Core Endurance Tests, Lumbar Lordosis, and Pain Onset During Standing

Variable 1	Variable 2	Correlation coefficient	Significant level (p-value)
McGill time	Lumbar Lordosis	-0.109	0.64
McGill time	Pain Onset	0.46	0.04*
McGill time	AHAbd test (Mean R & L)	-0.195	0.40
Sorensen test	Pain Onset	0.44	0.05*
Front Plank	Pain Onset	0.31	0.17
Flexor Trunk	Pain Onset	0.48	0.02*
Sorensen test	Lumbar Lordosis	-0.05	0.83
Flexor Trunk	Lumbar Lordosis	-0.02	0.92

Right Plank	AHAbd test (Right)	-0.154	0.51
Left Plank	AHAbd test (Left)	0.098	0.68

*P<0.05

4. Discussion

This study sought to elucidate the relationships among core muscle endurance, lumbar lordosis, hip abduction, and the onset of pain during prolonged standing in PDs. The findings provide critical insights into the multifactorial nature of LBP during standing and its association with biomechanical and muscular factors.

4.1. Core Endurance and Lumbar Lordosis

The findings of this study revealed no significant correlation between lumbar lordosis and core muscle endurance. This contrasts with some previous studies that highlighted a direct relationship between lumbar lordosis and core function (42) . However, other research has similarly suggested that lumbar lordosis alone may not be a definitive marker for spinal health or its link to pain (43). One potential explanation for the lack of correlation observed could be the structural variability and muscular adaptations across individuals. For instance, previous studies have emphasized that factors like gluteal muscle strength and pelvic alignment may have a greater impact on lumbar lordosis and its association with pain (44,45).

4.2. Core Endurance and Pain Onset

The significant association between core muscle endurance and delayed pain onset suggests that improving these muscles can be an effective strategy for managing LBP in PDs. Specifically, the positive correlations observed between the Sorensen test (r = 0.44, p = 0.05) and the flexor trunk test (r = 0.48, p = 0.02) with pain onset align with previous research findings (46). These results underscore the protective role of core endurance in mitigating the onset of pain, suggesting that individuals with better endurance in trunk flexor and extensor muscles are more resilient during standing tasks.

However, the non-significant results of other core endurance tests, such as the front plank and side plank, may indicate that these tests predominantly target superficial muscles, whereas deeper muscles like the transversus abdominis and multifidus might play a more critical role in pain prevention. Studies on healthy individuals have similarly highlighted the importance of core endurance for spinal stability, though its effects may manifest less in pain-related outcomes among healthy populations (43).

4.3. Core Endurance and Hip Abduction

The results showed minimal correlations between core endurance and the AHAbd test, which assesses pelvic stability. For instance, the right plank and right AHAbd score exhibited a non-significant negative trend (r = - 0.154, p = 0.51). This finding does not align with studies that emphasize the critical role of gluteal and core muscles in maintaining pelvic stability (47).

One possible explanation for this lack of association is that pelvic stability and core endurance may be influenced by different factors. For example, pelvic stability might rely more on the strength of the gluteus medius and maximus rather than core muscles (48). The absence of a healthy control group further limits the interpretation of whether this relationship is unique to PDs or generalizable to healthy populations. Since healthy individuals typically do not experience back pain during prolonged standing, and pain onset was one of the key factors in this study's correlation, they were not included in the testing.

5. Conclusions

This study demonstrates that core muscle endurance can delay pain onset in individuals with PDs; however, its relationship with lumbar lordosis and pelvic stability remains less clear. These findings highlight the multifactorial nature of LBP and the need for further studies comparing healthy and PD populations. Future research should utilize dynamic assessments, and perform simultaneous biomechanical-muscular analyses to better elucidate these relationships. Additionally, interventions targeting deep core muscles and pelvic stabilizers may prove more effective in managing and preventing LBP.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design, data analysis, and experimental procedures.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

This study was conducted in accordance with ethical standards, and the research protocol was approved by the Ethical Committee of the University of Tehran, Faculty of Sport Sciences and Health, under the code (IR.UT.SPORT.REC.1402.038). All participants provided informed consent before participation

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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Supplementary File (uploaded)

S1 Table. Scoring criteria of active thigh abduction test (AHAbd)