Core Muscles Endurance in Sedentary Staffs with and without Nonspecific Chronic Low Back: A Cross-sectional Study

N. Haddadi Esfahani¹,², J. Dommerholt³,⁴, Z. Sadat Rezaeian¹

¹ Musculoskeletal Research Center and Department of Physical Therapy, Rehabilitation Sciences Research Institute, Faculty of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran
² Student Research Committee of Rehabilitation Students (Treata), Faculty of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran
³ Bethesda Physiocare, Inc, Bethesda, MD, USA
⁴ School of Medicine, University of Maryland, Baltimore, MD, USA

SUMMARY

Background. Musculoskeletal dysfunction is one of the most important occupational health issues. Prolonged sitting may be a risk factor for low back pain (LBP) associated with reduced muscle endurance, although many people with a sedentary lifestyle and sitting-type job report no pain and discomfort in the lumbar region. In the present study, endurance of the core muscles in individuals with sedentary jobs with nonspecific chronic LBP were compared with those without LBP.

Objective. The present study compared core muscle endurance in individuals with sedentary jobs with and without nonspecific chronic low back pain.

Methods. A total of 50 sedentary staffs were selected and divided into LBP and control group. Trunk muscle endurance was measured in seconds using the McGill's trunk flexor endurance test, the Sorenson's trunk extensor endurance test, and the right and left trunk flexor endurance test (Side-bridge test). Differences between the two groups were analyzed using multivariate general linear models in 2 ways ANOVA.

Results. There were no significant between-group differences in the raw endurance of the extensor, flexor, right/ left flexor muscles (P ≥ 0.05). However, there were significant between-group differences in some self-reported physical fitness subscales (P < 0.05), duration of sitting at home (P = 0.035), frequency of assuming a slump sitting position (P = 0.049), and sitting with leaning back to the backrest (P = 0.02) at work. We developed uni- and multivariate general linear models, which showed adjustments to these parameters and unmasked fundamental between-group differences in extensor muscle endurance.

Conclusions. Our finding does not support the popular opinion that daily sitting-while-at-work for long durations is necessarily associated with LBP. Instead, sitting posture, lower physical fitness levels, and shorter duration of sitting activities at home may be associated with reduced extensor muscle endurance in nonspecific chronic low back pain.

KEY WORDS

Core muscle; Endurance; McGill tests; Nonspecific Chronic Low Back Pain; Sedentary Occupation.

IMPACT STATEMENT

Clinical Relevance: considering the association of LBP with sitting posture at work, sitting duration at home and level of physical fitness, it seems that back school programs to educate staff preventing this predisposing factors may help the care service to reduce sick leaves due to LBP.

What is known about this subject? Sitting for long time may be associated with increased LBP reports in staffs.

What this study adds to existing knowledge? Previous studies clearly distinguish how long-time sitting at work increased the prevalence of LBP in staff. In present study, for the first time, numerous background and sitting habits were self-reported by the participants. The correlation of these demographic and habitual factors with LBP was investigated in comparison to staffs of the same work background who did not suffer from LBP. The results are the first evidence that long duration sitting at work does not necessarily result in chronic LBP if correct sitting posture is followed and the subject be consistent in saving an acceptable level of general physical fitness.
BACKGROUND

Modern life has pushed human societies toward sedentary lifestyles (1, 2). A sitting lifestyle may be one of the most critical public health problems in the 21st century (3). Due to the lower centre of gravity and a wider base of support, sitting is a comfortable posture imposing low energy consumption (4). Likewise, performing daily activities in a sitting position contributes to a sedentary lifestyle.

Using computers has been increased considerably at home and at work during last recent decades (5, 6), as basic computer skills is now an essential requirement for all administrative occupations (7). In the industrial countries, two thirds of the employees work with computers (8). World Statistics Institute reported that using computers in a week increased from 5.9 hours in 1997 to 14.6 hours in 2003 (9). Considerable advances in technology, such as automation systems, have caused decrement in physical activity and resulted in lack of mobility in the work environments (10, 11).

Those individuals who do not have any physical activity are in the nonmoving or sedentary group (12). The activities of energy expenditure between 1.0-1.5 METS (Multiples of the basal metabolic rate) are classified as sedentary behaviors (12). Light intensity activity behaviors require expenditure of no more than 2.9 METs. Moderate-to-vigorous physical activity requires an energy expenditure of 3 to 8 METs. Medium to high level of activity are recommended for prevention and treatment of many chronic diseases (13).

A sedentary lifestyle increases the risk of musculoskeletal problems (5, 12). Maintaining the same position for extended periods may impose creep and deformation in soft tissues (14); however, the duration of sustained positions to cause creep or deformation varies (15).

Working in sitting positions imposes the period that the individual is not moving considerably. The employees in the administrative jobs are basically considered to suffer from lack of motion (16) since they sat one third to half of their working hours (13). Individuals in the industrial countries usually sit for many hours. For example in the United States and Australia about two thirds of the adults are occupied and 83% of these individuals work more than 35 hours a week (12). In Australia, the proportion of businesses with internet access raised from 29% in 1994 to 90% in 2008-2009 (16).

Low mobility increases the risk of musculoskeletal system complications (5, 12). World Health Organization defines musculoskeletal damages as damage to muscle, tendon, nerves, and vessels that is created or worsened due to the repetitive or long-term use of one part of the body (17, 18). Soft tissues adapt to fix postures as a result of creep and tissue mal-alignments (14). The time period at which maintaining a fixed posture will impose musculoskeletal adaptations varies according to the type of the positions. For example, this period is 60 to 85 minutes for sitting continuously per day (15). Long-term sitting changes muscular patterns and create skeletal problems and muscular pains (5, 19, 20). Prolonged sitting may result in increased disk load (21), lumbar spine weakness (22), changes in muscle activity and activation patterns, and a decrease of the endurance of core muscles (5, 19, 20), and therefore, predispose low back pain (LBP) (23-27).

Stabilization of trunk flexors and extensors are essential for normal lumbopelvic function (28). These muscles, known as “core muscles”, have a basic role in balance and coordination in sitting (29). The core is the lumbopelvic-hip complex which includes lumbar spine, pelvis, hips, and their respective musculature. On the other hand, core stability is critical for trunk and extremities movements as well (30). Pattern of core activity changes in sitting (31, 32) and dysfunction of core muscles increased the risk of damage of the upper and lower extremities segments (32). Powerful core muscles support stabilizes the vertebra and pelvis, prevents balance disorders (29) and decreases the rate of LBP which is one of the most prevalent occupational disorders (33).

Rapid change of the human lifestyle toward a computerized automated modern life dragged the research interests toward predicting long term consequences of adopting this lifestyle. Many studies investigated the role of core muscles properties on the individuals’ health and performance. Core muscles endurance is a key element for improving body health and fitness (34). Lower endurance of back extensor muscles is now evident in people who suffer from low back pain (35, 36) and their endurance has stronger correlation and predictive value with LBP than their strength (37). In the same way, normal endurance of trunk flexor muscles has important role in the normal lumbopelvic function in LBP clients (38).

In the present body of literature fixed prolonged sitting posture is a predisposing factor for LBP (24). In a study in 2005 (39), trunk muscle endurance was significantly lower in LBP clients than healthy matched individuals, thus they recommended trunk muscle endurance as a predictor for individual’s susceptibility to LBP. Another study in 2009 showed that people with standing jobs that require some sitting intervals were less exposed to LBP compared to those who were permanently working in standing (40). The individuals who had to sit permanently were also more exposed to LBP compared to those who had the chance for movement and standing up in their work hours; that confirms the negative consequences of working in a fixed position (40).
Nevertheless, since many individuals with sedentary jobs do not complain about lumbar pain and discomfort, perhaps this assumption is not substantiated. This fact highlights the hypothesis that core muscle endurance may not be different between these people and those sedentary staffs who suffer from LBP. The present study compared core muscle endurance in individuals with sedentary jobs with and without nonspecific chronic LBP using McGill tests. In previously published research, the minimum number of repetitions of the McGill tests in people suffering from nonspecific chronic LBP was determined (41).

MATERIALS AND METHODS
This study was a non-experimental (observational), cross-sectional and analytical study investigating core muscle endurance in sedentary individuals, who were in a sedentary position for at least half of their working hours during the past year (41).

Participants and sample size
The sample was selected from volunteers, with and without nonspecific chronic LBP aged 25-50 years (39), who had sedentary jobs in Isfahan administrative organizations. The target population consisted of people with at least four years of work experience with at least half of their working time in sitting postures (37). Subjects were recruited through advertising in public and private organizations of Isfahan and from the client list of the Musculoskeletal Research Centre database from August 21, 2016, until March 17, 2017. Using G*Power software (Version 3.1.5, University of Düsseldorf, Düsseldorf, Germany) (42) with $\alpha = 0.05$, $\beta = 0.8$, at least 50 subjects with and without nonspecific chronic LBP were needed to be included according to Arab et al. (39). Subjects with nonspecific chronic LBP had at least six weeks of continuous pain or three separate periods of pain with at least one week of continuous pain in each period (43). LBP was required to occur following their current employment. Diagnosis of nonspecific chronic LBP was confirmed by an orthopaedic specialist who was blind to our study protocol. Subjects were excluded from the study for any of the following characteristics: active lifestyle (an individual who had any type of exercise activity for at least 45 min three times a week, these people were excluded as active life style may be an outlier affecting both the LBP characteristics and the core muscle biomechanics) (44, 45); systemic diseases such as rheumatoid arthritis and diabetes; neurological problems; a history of fractures; anatomical or surgical lesions in the lower limb and spine (39); a history of rehabilitative exercises in the last six months, which could have altered their core muscle endurance (36); stopping the test due to exacerbated back pain (36), pregnancy (46); taking any painkillers or opiate medication within the week leading up to the test session; pain; and upper or lower extremity problems. A physiotherapist who was unaware of the research design determined the inclusion and exclusion criteria through an in-person interview and a comprehensive clinical examination. Consultation with relevant specialists was requested as needed.

Subjects were divided into groups of subjects with nonspecific chronic LBP (LBP group) and subjects without LBP (control group). A physician who was unaware of the study design confirmed the diagnosis of nonspecific chronic LBP. The examiner responsible for determining the inclusion and exclusion criteria confirmed the physician’s diagnosis through the evaluation process. The Institutional Ethics Committee approved all stages of this study. Individuals eligible to participate in the study were given 48 hours to read and sign the informed consent form.

Measurement and data collection
After signing the ethical consent form, other data were collected, including demographic data (age and gender), body mass index (BMI measured using Portable stadiometer-scale unit, Model No. 220, Seca gmbh & Co. Germany, Precision: 1 cm, 50 gr), work experience, physical activity, sitting position (self-reported sitting time and posture is usually underestimated; (47, 48) therefore we supposed that this report can be trusted as the actual duration of sitting position is higher), secondary employment, sleep habits, and the Oswestry Disability Index (ODI Score) questionnaire. The ODI is a valid and highly reliable instrument to assist in determining the level of disability from LBP. The questionnaire consists of 10 items with answers in a 6-point Likert format. The score may vary between 10 to 50 (49). The level of physical fitness was determined by a self-assessed physical fitness instrument that is valid and reliable in people with LBP (50). It has five self-reported subclasses, including aerobic fitness, muscular strength, endurance, flexibility, and balance based on Visual Analogue Scales (VAS). The McGill tests were assigned randomly for each person using a draw to increase accuracy. McGill clinical tests consist of the flexor endurance test, the extensor endurance test, and the side-bridge endurance test (51). They are used to assess the endurance of the anterior, posterior, and lateral trunk muscles respectively. They have high reliability and validity (39, 43, 45, 52-56). The method of performing the tests has been described in detail previously (41). Time of maintaining the test position was recorded with a calibrated stopwatch (Precision: 0.17 second, Elec-
tronic Digital Timer, National Presto Industries, Inc., Eau Claire, WI, USA) for each McGill Test. Subjects completed all the tests in one session with each test repeated twice with at least five minutes of rest in between tests. The maximal score on each test was used in the statistical analysis (41).

Statistical analyses
The Shapiro-wilk test was used to determine the distribution of statistical data. The independent t-test (if data distribution followed normal distribution) and the Mann-Whitney test (if data distribution did not follow a normal distribution) were used to compare muscle endurance between groups. The correlations between demographic characteristics, motor habits, and core muscle endurance were analyzed by calculating the Pearson correlation coefficient (if the data distribution was normal) or the Spearman Rho (if the data distribution was not normal). Correlations were categorized as strong \(( r > 0.7)\), moderate \((0.7 \leq r < 0.3)\), or weak \((0.3 \leq r)\) (42). In the case of a significant difference between groups in terms of demographic and background variables, general linear models (GLM) were developed to adjust the effect of any covariate. The correlation between the endurance of four groups of core muscles was analyzed using Spearman’s Correlation Coefficient. Therefore, if more than one background variable was significantly different between groups, and the correlation coefficient was between \(0.3-0.7\), multivariate GLM would be proposed. The qualitative variables included in the models as fixed factors. The effect size was reported calculating difference between the means of the study groups divided by standard deviation of either group (Cohen \(d\)). Cohen \(d\) was labeled as very small \((= 0.01)\), small \((= 0.2)\), medium \((= 0.5)\), large \((= 0.8)\), very large \((= 1.2)\), and huge \((= 2.0)\) (47, 57). Receiver operating characteristic (ROC) curve analysis was adopted for core muscle endurance with cut off set at 0.5. The statistical analysis was performed using SPSS 21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA.) at \(\alpha = 0.05\).

RESULTS
Of 63 volunteers, 52 were included in the study. Figure 1 summarizes participants’ adherence to the study during recruitment to analysis phases. Ten people did not match the inclusion criteria; one regretted performing the McGill tests because of fear of pain. After allocation in study groups, two people were excluded from the LBP group due to severe pain during the tests. Thus, the attrition rate was 7.41% in the LBP group, 0% in the control group, and 3.85% in the whole sample. There was no missing data for this study. The demographic characteristics of the sample are presented in table I. There was no significant difference in the demographic characteristics between groups (\(P > 0.05\)) except for the duration of sitting at home, which was significantly longer in the control group (\(P = 0.035\)). Participants were purposefully selected among people with and without LBP thus
Table I. Mean values of demographic variables in study groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LBP</th>
<th>Control</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>37.6 ± 6.4</td>
<td>38.6 ± 4.4</td>
<td>0.50</td>
</tr>
<tr>
<td>Weight (kilogram)</td>
<td>71.8 ± 14.5</td>
<td>74.3 ± 13.6</td>
<td>0.53</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.6 ± 10.1</td>
<td>169.8 ± 9.4</td>
<td>0.77</td>
</tr>
<tr>
<td>Body mass index (BMI)</td>
<td>24.5 ± 2.9</td>
<td>25.6 ± 3.1</td>
<td>0.18</td>
</tr>
<tr>
<td>Oswestry disability index score</td>
<td>17.1 ± 10.4</td>
<td>3.3 ± 3.7</td>
<td>≤ 0.001*</td>
</tr>
<tr>
<td>Pain Intensity (VAS)</td>
<td>3.6 ± 0.9</td>
<td>0.0 ± 0.0</td>
<td>≤ 0.001*</td>
</tr>
<tr>
<td>Daily work duration (hours)</td>
<td>8.8 ± 1.8</td>
<td>8.5 ± 2.6</td>
<td>0.35</td>
</tr>
<tr>
<td>Time sitting at work (hours)</td>
<td>7.2 ± 2.1</td>
<td>7.2 ± 1.7</td>
<td>1</td>
</tr>
<tr>
<td>Time sitting at home (hours)</td>
<td>2.3 ± 1.3</td>
<td>3.1 ± 1.4</td>
<td>0.035*</td>
</tr>
<tr>
<td>Total Daily Sitting Time</td>
<td>9.0 ± 1.9</td>
<td>10.0 ± 2.1</td>
<td>0.28</td>
</tr>
<tr>
<td>Duration of employment in current job (year)</td>
<td>11.0 ± 6.5</td>
<td>13.2 ± 6.0</td>
<td>0.22</td>
</tr>
</tbody>
</table>

*P < 0.05.

their scores on the ODI and VAS were significantly different between groups (P ≤ 0.001). According to ODI scores, the LBP group suffered from minimal disability (49). Gender distribution, educational level, smoking history, marital status, sleep position, and secondary employment were similar in the two groups (P > 0.05, Table II).

Table II summarizes the types of sitting position: slump sitting (with the spinal column in a kyphotic posture), straight sitting (with normal spinal curvatures) on the front edge of the chair (58), straight sitting relying on the backrest, reclined sitting (posterior sitting), and forward lean sitting on the front edge of the chair with forearms on the table or desk. The Chi-square test showed that the control group used straight sitting relying on the backrest significantly more frequently than the LBP group (P = 0.02). In contrast, the frequency of other sitting habits, on the chair or the ground, was not significantly different between groups (P > 0.05). Slump sitting (the last row) presents the number of people in either group that used slump sitting at home or work or both. It was also significantly different between groups (P = 0.049). Table III summarizes the mean physical fitness subscales recorded using self-administered VAS measures.

The independent t-test showed that all self-reported physical fitness indices were lower in the LBP group. The difference was statistically significant for aerobic fitness, endurance, and balance (P < 0.05). The correlation analysis revealed that in the LBP group, the endurance of core muscles was significantly and moderately correlated with gender, height, BMI, and self-reported strength, but not with slump sitting (0.17 ≤ r ≤ 0.14, P > 0.05), the ODI score or other background variables, including sitting habits and durations (Table IV).

The control group showed different patterns of significant correlations. In contrast to the LBP group, in the control group, the endurance of the flexor muscle and the left lateral flexors showed a moderate but significant correlation with sitting duration at work (r = -0.424, P = 0.049; and r = -0.531, P = 0.008, respectively) and total sitting duration (r = -0.493, P = 0.023 and r = -0.500, P = 0.021, respectively). The Shapiro-wilk test confirmed that the distribution of the maximum score of core muscle endurance followed a normal distribution only in the left lateral flexion score in the control group and extension score in the LBP group. Therefore, core muscle endurance was compared between groups using the Mann-Whitney U test (Table V).

The maximum duration of holding each McGill test was longer in the control group, although the difference was not statistically significant (P > 0.05). Considering Cohen d, the effect size was very small on left lateral flexors endurance, small for right lateral flexor endurance, and medium for flexor and extensor endurance. Besides, the endurance of the right lateral flexors was not significantly different from that of the left lateral flexors in either group (P > 0.05). Because of the significant between-group difference of the duration of sitting at home, and some physical fitness variables, univariate general linear models were developed with adjustments to each of these background variables. However, the differences only changed the study results for the extensor muscle endurance when adjustments were made for aerobic fitness (Table VI).

The models showed that the extensor endurance might be statistically less compared to the control group when adjusted to self-reported aerobic fitness level (Partial η² = 10%, P = 0.024), and duration of daily sitting at home (Partial η² = 10%, P = 0.037). On the other hand, the Spearman's
### Table II. Background data in term of gender, education level, marital status, smoking history, sleep, and sitting position.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subgroups</th>
<th>LBP</th>
<th>Control</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>Male</td>
<td>12 (48)</td>
<td>12 (48)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>13 (52)</td>
<td>13 (52)</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>Alliterated</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Elementary</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diploma</td>
<td>1 (4)</td>
<td>3 (12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Associate’s</td>
<td>1 (4)</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bachelor’s</td>
<td>11 (44)</td>
<td>7 (28)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Master’s</td>
<td>8 (32)</td>
<td>8 (32)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PhD</td>
<td>4 (16)</td>
<td>4 (16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Missing Data</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td><strong>Smoking History</strong></td>
<td>Positive</td>
<td>2 (8)</td>
<td>1 (4)</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td>Single</td>
<td>2 (8)</td>
<td>2 (8)</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Married</td>
<td>23 (92)</td>
<td>22 (88)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Divorced</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Widow</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td><strong>Sleep position</strong></td>
<td>Supine</td>
<td>3 (12)</td>
<td>5 (20)</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Sidelying</td>
<td>15 (60)</td>
<td>16 (64)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prone</td>
<td>6 (24)</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Missing Data</td>
<td>1 (4)</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td><strong>2nd employment</strong></td>
<td>Positive</td>
<td>1 (4)</td>
<td>3 (12)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sitting on the chair</strong></td>
<td>Slump sitting</td>
<td>10 (40)</td>
<td>7 (28)</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Straight sitting on the front edge of the chair</td>
<td>4 (16)</td>
<td>6 (24)</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Straight sitting relying on the backrest</td>
<td>7 (28)</td>
<td>15 (60)</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Reclined sitting</td>
<td>8 (32)</td>
<td>6 (24)</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>Forward lean sitting on the front edge of the chair</td>
<td>7 (28)</td>
<td>12 (48)</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Sitting on the floor</strong></td>
<td>Slump sitting</td>
<td>9 (36)</td>
<td>5 (20)</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Straight sitting</td>
<td>2 (8)</td>
<td>4 (16)</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Straight sitting relying on the wall or cushion</td>
<td>9 (36)</td>
<td>12 (48)</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Reclining on wall or cushion</td>
<td>10 (40)</td>
<td>15 (60)</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>Slump sitting</strong></td>
<td>Those sat in slump position at work or at home</td>
<td>15 (60)</td>
<td>8 (32)</td>
<td>0.049*</td>
</tr>
</tbody>
</table>

*P < 0.05.

Correlation Coefficient confirmed multivariate GLMs might be developed since endurance of each core muscle was correlated with all other muscles (0.3 < r < 0.7). In the LBP group, the endurance of core muscles was correlated with acceptable correlation coefficients (0.45 < r < 0.64) except for trunk flexors and extendors (r = 0.383, P = 0.059). In the control group, there was a statistically acceptable correlation coefficient between trunk flexors and extendors (r = 0.521, P = 0.008) and a strong correlation for lateral flexors (r = 0.816, P ≤ 0.001). These results imply that multivariate GLMs may be developed regarding the control group, although the left and right lateral flexors may not be included in one model simultaneously. Besides, because of the sample size, at most three covariates might be included in GLMs. The first multivariate models were adjusted to each possible pair of background data that were significantly different between groups (self-reported aerobic fitness, endurance, balance and sitting duration at home). The results showed that only adjustments to aerobic fitness and sitting duration at home (Wilks Lambda = 0.79, F (1, 48) = 3.38, Partial η² =
Core endurance in Sedentary Staff

The results showed that only when using the left lateral flexor endurance in the model, adjustments to aerobic fitness, and sitting duration at home with inclusion of slump sitting (Wilks Lambda = 0.76, $F_{(1,47)} = 3.83$, Partial $\eta^2 = 0.24$, $P = 0.02$, $\beta = 0.78$) might unmask a significant between-group difference of the extensor endurance. The models revealed that a multivariate 2 ways (group*slump position) GLM with an adjustment to aerobic fitness, and sitting duration at home might be needed to predict the

Table III. Mean values of physical fitness variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LBP</th>
<th>Control</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic Fitness (cm)</td>
<td>5.3 ± 1.6</td>
<td>6.3 ± 1.6</td>
<td>0.03*</td>
</tr>
<tr>
<td>Muscular Strength (cm)</td>
<td>5.3 ± 1.4</td>
<td>5.9 ± 1.7</td>
<td>0.14</td>
</tr>
<tr>
<td>Endurance (cm)</td>
<td>5.1 ± 1.6</td>
<td>6.2 ± 1.7</td>
<td>0.02*</td>
</tr>
<tr>
<td>Flexibility (cm)</td>
<td>4.9 ± 1.6</td>
<td>5.6 ± 1.7</td>
<td>0.16</td>
</tr>
<tr>
<td>Balance (cm)</td>
<td>5.3 ± 1.5</td>
<td>6.3 ± 1.6</td>
<td>0.02*</td>
</tr>
</tbody>
</table>

*P < 0.05.

0.21, $P = 0.028$, $\beta = 0.72$) might reveal a significant lower extensor endurance concerning the control group. Qualitative variables are not allowed to be adjusted to in covariate models however, the frequency of sitting on the chair relying on the backrest, and sitting in slump position were significantly different between groups; thus, multivariate 2 ways ANOVA models were developed adding sitting posture and slump position separately as fix factors while adjusting the model to aerobic fitness and daily sitting duration at home.

Table IV. Spearman’s correlation coefficient for core muscle tests records and background and demographic variables.

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>Flexion</th>
<th>Extension</th>
<th>Right Lateral Flexion</th>
<th>Left Lateral Flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP</td>
<td>Age (year)</td>
<td>- 0.015 (0.945)</td>
<td>- 0.356 (0.079)</td>
<td>0.033 (0.877)</td>
<td>- 0.091 (0.666)</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.033 (0.874)</td>
<td>- 0.239 (0.250)</td>
<td>- 0.539** (0.005)</td>
<td>- 0.533** (0.006)</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>0.133 (0.326)</td>
<td>0.212 (0.309)</td>
<td>0.477* (0.016)</td>
<td>0.541** (0.005)</td>
</tr>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>- 0.069 (0.745)</td>
<td>- 0.192 (0.358)</td>
<td>0.217 (0.297)</td>
<td>0.222 (0.287)</td>
</tr>
<tr>
<td></td>
<td>BMI (kg/m2)</td>
<td>- 0.247 (0.234)</td>
<td>- 0.400* (0.048)</td>
<td>- 0.009 (0.966)</td>
<td>- 0.091 (0.666)</td>
</tr>
<tr>
<td></td>
<td>Aerobic Fitness (cm)</td>
<td>- 0.034 (0.872)</td>
<td>0.106 (0.615)</td>
<td>0.264 (0.203)</td>
<td>0.279 (0.177)</td>
</tr>
<tr>
<td></td>
<td>Muscular Strength (cm)</td>
<td>0.144 (0.493)</td>
<td>0.417* (0.038)</td>
<td>0.398* (0.049)</td>
<td>0.389 (0.055)</td>
</tr>
<tr>
<td></td>
<td>Endurance (cm)</td>
<td>0.033 (0.875)</td>
<td>0.157 (0.453)</td>
<td>0.191 (0.359)</td>
<td>0.133 (0.526)</td>
</tr>
<tr>
<td></td>
<td>Flexibility (cm)</td>
<td>0.008 (0.971)</td>
<td>0.346 (0.090)</td>
<td>0.101 (0.629)</td>
<td>0.079 (0.708)</td>
</tr>
<tr>
<td></td>
<td>Balance (cm)</td>
<td>0.128 (0.543)</td>
<td>0.144 (0.492)</td>
<td>0.103 (0.623)</td>
<td>0.179 (0.393)</td>
</tr>
<tr>
<td>Control</td>
<td>Age (year)</td>
<td>0.130 (0.537)</td>
<td>0.153 (0.467)</td>
<td>0.372 (0.067)</td>
<td>0.482* (0.015)</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.633** (0.001)</td>
<td>0.383 (0.059)</td>
<td>- 0.200 (0.338)</td>
<td>0.056 (0.792)</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>- 0.604** (0.001)</td>
<td>- 0.371 (0.068)</td>
<td>0.318 (0.121)</td>
<td>0.137 (0.515)</td>
</tr>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>- 0.642** (0.001)</td>
<td>- 0.568** (0.003)</td>
<td>0.043 (0.837)</td>
<td>- 0.019 (0.929)</td>
</tr>
<tr>
<td></td>
<td>BMI (kg/m2)</td>
<td>- 0.520** (0.008)</td>
<td>- 0.658** (≤ 0.001)</td>
<td>- 0.209 (0.316)</td>
<td>- 0.136 (0.518)</td>
</tr>
<tr>
<td></td>
<td>Aerobic Fitness (cm)</td>
<td>0.005 (0.982)</td>
<td>- 0.231 (0.266)</td>
<td>0.069 (0.745)</td>
<td>- 0.052 (0.806)</td>
</tr>
<tr>
<td></td>
<td>Muscular Strength (cm)</td>
<td>0.017 (0.934)</td>
<td>0.081 (0.701)</td>
<td>0.214 (0.305)</td>
<td>0.132 (0.529)</td>
</tr>
<tr>
<td></td>
<td>Endurance (cm)</td>
<td>0.016 (0.939)</td>
<td>0.161 (0.443)</td>
<td>0.314 (0.127)</td>
<td>0.139 (0.508)</td>
</tr>
<tr>
<td></td>
<td>Flexibility (cm)</td>
<td>0.252 (0.225)</td>
<td>0.031 (0.884)</td>
<td>0.418* (0.038)</td>
<td>0.201 (0.336)</td>
</tr>
<tr>
<td></td>
<td>Balance (cm)</td>
<td>- 0.123 (0.558)</td>
<td>- 0.006 (0.978)</td>
<td>0.352 (0.085)</td>
<td>0.072 (0.732)</td>
</tr>
</tbody>
</table>

*P values in parenthesis. *P < 0.05, **P < 0.001.
difference between core extensor muscles endurance in individuals with or without LBP.
Clearly, self-reported aerobic fitness and duration of sitting activities at home anticipated more than 20 percent of the endurance of core extensors in people suffering from LBP compared to individuals who did not complain from LBP under similar job situations. Power confirmed that negative results may not be a consequence of our sample size. The results of ROC curve analysis are shown in table VII. Only in Extensor Endurance the area under Curve was at the margin of statistical significance (p = 0.07). The thresholds that best discriminates between the presence or the absence of pain, was 76.0, With Sensitivity of 68.0 and Specificity of 60.0.

**DISCUSSION**
McGill test are used extensively in clinical practice and research to measure core muscle endurance (59-63). The flexor muscle endurance test engages the transverse abdominal muscles, the internal and external oblique muscles, and the rectus abdominis muscles (64). The extensor test recruits primarily the multifidus and iliocostalis lumbarum muscles (65) and the right and left lateral flexor tests engage primarily the quadratus lumborum muscle (54, 56). This cross-sectional study compared core muscle endurance using McGill test between subjects who were required to work in a sitting position for more than half of their work hours during the past year. A simple analysis of the maximum duration of performing McGill tests showed that...
subjects in the LBP group performed at 70-87% of subjects in the control group for trunk flexion, extension, and right lateral flexion. Although this difference was not statistically significant, it still worth noticing in the clinic. The participants did score significantly different for self-reported physical fitness, duration of sitting activities at home, and the preferred posture when sitting.

There is not a precise specific test available for measuring strength and endurance of core muscles. Researchers often recommend electromyography (EMG) methods for analyzing core strength and endurance (66). Other methods such as fine wire EMG, Ultrasonography and Isokinetic tests are highly valid and reliable as well (67–69); however, these procedures are expensive and may not be adopted in a clinical set up. Clinicians prefer cheap, easy to perform, and fast exams to evaluate core muscle function. McGill tests are fast and cheap clinical test of acceptable validity and reliability and evaluate core muscles in extension, flexion and lateral flexion (70).

In spite of excluding physically active people and athletes, subjects in the control group had statistically higher physical fitness levels for aerobic fitness, endurance, and balance, as noted on self-reported visual analogue scales. They estimated their physical capabilities at higher levels than subjects in the LBP group.

Previous studies have shown that people have lower back muscle endurance when they exercise less, watch more TV (71, 72), have lower self-efficacy (73) or lower muscular fitness (74, 75). Therefore, the results of the present study were in line with previous researches. A statistically significant decrease of extensor endurance was noted in the LBP group after univariate model adjustments to aerobic fitness. On the other hand, subjects in the LBP group suffered from minimal pain and disability based on the VAS and ODIQ, which implies that the difference may not be related to their pain levels or their pain-induced fear of being active. Further research is highly recommended to investigate physical fitness in individuals with and without nonspecific chronic LBP using objective measures. Besides, considering these parameters would seem to be required in studies that compare people with and without nonspecific chronic LBP. Slump posture while sitting and duration of daily sitting at home were the other variables with significant differences between groups. Aerobic fitness, slump posture, and duration of sitting at home were recognized as main covariates for analyzing extensor muscle endurance.

Muscular activity patterns vary in different sitting postures; and the activity of the stabilizer muscles is closely correlated with individual’s sitting posture (72). While sitting, the low back reaches terminal flexion range (72). Inappropriate sitting postures tilt the pelvis, reduce the lumbar curve, increase the load on the intervertebral disks and finally produce back pain (24). One inappropriate sitting posture is the slump position in which the pelvic is in the posterior tilt, thoracolumbar region is fully relaxed and head & neck are flexed (72).

Paravertebral muscles are postural muscles that actively save body upright and control bending in lumbar vertebrae. The activity of these muscles is limited while sitting (72); in addition, abdomen and back muscles’ activity decrease in the slump position (26, 72, 76), i.e., rate of multifidus and abdomen muscles activity reaches to the minimum thus, more stress will be imposed on the non-active tissues that support the spinal column and the pelvis (26). Reduced muscular activity in slump position is probably due to the changes in control motor patterns (77).
moderate correlation to extensor endurance. The right and left lateral flexors were moderately correlated to the individual’s height and gender. Males featured greater endurance than females. Flexor endurance showed no significant correlation to physical and anthropometric parameters in the LBP group, but in the control group, it was moderately and reversely correlated with weight, height, and BMI and greater in females. For the control group, extensor endurance was reversely correlated to weight and BMI. The difference in patterns of between-group correlations may be a consequence of the chronicity of symptoms in the LBP group.

Modern age has imposed a more sedentary lifestyle (1, 2), which in turn, may increase the risk of musculoskeletal problems (5, 12). Prolonged malposture may be one of the contributing factors to a higher prevalence of musculoskeletal problems (5, 72, 78). Proper posture may maintain the normal spinal curves even in the sitting position, while reduced spinal curvatures may increase stress in the ligamentous structures and possibly results in pain (78). Activity levels and activation pattern of muscles are different in various sitting postures. Comparing the lumbo-pelvic upright sitting posture to a thoracic upright sitting posture shows altered trunk muscle activation. During the thoracic upright posture, the global muscles, such as the thoracic erector spinae, co-activate more compared to the local spinal muscles, such as the lumbar multifidus (58). Additionally, the activity level of the thoracic erector spinae is higher in thoracic upright sitting compared to slump and lumbo-pelvic postures (79). The best sitting posture is not definitely clarified in the literature and whether there is an ideal posture continues to be surrounded by controversy among researchers and clinicians. Qualitative assessments recommended sitting with a neutral shape of the spine, which generally is comfortable and relaxed without extreme muscle tone (80, 81). Over 70% of physiotherapists considered the upright lordotic sitting posture as the optimal posture (82).

Major stakeholders in the healthcare systems around the world commonly agree that prolonged sitting is associated with a higher prevalence of LBP (25, 83-88). Sustained sitting for more than thirty minutes is considered a common aggravating factor for many people with LBP (81), although there is a lack of evidence in support of this concept (89-91). The back extensor muscles play an essential role in motor control dysfunctions, such as limited balance in LBP (92). Star excursion balance exercises are suggested as a part of treatment plan in people with CLBP (93). Similarly, the present results showed significantly lower levels of balance capabilities in the LBP group when measured by a self-report scale.

When sitting in a more balanced position, the paravertebral muscles stabilize the spine (94, 95). The activity of the back extensor muscles and multifidi are respectively 2 and 5 times and up to 10 times smaller with the slump position than with sitting with a backrest. People who frequently sit in a slump position may develop gradual weakness of the dorsal muscles, including the multifidus and erector spine muscles, which may cause instability and, ultimately, pain (32). Biomechanical studies have shown that prolonged sitting leads to slump or flexed positions of the spine (96). Creep happens following continuous or repeated spinal flexion that stretches the viscoelastic tissues of the spine (97, 98) and actuates the experience of pain and inflammation. Chronic inflammation decreases the sensitivity of muscle spindles in the trunk extensors (99) and subsequently, diminishes their endurance (72). The creep in the viscoelastic tissues expands within 20 minutes of static flexion (14). It is conceivable that prolonged sitting may move the spine into flexed sitting resulting in creep phenomena, flexion-relaxation (reduced extensor muscle activity due to a flexed posture), and fatigue of the back extensor muscles, especially the multifidus (98, 100).

The present study supported these concepts. The subjects were employed in their current position for at least the past five years. Sixty percent of the LBP subjects reported slump position on a chair or floor while 60% of the control participants reported straight sitting on chair relying on a backrest. Interestingly, the duration of sitting at home was 35% longer in the control group while the groups did not differ significantly in the sitting duration at work. The study provides evidence that prolonged sitting may not be inevitably unsafe if people adopt proper postures; however, further research is recommended.

We did not observe a statistically remarkable difference for trunk muscle endurance between the groups, although the mean muscle endurance was 23-30% less in LBP subjects for the flexors, extensors, and right lateral flexors. This difference is clinically remarkable since it provides evidence of ongoing weakness in all core muscles groups in the LBP group. Perhaps, the large standard deviations in the present study masked the underlying differences in muscle endurance. The extensor muscle endurance in the control group of the present study was significantly lower than in the study by McGill (56). Low muscle endurance in the present control group may also be a reason for insignificant differences between groups. On average, subjects in this study were 1.5 times older than the participants in the McGill study and the difference in the type of the daily activities and age may explain the differences between the two studies. In a study of healthy Nigerians, the endurance of 21- to 30-year-olds (the age range in the McGill study) was signifi-
cantly higher than that of 31-40-year-olds (the age range in the present study). Besides, muscle mass and muscle function decrease with age in adults (25). Therefore, it is important to consider the age of the participants when comparing the results in various studies. Moreover, racial, and ethnic variations among studies should be taken into account.

One notable result of the present study was that because of the strong correlation of endurance in the right and left lateral flexors, they were not included as dependent variables in any single MANCOVA model. In line with previous studies (43, 56, 101), the endurance of the lateral flexors did not differ significantly in either group. Conversely, adjustment to the main background variables uncovered significantly less extensor endurance in the LBP group only in models that featured the lateral flexors endurance as a dependent variable.

Swain (54) and Evans (102) reported higher endurance of the lateral flexors on the dominant side in ballerinas and elite golfers. In gymnasts, trunk flexor endurance is higher compared to extensor endurance (103). These findings imply the importance of fitness levels and athletic background of the participants when studying core muscle endurance. Controlling this effect, none of the participants of this study were athletes or physically active, however, self-reported physical fitness estimations showed significant differences between groups. This finding may be attributed to avoidance-coping of people with chronic LBP that adversely diminishes their perceived level of physical capabilities.

94% percent of the participants in the present study were right-handed. Right lateral flexor endurance in the LBP group was 87% compared to the control group. For left lateral flexor endurance, the ratio increased to 97.5%. While hand dominance does not effectively change the endurance of lateral flexors (101), subjects in the LBP group presented with reduced right lateral flexor endurance greater than left lateral flexor endurance. This is another topic requiring more research in future studies.

Limitations and problems

This study does not include any cluster sampling. Because there is no database of state and private companies and organizations in our province, it was not possible to extract the number of employees and their regional distribution. Therefore, recruitment was carried out through advertising in public and social media throughout Isfahan. Besides, people with severe LBP, that their pain interfered with their work activity, and those who were moderately to extremely disable because of their pain did not volunteer to participate in the study. We did not investigate the mental well-being of the participants, which may have played a role in reducing core muscle endurance. Therefore, the results of this study are applicable only to those who continue their routine work despite of LBP.

The present study focused on core muscle endurance based on the existing body of literature. However, the concept of peak strength of core muscles worth further investigation specifically in comparison to the core muscle endurance and coordination.

Given this is a negative study, we strongly recommend further similar studies of larger sample size to develop regression models.

Implications

People with a minimum disability score based on the ODI scale volunteered in the present study. Future studies may consider the pain severity. Also, similar studies of different types of specific LBP are recommended. A basic study providing a normative range of core muscle endurance in Iranian people of different age groups, working in various occupations, and athletes will be clinically valuable. Clinical trials to discuss the effect of exercises aimed at improving endurance of core muscles, especially extensor muscles, for various severities of LBP or the risk of LBP in future will provide better understanding of the interaction of LBP and core muscle endurance. It would be of great value to consider long-term interventions and long-term follow-up to observe any pertinent changes.

CONCLUSIONS

Our finding does not support the popular opinion that sitting-while-at-work for long durations as a daily routine is necessarily associated with LBP; instead, the sitting posture, lower level of physical fitness and shorter duration of sitting activities at home may be associated with reduced extensor muscle endurance in nonspecific chronic LBP. The study was conducted according to the journal’s guidelines (104).

FUNDINGS

The study has been funded and ethically approved by Isfahan University of Medical Sciences (Ethics Code: IR.MUI.REC.1395.3.355) as a thesis for Master’s Degree in Physical Therapy by Naimeh Haddadi Esfahani (Registration code: 395355). The sponsor has no role in data collection, analysis of the data and drafting the manuscript.
ACKNOWLEDGMENTS

The study has been funded and ethically approved by Isfahan University of Medical Sciences (Ethics Code: IR.MUI.REC.1395.3.355) as a thesis for Master’s Degree in Physical Therapy by Naeimeh Haddadi Esfahani (Registration code: 395355). The sponsor has no role in data collection, analysis of the data and drafting the manuscript. Special thanks to Mrs. Najime Tarkesh (Biostatistician, Islamic Azad University, Khorasgan Branch) for contribution in statistical analysis and interpretation. The authors also thank all of the participants who kindly gifted their time and supported the project. This investigation was performed according to the MLTJ guidelines http://www.mltj.online/basic-principles-and-recommendations-in-clinical-and-field-science-research-2018-update/

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

15. Van Uffelen JG, Heesch KC, Brown W. Correlates of sitting time in working age Australian women: who should be target-


65. Ng JK, Richardson CA, Jull GA. Electromyographic amplitude and frequency changes in the iliocostalis lumborum and multifidi muscles during a trunk holding test. PT 1997;77(9):954-61.


90. Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP. Eur Spine J 2007;16(2):283-98.


100. Armstrong J. Evaluation of flexion-relaxation in the thoracic erector spinae and superficial lumbar multifidus during standing flexion and slumped sitting 2013.