ORIGINAL ARTICLE

Nr 2021;11 (1):136-150

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

N. Haddadi Esfahani[1,2], J. Dommerholt[3,4], Z. Sadat Rezaeian[1]

[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*

CORRESPONDING AUTHOR:
Zahra Sadat Rezaeian
Musculoskeletal Research Center and Department of Physical Therapy
Rehabilitation Sciences Research Institute
Faculty of Rehabilitation Sciences
Isfahan University of Medical Sciences
Hezar Jerib Avenue
Isfahan, Iran 8174673461
E-mail: zrezaeian@rehab.mui.ac.ir

DOI:
10.32098/mltj.01.2021.15

LEVEL OF EVIDENCE: 2C

ABBREVIATIONS:
LBP: Low Back Pain
BMI: Body Mass Index
VAS: Visual Analogue Scales

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 ($P \geq 0.05$). 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 health 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 back ground 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

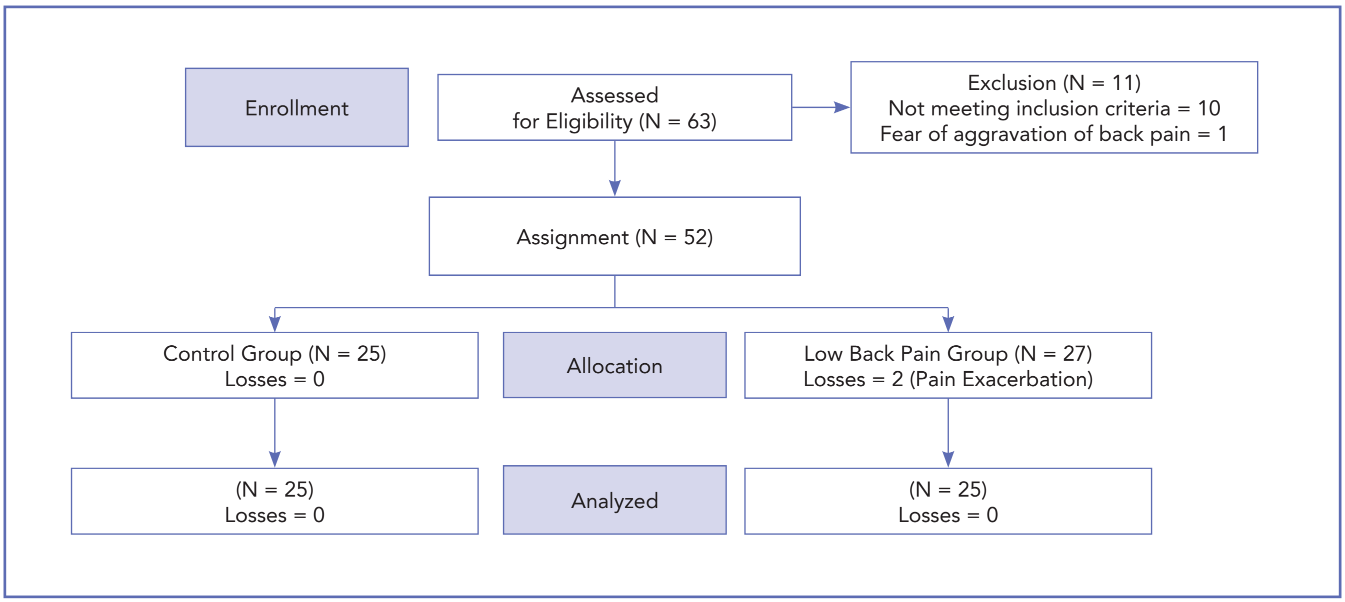

Figure 1. Study procedure and participant attrition.

Table I. Mean values of demographic variables in study groups.

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

*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 η^2 = 10%, P = 0.024), and duration of daily sitting at home (Partial η^2 = 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.

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

*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 extensors ($r = 0.383$, $P = 0.059$). In the control group, there was a statistically acceptable correlation coefficient between trunk flexors and extensors ($r = 0.521$, $P = 0.008$) and a strong correlation for lateral flexors ($r = 0.816$, $P \leq 0.001$). 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 $\eta^2 =$

Table III. Mean values of physical fitness variables.

Variable	LBP	Control	P-value
Aerobic Fitness (cm)	5.3 ± 1.6	6.3 ± 1.6	0.03*
Muscular Strength (cm)	5.3 ± 1.4	5.9 ± 1.7	0.14
Endurance (cm)	5.1 ± 1.6	6.2 ± 1.7	0.02*
Flexibility (cm)	4.9 ± 1.6	5.6 ± 1.7	0.16
Balance (cm)	5.3 ± 1.5	6.3 ± 1.6	0.02*

*P < 0.05.

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

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

* P values in parenthesis: *P < 0.05, ** P < 0.001.

0.21, P = 0.028, β = 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.

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, β = 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 V. Maximum endurance of each muscle in two groups.

Dependent Variable	Group	N	Mean ± SD	P-value	Ratio (LBP/ Control) × 100	Cohen d
Flexor Endurance (s)	LBP	25.00	129.96 ± 105.90	0.14	74.20%	- 0.38
	Control	25.00	175.16 ± 129.62			
	Total	50.00	152.56 ± 119.35			
Extensor Endurance (s)	LBP	25.00	68.20 ± 38.06	0.70	70.11%	- 0.56
	Control	25.00	97.28 ± 59.98			
	Total	50.00	82.74 ± 51.84			
Endurance of Right Lateral Flexors (s)	LBP	25.00	53.20 ± 43.99	0.19	86.87%	- 0.20
	Control	25.00	61.24 ± 38.03			
	Total	50.00	57.22 ± 40.90			
Endurance of Left Lateral Flexors (s)	LBP	25.00	56.64 ± 40.56	0.48	97.52%	- 0.04
	Control	25.00	58.08 ± 29.92			
	Total	50.00	57.36 ± 35.28			

Table VI. Univariate general linear models developed according to the basic difference between groups when extensor endurance set as a dependent variable.

Adjusted to	B	95% Confidence Interval		Std. Error	t	$F_{(1, 48)}$	P- value	Partial Eta Squared	Observed Power
		Lower Bound	Upper Bound						
Aerobic	- 34.76	- 64.69	- 4.83	14.88	- 2.34	5.46	0.024*	0.10	0.63
Endurance	- 24.67	- 54.88	5.54	15.02	- 1.64	2.70	0.11	0.05	0.36
Balance	- 28.31	- 58.84	2.23	15.18	- 1.87	3.48	0.07	0.07	0.45
Daily Sitting at Home	- 35.47	- 68.75	- 2.19	16.48	- 2.15	4.63	0.037*	0.10	0.56

* P < 0.05.

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 lumborum 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

Table VII. The result of roc curve analysis used for differentiating participants with and without back pain based on flexor endurance, extensor endurance, endurance of right lateral flexors and endurance of left lateral flexors.

Variable	Cutoff Score	Sensitivity	Specificity	Area Under Curve (%)	P Value	Asymptotic 95% Confidence Interval	
						Lower Bound	Upper Bound
Endurance of Flexors	< 101.5	64.0	60.0	62.2	0.138	46.5	78.0
Endurance of Extensors	< 76.0	68.0	60.0	65.0	0.070	49.6	80.3
Endurance of Right Lateral Flexors	< 39.0	76.0	52.0	60.9	0.187	44.9	76.9
Endurance of Left Lateral Flexors	< 47.5	72	48.0	55.8	0.479	39.5	72.2

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 the 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 lumber 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).

Although balance, endurance and straight sitting relying on backrest were significantly different between groups, there were no group differences with univariate models; however, they were significantly effective in combination as a pair of main covariates. More precise studies may help understanding the mechanism through which these parameters alter extensor muscle endurance.

Correlation coefficients showed that in the LBP group extensor endurance is moderately but reversely correlated to BMI. Also, self-reported muscle strength showed a 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 significantly 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 Naeimeh 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

1. Egger GJ, Vogels N, Westerterp KR. Estimating historical changes in physical activity levels. Med J Aust 2001;175(11-12):635-6.
2. Jans MP, Proper KI, Hildebrandt VH. Sedentary behavior in Dutch workers: differences between occupations and business sectors. Am J Prev Med 2007;33(6):450-4.
3. Pauwels S, Wilmaerts J. Sedentary lifestyle and influence on trunk flexors and extensors muscle endurance among first year university students: UHasselt 2017.
4. Ainsworth BE, Haskell WL, Whitt MC, *et al*. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(9 Suppl):S498-504.
5. Ayanniyi O, Ukpai B, Adeniyi A. Differences in prevalence of self-reported musculoskeletal symptoms among computer and non-computer users in a Nigerian population: a cross-sectional study. BMC Musculoskelet Disord 2010;11(1):177.
6. Gerr F, Monteilh CP, Marcus M. Keyboard use and musculoskeletal outcomes among computer users. J Occup Rehabil 2006;16(3):259.
7. Wærsted M, Hanvold TN, Veiersted KB. Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review. BMC Musculoskelet Disord 2010;11(1):79.
8. Zemp R, Taylor WR, Lorenzetti S. In vivo spinal posture during upright and reclined sitting in an office chair. BioMed Res Int 2013;2013.
9. Kang J-H, Park R-Y, Lee S-J, Kim J-Y, Yoon S-R, Jung K-I. The effect of the forward head posture on postural balance in long time computer based worker. Ann Rehabil Med 2012;36(1):98.
10. Parry S, Straker L. The contribution of office work to sedentary behaviour associated risk. BMC public health 2013;13(1):1-10.
11. Choi B, Schnall PL, Yang H, *et al*. Sedentary work, low physical job demand, and obesity in US workers. Am J Ind Med 2010;53(11):1088-101.
12. Van Uffelen JG, Wong J, Chau JY, *et al*. Occupational sitting and health risks: a systematic review. Am J Prev Med 2010;39(4):379-88.
13. Chau JY, Van Der Ploeg HP, Van Uffelen JG, *et al*. Are workplace interventions to reduce sitting effective? A systematic review. Prev Med 2010;51(5):352-6.
14. Solomonow M, Baratta R, Zhou B-H, Burger E, Zieske A, Gedalia A. Muscular dysfunction elicited by creep of lumbar viscoelastic tissue. J Electromyogr Kinesiol 2003;13(4):381-96.
15. Van Uffelen JG, Heesch KC, Brown W. Correlates of sitting time in working age Australian women: who should be targeted with interventions to decrease sitting time? J Phys Act Health 2012;9(2):270-87.
16. Healy G, Lawler S, Thorp A, *et al*. Reducing prolonged sitting in the workplace. HFES 2012.
17. Lafond D, Champagne A, Descarreaux M, Dubois J-D, Prado JM, Duarte M. Postural control during prolonged standing in persons with chronic low back pain. Gait Posture 2009;29(3):421-7.
18. Lee J-H, Park S-Y, Yoo W-G. Changes in craniocervical and trunk flexion angles and gluteal pressure during VDT work with continuous cross-legged sitting. J Occup Health 2011:1108010202-.
19. Madeleine P, Vangsgaard S, Andersen JH, Ge H-Y, Arendt-Nielsen L. Computer work and self-reported variables on anthropometrics, computer usage, work ability, productivity, pain, and physical activity. BMC Musculoskelet Disord 2013;14(1):226.
20. Sharan D, Parijat P, Sasidharan AP, Ranganathan R, Mohandoss M, Jose J. Workstyle risk factors for work related musculoskeletal symptoms among computer professionals in India. J Occup Rehabil 2011;21(4):520-5.
21. Nachemson A. The load on lumbar disks in different positions of the body. Clin Orthop Relat Res 1966;45:107-22.
22. Beach TA, Parkinson RJ, Stothart JP, Callaghan JP. Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. Spine J 2005;5(2):145-54.
23. Corlett E. Background to sitting at work: research-based requirements for the design of work seats. Ergonomics 2006;49(14):1538-46.
24. Janwantanakul P, Pensri P, Jiamjarasrangsi W, Sinsongsook T. Associations between prevalence of self-reported musculoskeletal symptoms of the spine and biopsychosocial factors among office workers. J Occup Health 2009;51(2):114-22.
25. Gupta N, Christiansen CS, Hallman DM, Korshøj M, Carneiro IG, Holtermann A. Is objectively measured sitting time associated with low back pain? A cross-sectional investigation in the NOMAD study. PLoSOne 2015;10(3):e0121159.
26. Mork PJ, Westgaard RH. Back posture and low back muscle activity in female computer workers: a field study. Clin Biomech 2009;24(2):169-75.
27. Mörl F, Bradl I. Lumbar posture and muscular activity while sitting during office work. J Electromyogr Kinesiol 2013;23(2):362-8.
28. Yoo W-G, An D-H. The relationship between the active cervical range of motion and changes in head and neck posture after continuous VDT work. Ind Health 2009;47(2):183-8.

29. Maribo T, Schiøttz-Christensen B, Jensen LD, Andersen NT, Stengaard-Pedersen K. Postural balance in low back pain patients: criterion-related validity of centre of pressure assessed on a portable force platform. Eur Spine J 2012;21(3):425-31.
30. Nesser TW, Huxel KC, Tincher JL, Okada T. The relationship between core stability and performance in division I football players. J Strength Cond Res 2008;22(6):1750-4.
31. Knežević O, Mirkov D. Trunk muscle activation patterns in subjects with low back pain. Vojnosanitetski pregled 2013;70(3):315-8.
32. O'Sullivan PB, Grahamslaw KM, Kendell M, Lapenskie SC, Möller NE, Richards KV. The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. Spine 2002;27(11):1238-44.
33. Johnson J. Functional rehabilitation of low back pain with core stabilizations exercises: suggestions for exercises and progressions in athletes, 2012.
34. Borghuis J, Hof AL, Lemmink KA. The importance of sensory-motor control in providing core stability. Sports Med 2008;38(11):893-916.
35. Hultman G, Nordin M, Saraste H, Ohlsen H. Body composition, endurance, strength, cross-sectional area, and density of MM erector spinae in men with and without low back pain. J Spinal Disord 1993;6(2):114-23.
36. Nourbakhsh MR, Arab AM. Relationship between mechanical factors and incidence of low back pain. J Orthop Sports Phys Ther 2002;32(9):447-60.
37. Luoto S, Heliövaara M, Hurri H, Alaranta H. Static back endurance and the risk of low-back pain. Clin Biomech 1995;10(6):323-4.
38. Tsuboi T, Satou T, Egawa K, Izumi Y, Miyazaki M. Spectral analysis of electromyogram in lumbar muscles: fatigue induced endurance contraction. Eur J Appl Physiol Occup Physiol 1994;69(4):361-6.
39. Massoud Arab A, Salavati M, Ebrahimi I, Ebrahim Mousavi M. Sensitivity, specificity and predictive value of the clinical trunk muscle endurance tests in low back pain. Clin Rehabil 2007;21(7):640-7.
40. Tissot F, Messing K, Stock S. Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day. Ergonomics 2009;52(11):1402-18.
41. Esfahani NH, Rezaeian ZS, Dommerholt J. The number of repetitions of the McGill tests to reliably determine core muscle endurance in subjects with and without chronic nonspecific low back pain: A cross sectional study. Med Sci 2019;23(98):452-61.
42. Akoglu H. User's guide to correlation coefficients. Turk J Emerg Med 2018;18(3):91-3.
43. Shamsi MB, Rezaei M, Zamanlou M, Sadeghi M, Pourahmadi MR. Does core stability exercise improve lumbopelvic stability (through endurance tests) more than general exercise in chronic low back pain? A quasi-randomized controlled trial. Physiother Theory Pract 2016;32(3):171-8.
44. Hodges PW, Richardson CA. Contraction of the abdominal muscles associated with movement of the lower limb. PT 1997;77(2):132-42.
45. Reiman MP, Krier AD, Nelson JA, Rogers MA, Stuke ZO, Smith BS. Reliability of alternative trunk endurance testing procedures using clinician stabilization vs. traditional methods. J Strength Cond Res 2010;24(3):730-6.
46. Mbada CE, Ayanniyi O, Adedoyin RA. Reference values of static back extensor muscle endurance in healthy Nigerian adults. Med Princ Pract 2009;18(5):345-50.
47. Clemes SA, David BM, Zhao Y, Han X, Brown W. Validity of two self-report measures of sitting time. J Phys Act Health 2012;9(4):533-9.
48. Gupta N, Christiansen CS, Hanisch C, Bay H, Burr H, Holtermann A. Is questionnaire-based sitting time inaccurate and can it be improved? A cross-sectional investigation using accelerometer-based sitting time. BMJ open 2017;7(1).
49. Fairbank JC, Pynsent PB. The Oswestry disability index. Spine 2000;25(22):2940-53.
50. Strøyer J, Jensen LD, Avlund K, Essendrop M, Warming S, Schibye B. Validity and reliability of self-assessed physical fitness using visual analogue scales. Percept Mot Skills 2007;104(2):519-33.
51. Hudes K. Low Back Disorders: Evidence Based Prevention and Rehabilitation. J Can Chiropr Assoc 2007;51(2):124.
52. Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc 2004;36(6):926-34.
53. Waldhelm A, Li L. Endurance tests are the most reliable core stability related measurements. J Sport Health Sci 2012;1(2):121-8.
54. Swain C, Redding E. Trunk muscle endurance and low back pain in female dance students. J Dance Med Sci 2014;18(2):62-6.
55. Johnson OE, Mbada CE, Akosile CO, Agbeja OA. Isometric endurance of the back extensors in school-aged adolescents with and without low back pain. J Back Musculoskelet Rehabil 2009;22(4):205-11.
56. McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil 1999;80(8):941-4.
57. Sawilowsky SS. New effect size rules of thumb. J Mod Appl Stat Methods 2009;8(2):26.
58. O'Sullivan PB, Dankaerts W, Burnett AF, *et al*. Effect of different upright sitting postures on spinal-pelvic curvature and trunk muscle activation in a pain-free population. Spine 2006;31(19):E707-E12.
59. Abdelraouf OR, Abdel-aziem AA. The relationship between core endurance and back dysfunction in collegiate male athletes with and without nonspecific low back pain. Int J Sports Phys Ther 2016;11(3):337.
60. Dejanovic A, Cambridge ED, McGill S. Isometric torso muscle endurance profiles in adolescents aged 15–18: normative values for age and gender differences. Annals Hum Biol 2014;41(2):153-8.
61. Cobanoglu G, Zorlular A, Polat EA, *et al*. The relationship between scapular and core muscle endurance in professional athletes 2019.
62. Werner DM, Barrios JA. Trunk muscle endurance in individuals with and without a history of anterior cruciate ligament reconstruction. J Strength Cond Res 2018.
63. Cengizhan PA, Cobanoglu G, Gokdogan CM, *et al*. The relationship between postural stability, core muscle endurance and agility in professional basketball players. Ann Med Res 2019;26(10):2181-6.

64. ShahAli S, Arab AM, Talebian S, *et al*. Reliability of ultrasound thickness measurement of the abdominal muscles during clinical isometric endurance tests. J Bodyw Mov Ther 2015;19(3):396-403.
65. Ng JK, Richardson CA, Jull GA. Electromyographic amplitude and frequency changes in the iliocostalis lumborum and multifidus muscles during a trunk holding test. PT 1997;77(9):954-61.
66. Demoulin C, Crielaard J-M, Vanderthommen M. Spinal muscle evaluation in healthy individuals and low-back-pain patients: a literature review. Joint Bone Spine 2007;74(1):9-13.
67. Marshall P, Murphy B. The validity and reliability of surface EMG to assess the neuromuscular response of the abdominal muscles to rapid limb movement. J Electromyogr Kinesiol 2003;13(5):477-89.
68. Richardson CA, Hodges P, Hides JA. Therapeutic exercise for lumbopelvic stabilization: a motor control approach for the treatment and prevention of low back pain 2004.
69. Willson JD, Dougherty CP, Ireland ML, Davis IM. Core stability and its relationship to lower extremity function and injury. JAAOS 2005;13(5):316-25.
70. McGill S. Low back disorders: evidence-based prevention and rehabilitation: Human Kinetics 2015.
71. Holth HS, Werpen HKB, Zwart J-A, Hagen K. Physical inactivity is associated with chronic musculoskeletal complaints 11 years later: results from the Nord-Trøndelag Health Study. BMC Musculoskelet Disord 2008;9(1):159.
72. O'Sullivan PB, Mitchell T, Bulich P, Waller R, Holte J. The relationship beween posture and back muscle endurance in industrial workers with flexion-related low back pain. Man Ther 2006;11(4):264-71.
73. Smith AJ, O'Sullivan PB, Campbell AC, Straker LM. The relationship between back muscle endurance and physical, lifestyle, and psychological factors in adolescents. J Orthop Sports Phys Ther 2010;40(8):517-23.
74. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. Sports Med 2014;44(9):1209-23.
75. Wormgoor ME, Indahl A, van Tulder MW, Kemper HC. The impact of aerobic fitness on functioning in chronic back pain. Eur Spine J 2008;17(4):475-83.
76. O'Sullivan K, McCarthy R, White A, O'Sullivan L, Dankaerts W. Can we reduce the effort of maintaining a neutral sitting posture? A pilot study. Man Ther 2012;17(6):566-71.
77. Straker L, Maslen B, Burgess-Limerick R, Pollock C. Children have less variable postures and muscle activities when using new electronic information technology compared with old paper-based information technology. J Electromyogr Kinesiol 2009;19(2):e132-e43.
78. Casas S, Aminta S, Patiño S, María S, Camargo L, Diana M. Association between the sitting posture and back pain in college students. Salud UIS 2016;48(4):446-54.
79. Caneiro JP, O'Sullivan P, Burnett A, *et al*. The influence of different sitting postures on head/neck posture and muscle activity. Man Ther 2010;15(1):54-60.
80. O'Sullivan K, O'Dea P, Dankaerts W, O'Sullivan P, Clifford A, O'Sullivan L. Neutral lumbar spine sitting posture in pain-free subjects. Man Ther 2010;15(6):557-61.
81. O'Sullivan K, O'Sullivan P, O'Sullivan L, Dankaerts W. What do physiotherapists consider to be the best sitting spinal posture? Man Ther 2012;17(5):432-7.
82. Korakakis V, O'Sullivan K, O'Sullivan PB, *et al*. Physiotherapist perceptions of optimal sitting and standing posture. Musculoskelet Scie Pract 2019;39:24-31.
83. Fogleman M, Lewis RJ. Factors associated with self-reported musculoskeletal discomfort in video display terminal (VDT) users. Int J Ind Ergon 2002;29(6):311-8.
84. Korshøj M, Jørgensen MB, Hallman DM, Lagersted-Olsen J, Holtermann A, Gupta N. Prolonged sitting at work is associated with a favorable time course of low-back pain among blue-collar workers: a prospective study in the DPhacto cohort. Scand J Work Environ Health 2018;44(5):530-8.
85. De Carvalho DE, de Luca K, Funabashi M, *et al*. Association of exposures to seated postures with immediate increases in back pain: a systematic review of studies with objectively measured sitting time. J Manipulative Physiol Ther 2020.
86. Park S-M, Kim H-J, Jeong H, *et al*. Longer sitting time and low physical activity are closely associated with chronic low back pain in population over 50 years of age: a cross-sectional study using the sixth Korea National Health and Nutrition Examination Survey. Spine J 2018;18(11):2051-8.
87. Lunde L-K, Koch M, Knardahl S, Veiersted KB. Associations of objectively measured sitting and standing with low-back pain intensity: a 6-month follow-up of construction and healthcare workers. Scand J Work Environ Health 2017:269-78.
88. Hanna F, Daas RN, Elshareif TJ, Almarridi HHFH, Al-Rojoub ZMdB, Adegboye D. The relationship between sedentary lifestyle, back pain and psychosocial correlates among university employees. Front Public Health 2019;7:80.
89. Chen S-M, Liu M-F, Cook J, Bass S, Lo SK. Sedentary lifestyle as a risk factor for low back pain: a systematic review. Int Arch Occup Environ Health 2009;82(7):797-806.
90. Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP. Eur Spine J 2007;16(2):283-98.
91. Roffey DM, Wai EK, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational sitting and low back pain: results of a systematic review. Spine J 2010;10(3):252-61.
92. Behennah J, Conway R, Fisher J, Osborne N, Steele J. The relationship between balance performance, lumbar extension strength, trunk extension endurance, and pain in participants with chronic low back pain, and those without. Clin Biomech 2018;53:22-30.
93. Ganesh GS, Chhabra D, Pattnaik M, Mohanty P, Patel R, Mrityunjay K. Effect of trunk muscles training using a star excursion balance test grid on strength, endurance and disability in persons with chronic low back pain. J Back Musculoskelet Rehabil 2015;28(3):521-30.
94. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. Clin Spine Surg 1992;5(4):383-9.
95. Shin G, D'Souza C, Liu Y-H. Creep and fatigue development in the low back in static flexion. Spine 2009;34(17):1873-8.
96. Callaghan JP, Dunk NM. Examination of the flexion relaxation phenomenon in erector spinae muscles during short duration slumped sitting. Clin Biomech 2002;17(5):353-60.
97. Hendershot B, Bazrgari B, Muslim K, Toosizadeh N, Nussbaum MA, Madigan ML. Disturbance and recovery of trunk

stiffness and reflexive muscle responses following prolonged trunk flexion: influences of flexion angle and duration. Clin Biomech 2011;26(3):250-6.
98. Little JS, Khalsa PS. Human lumbar spine creep during cyclic and static flexion: creep rate, biomechanics, and facet joint capsule strain. Ann Biomed Eng 2005;33(3):391-401.
99. Solomonow M. Neuromuscular manifestations of viscoelastic tissue degradation following high and low risk repetitive lumbar flexion. J Electromyogr Kinesiol 2012;22(2):155-75.
100. Armstrong J. Evaluation of flexion-relaxation in the thoracic erector spinae and superficial lumbar multifidus during standing flexion and slumped sitting 2013.
101. Chan RH. Endurance times of trunk muscles in male intercollegiate rowers in Hong Kong. Arch Phys Med Rehabil 2005;86(10):2009-12.
102. Evans K, Refshauge KM, Adams R, Aliprandi L. Predictors of low back pain in young elite golfers: a preliminary study. PT in Sport 2005;6(3):122-30.
103. Buchanan K. Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts: Miami University 2003.
104. Padulo J, Oliva F, Frizziero A, Maffulli N. Muscles, Ligaments and Tendons Journal - Basic principles and recommendations in clinical and field Science Research: 2018 update. MLTJ 2018;8(3): 305-307.