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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

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ABSTRACT

McGill tests are popular and practical clinical tests for evaluating the isometric endurance of core muscles. Previous studies have reported the mean or maximum rate of the McGill tests from one to three times of Mc Gill tests. *Objective:* To assess the number of repetitions of the McGill tests to reliably determine core muscle endurance in subjects with and without nonspecific low back pain. *Methods:* The participants were 50 (24 males and 26 females) sedentary subjects with and without chronic nonspecific low back pain. Isometric core muscle endurance of the trunk flexion, extension and lateral flexion (right and left) was measured using the McGill tests. The order of the test was set randomly and each test was repeated three times with 5-minute rest intervals. The subjects were recruited from state and private companies and organizations and were purposefully assigned into low back pain and without low back Pain group. In each test, three trial scores, maximal score and mean score were reported. The frequency of reporting maximal score in first, second and third trial was determined and compared within groups using McNemar test and between groups using Mann-Whitney U test. *Results:* For all Mc Gill test, the maximum score trials was significantly greater than the mean score in both groups ($P \leq 0.001$). For trunk flexion endurance, the probability of obtaining the maximal score in the first couple of trials was up to 80% and 92%, 76% and 84% for the trunk extension endurance, 72% and 76% for right lateral flexion endurance and 92% and 76% for left lateral flexion endurance in LBP and WLBP subjects respectively. *Conclusion:* Two repetitions of McGill tests seem to be sufficient to detect core muscle endurance in subjects with and without chronic nonspecific low back pain.

Keywords: Low back pain, core muscle endurance, McGill tests

1. INTRODUCTION

During the past two decades, many researchers and clinicians have paid particular attention to core stability, because of its critical role in rehabilitation and athletic training (Borghuis et al., 2008). Forming a muscular corset around the torso, the core consists of the abdominals anteriorly, the para-spinal and gluteal muscles posteriorly, the diaphragm superiorly, and the pelvic floor and hip girdle musculature inferiorly (Akuthota & Nadler, 2004). The core works as a unit to stabilize the body and the spine. Core stability is a key element to improve clinical rehabilitation, health, and physical fitness (Borghuis et al., 2008). Several studies have found an association between the loss of core stability and an increased risk of low back pain (Borghuis et al., 2008). Low back pain is a worldwide challenge for public health systems (Balagué et al., 2012). Up to 90% of the populations suffer from non-specific low back pain (LBP) at some point during their life without any specific or original cause (Shamsi et al., 2016).

Strength, endurance, flexibility, motor control, and function are the main components of core stability (Waldhelm & Li, 2012). Endurance of the trunk extensors is more important than muscle strength in low back pain (Massoud et al., 2007), and is an excellent predictor of back health (Nourbakhsh & Arab, 2002; Payne et al., 2000). Limited strength of trunk extensors is assumed to be one probable cause of LBP. On the other hand, people with poor trunk muscle endurance seem to have lower fatigue thresholds (Van Tulder et al., 2000) and previous studies have shown a significant decrease in endurance of back extensors in subjects with low back pain (Massoud et al., 2007; O'Sullivan et al., 2006). Moreover, some studies have focused on the endurance of the trunk flexors in low back pain, because of their role in normal functioning of the lumbo pelvic region (Massoud et al., 2007).

Several tests and measurements are available to assess the components of core stability (Shamsi et al., 2016); although there are highly reliable tests for each of the core stability components, core endurance tests, such as the McGill tests, are the most reliable measures (Waldhelm & Li, 2012; Ameneh Shaykh & Najla Anvari, 2018; Naser Shirani et al. 2019). Endurance is the ability to work for a long period of time or the capability of maintaining a specific force for a while (Kisner C, Colby, 2012). Similarly, core endurance tests require the participants to maintain an unsupported static trunk position for a period of the time (Shamsi et al., 2016).

The McGill tests are safe, low-tech, and no-cost isometric techniques that may be incorporated by any practitioner (Hudes, 2007; Evans et al., 2007). The reliability of endurance tests has been reported as ranging from high moderate to excellent (McGill et al., 1999). Also, each test has been identified as reliable, safe, sensitive to trunk muscle endurance, and of good predictive value for persons with LBP (Massoud et al., 2007; Swain & Redding, 2014). They have been used in many studies, either in their original version (Swain & Redding, 2014; Michael et al., 2005), or as modifications (Michael et al., 2005; Jalayondeja & Kraingchieocharn, 2015; Johnson et al., 2009; Moreau et al., 2001; Leetun et al., 2004; Chan, 2005; Waldhelm, 2011; Bernard et al., 2008) in people with low back pain (Nourbakhsh & Arab, 2002; Swain & Redding, 2014), healthy subjects (Nourbakhsh & Arab, 2002) and athletes (Leetun et al., 2004; Chan, 2005; Ashmen et al., 1996). Routinely, the mean or maximum (Shamsi et al., 2016) outcomes of the McGill test are reported following one (Nourbakhsh & Arab, 2002; Bernard et al., 2008) two (Kumar et al., 2011) to three repetitions, while most studies did not report the number of the trials. No study to date has discussed how many trials are required to reliably report the McGill scores in healthy subjects and those with LBP. The present study compares the McGill test scores following one to three trials. Considering muscle endurance, we hypothesized that the maximum and not the mean score is a valid measure of core muscle endurance.

2. METHODS

Participants

Fifty subjects (25-50 years of age) with sedentary jobs were recruited via a local advertisement from state and private companies and organizations in Isfahan, Iran in 2016. The subjects were included if they worked in a sitting position for at least half of the working hours (Ayanniyi et al., 2010) or for 4 hours (Billy et al., 2014) for at least 4 years. Subjects who suffered from systemic diseases such as rheumatoid arthritis, diabetes, neurologic disease, lower extremities and spinal or pelvic fracture based on radiologic evidence, osteoarthritis, head trauma or balance disorders were excluded as were subjects with a history of hospitalization for severe trauma, active subjects (Ebrahimi et al., 2005), and pregnant women. Taking sedatives or opioids during the week preceding the study, participation in rehabilitation exercises for hip or spine within the last six months, pain and dysfunction in the upper and lower extremities were also considered as exclusion criteria. Patients were included if they had a history of low back pain for more than six weeks before the study, or had on and off back pain, and had experienced at least three episodes of low back pain, each lasting more than one week, during the year before the study. None of the patients or control subjects had referred leg pain.

A medical doctor and a physical therapist, which were blinded to the study procedure and study groups, evaluated the volunteers to determine if they met the inclusion criteria. Subjects were assigned to a “low back pain (LBP)” group of a “without low back pain (WLBP)” group. The groups were matched for demographical characteristics (age, sex, BMI, work record).

The Ethics committee of Isfahan University of Medical Sciences approved and supervised the whole procedure (registration code: 395355, Ethics Code: IR.MUI.Rec.1395.3.355). All participants signed an informed consent prior to the study.

Procedures

The individuals attended the Musculoskeletal Research Center. To make sure that the test reflects true muscle endurance, the subjects who stopped the test because of pain were excluded from further analysis. All the procedures were conducted in a single day for each subject.

The participants were tested with three different isometric tests for trunk muscle endurance. The order of the tests was randomly assigned by blind selection of concealed numbers by the subject in person. Each test was performed in a set of three trials with five-minute rest intervals between trials. Core endurance was measured in seconds. Subjects were requested to maintain the testing position as long as possible. The tests were stopped when either the participant requested to stop or could no longer maintain the proper position. Subjects did not receive any indication about the results until the last trial.

Sorensen test

Each participant was positioned in prone with the top of the iliac crests on the upper edge of the table and the ankle, knee, and pelvis fixed with three straps (Figure 1a). The test bed surface was approximately 75 cm above the floor. A chair was available at the same height of the bed for support immediately before and after the test. At the beginning of the test the upper limbs were held across the chest with the hands resting on the opposite shoulders, and the upper body was lifted off and maintained in a horizontal torso position for as long as possible. The test was concluded when the subject could no longer maintain a horizontal position and came in contact with the floor (Swain & Redding, 2014).

Flexor endurance test

Each participant was in the sit-up position with the back resting against a back support angled at 60 degrees from the floor. The knees and hips were flexed at 90, and the feet were fixed to the bed with a strap. The arms were crossed over the chest. To begin, the support was removed back 10 cm (Figure 1b), and the participant was asked to hold the body position as long as possible. The test ended when the subject was no longer able to hold the position (Brumitt, 2010).

The side bridge tests

Each subject was in the side-lying position. The legs were extended, and the upper foot was placed in front of the lower foot for support (Figure 1c). Participants supported themselves on the elbow and the feet. Subjects were asked to lift their hip off the floor using only their feet and lower elbow for support. The uninvolved arm was held across the chest with the hand resting on the opposite shoulder. The test ended when the hip returned to the bed (Shamsi et al., 2016; Brumitt, 2010). The total time the participant was able to hold the tests was recorded with a stopwatch (Shamsi et al., 2016).

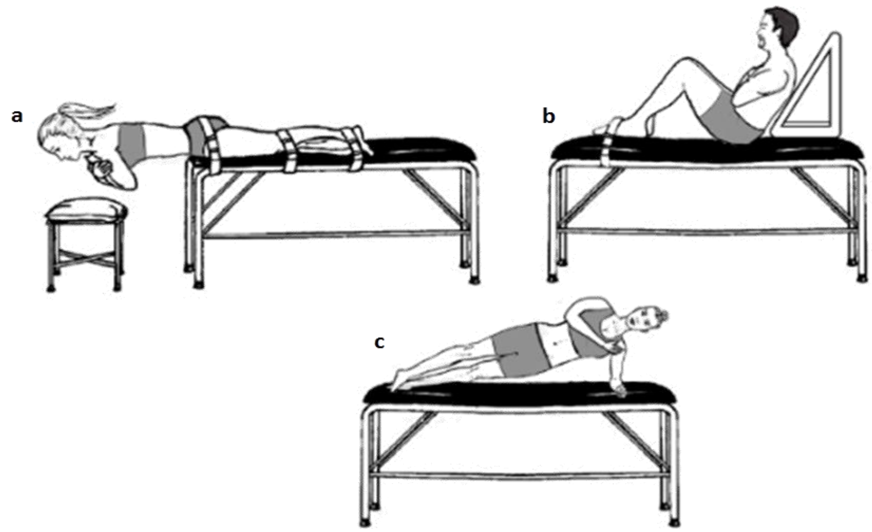

Figure 1 The McGill test positions: a. Sorensen test, b. flexion test, c. side bridge test

Statistical Analysis

The primary outcome measure was the duration of each trial. The distribution of the variables was analyzed using the Shapiro-Wilk test. Consistency of the test results was determined by interclass correlation coefficient (ICC) score ICC values classified as little, if any (0.00-0.25), low (0.26-0.49), moderate (0.50-0.69), high (0.70-0.89), and very high (0.90-1.00) (Waldhelm, 2011).

If the distribution of the test variables followed a normal distribution, the independent sample T test was adopted to compare the groups; otherwise, non parametric Wilcoxon test would be the choice. The statistical significance was set at $\alpha = 0.05$. In addition to three trial scores, the mean and maximum scores were reported for each test. The frequency of recording the maximal scores in each trial was analyzed using the McNemar test. The statistical analysis was performed using SPSS 18 (PASW statistics 18 2009, SPSS Inc., Chicago, USA).

3. RESULTS

According to Shapiro-Wilk test, the distribution of the third trial score and mean score of flexion endurance test in WLBP group followed normal distribution. Distribution of all extension endurance scores in LBP group and second and third trial scores in WLBPgroup were normal. Second and third trial scores and mean score in right lateral flexion test in WLBP group, third trial score and mean score in left lateral flexion test in LBP group and all scores in left lateral flexion test in WLBP group followed normal distribution. The demographic characteristics of the subjects are summarized in table 1.

Table 1 The demographic characteristics of the Low Back Pain and without Low Back Pain groups

	Gender: Number of Men(%)	Age (Year)	Height (m)	Weight (Kg)	BMI (Kgm^2)	Oswestry Score
Low Back Pain (N=25)	12 (48)	37.6±6.4	1.71±0.10	71.8±14.5	24.5±2.9	17.1±10.4*
Without Low Back Pain (N=25)	12 (48)	38.6±4.4	1.70±0.94	74.3±13.6	25.6±3.1	3.3±3.7*
All (N=50)	24(48)	38.1±5.4	1.70±0.54	73.1±14.0	25.0±3.0	10.2±10.4

* $P<0.05$

The groups were different only in oswestry disability score ($P \leq 0.001$). ICC scores revealed that there was high to very high (Waldhelm, 2011) intra-rater reliability for each test in each study group (table 2)

Table 2 Intra-rater reliability (ICC Scores) for core stability measurements

Tests / Groups	Trunk Flexion	Trunk Extension	Right Side Bridge	Left Side Bridge
Low Back Pain (N=25)	0.79‡	0.83‡	0.73‡	0.90†
Without Low Back Pain (N=25)	0.80‡	0.90†	0.88‡	0.89‡

*Note: reliability score interpretation: †Very High: 0.90-1.00, ‡High: 0.7-0.89, *Moderate: 0.50-0.69, •Low: 0.26-0.49, ⁰Little: 0.01-0.25, ▫None: 0 (30).*

The mean of the trial scores for each endurance test are summarized in table 3.

Table 3 The mean of each trial score for each test in either group

Test	Group	1st Trial Score (S)	2nd Trial Score (S)	3rd Trial Score (S)	Mean Score (S)	Maximal Score (S)
Trunk Flexion	Low Back Pain (N=25)	122.5±103.0	104.6±77.6	98.0±81.6	108.4±78.2⁰	134±107.2
	Without Low Back Pain (N=25)	160.5±126.8‡	134.4±104.6	116.4±72.7*	137.1±92.0⁰	177.1±128.3
	All (N=50)	141.5±115.9	119.5±92.4	107.2±77.0	122.7±85.8	155.6±119.0
Trunk Extension	Low Back Pain (N=25)	61.4±38.8	61.3±34.6	52.1±29.3	58.3±30.7⁰	71.5±37.7
	Without Low Back Pain (N=25)	89.1±64.0	80.6±48.4	74.4±40.8	81.3±49.1⁰	98.5±59.1
	All (N=50)	75.3±54.2	70.9±42.8	63.3±36.9	69.8±42.2	85.0±50.9
Right Lateral Flexion	Low Back Pain (N=25)	49.0±42.3	48.6±40.3	48.3±31.3	48.6±32.1⁰	60.9±45.6
	Without Low Back Pain (N=25)	57.7±40.1	48.4±25.1	47.0±23.6	51.1±28.4⁰	63.1±37.2
	All (N=50)	53.3±41.0	48.5±33.2	47.7±27.4	49.8±30.0	62.0±41.2
Left Lateral Flexion	Low Back Pain (N=25)	51.2±41.1‡	49.1±34.7‡	39.2±25.2*†	46.8±32.3⁰	57.3±40.1
	Without Low Back Pain (N=25)	53.9±30.8	50.8±24.3	48.0±21.4	50.9±24.1⁰	60.5±28.9
	All (N=50)	52.5±36.0	50.0±29.7	43.6±23.6	48.9±28.3	58.9±34.6

** P<0.05 in comparison to 1st trial score*
† P<0.05 in comparison to 2nd trial score
‡ P<0.05 in comparison to 3rd trial score
⁰ P<0.05 in comparison to maximal score of the same group
• P<0.05 in comparison to the same score of the WLBP group

The frequency of getting maximal score in each trial was not significantly different between groups for any test (P≥0.16). In the LBP group the flexion endurance score was not significantly different in three trials (P=0.42). The distribution of the flexion trial scores did not follow a normal distribution in the WLBP group. The nonparametric analysis showed that there was a significant difference between flexion scores in three trials (P=0.03). The difference was statistically significant because of an obvious lower score in the third trial in comparison to first trial (P=0.008). In both groups the maximal flexion scores were significantly more than the mean flexion scores (P≤ 0.001).

There was no significantly difference among the three trials for extension endurance scores in the LBP and WLBP groups (P=0.22 and P=0.05 respectively); while the maximum extension score was significantly more than the mean extension score in the LBP and WLBP groups (both P ≤0.001).

The same results were documented for the three trials of right lateral flexion endurance in the LBP (P=0.71) and WLBP (P=0.13) groups. The maximum right lateral flexion score was remarkably greater than the mean score in both groups (P≤ 0.001).

According to the non-parametric analysis, the left lateral flexion score was significantly different among the three trials in the LBP group (P=0.01); the first and second trials were significantly longer than the third one (P=0.01 and P=0.002 respectively). In the WLBP group, the parametric analysis showed no significant difference among three trials (P=0.32). The maximum left lateral flexion score was significantly more than the mean score in both groups (P≤ 0.001). The frequency of recording the maximal endurance in each trial for each test in either group is summarized in table 4.

Table 4 The frequency of recording the maximal endurance in each trial for each test in either group

Test	Groups	Frequency of Maximal Score in 1st Trial (%)	Frequency of Maximal Score in 2nd Trial (%)	Frequency of Maximal Score in 3rd Trial (%)
Trunk Flexion	Low Back Pain (N=25)	44%	36%	28%
	Without Low Back Pain (N=25)	56%‡	36%	12%*
	All (N=50)	50%	36%	20%
Trunk Extension	Low Back Pain (N=25)	52%	24%	28%
	Without Low Back Pain (N=25)	64%‡	20%‡	16%*†
	All (N=50)	58%	22%	22%
Right Lateral Flexion	Low Back Pain (N=25)	40%	32%	48%
	Without Low Back Pain (N=25)	60%†	16%*	24%
	All (N=50)	50%	24%	36%
Left Lateral Flexion	Low Back Pain (N=25)	48%	44%	20%
	Without Low Back Pain (N=25)	48%	28%	32%
	All (N=50)	48%	36%	26%

** P<0.05 in comparison to 1st trial score*

† P<0.05 in comparison to 2nd trial score

‡ P<0.05 in comparison to 3rd trial score

As shown in table 4, the McNemar test revealed that in the LBP group, the frequency of getting the maximal flexion endurance score was not significantly different in three trials (P≥0.4) while in the WLBP group, the maximal score was significantly more recorded in the first trial rather than the third trial (P=0.01) (Figure 1a).

In the LBP group, there was no significant difference among frequency of maximum extension score in three trials (P≥1.0); in contrast, in the WLBP group the first trial score was the maximal score in 64% of the cases that was significantly higher rate than the rate of maximal score in the second and third trials (P=0.03 and P=0.01); there was no significant difference between the rate of the maximal score in the second and third trials (P=1.0).

The same pattern was detected for the frequency of recording the maximum score of right lateral flexion (P≥0.4). The first trial revealed significantly more frequency than the second trial (P=0.02) without significant difference between the second and third trials (P=0.75) and between the first and third trials (P=0.08). There was no significant difference between the frequencies recording the maximal score for left lateral flexion endurance in the three trials in either group (P≥0.1).

Figure 2 provides a better understanding of the frequency of getting maximal scores in each test for either group.

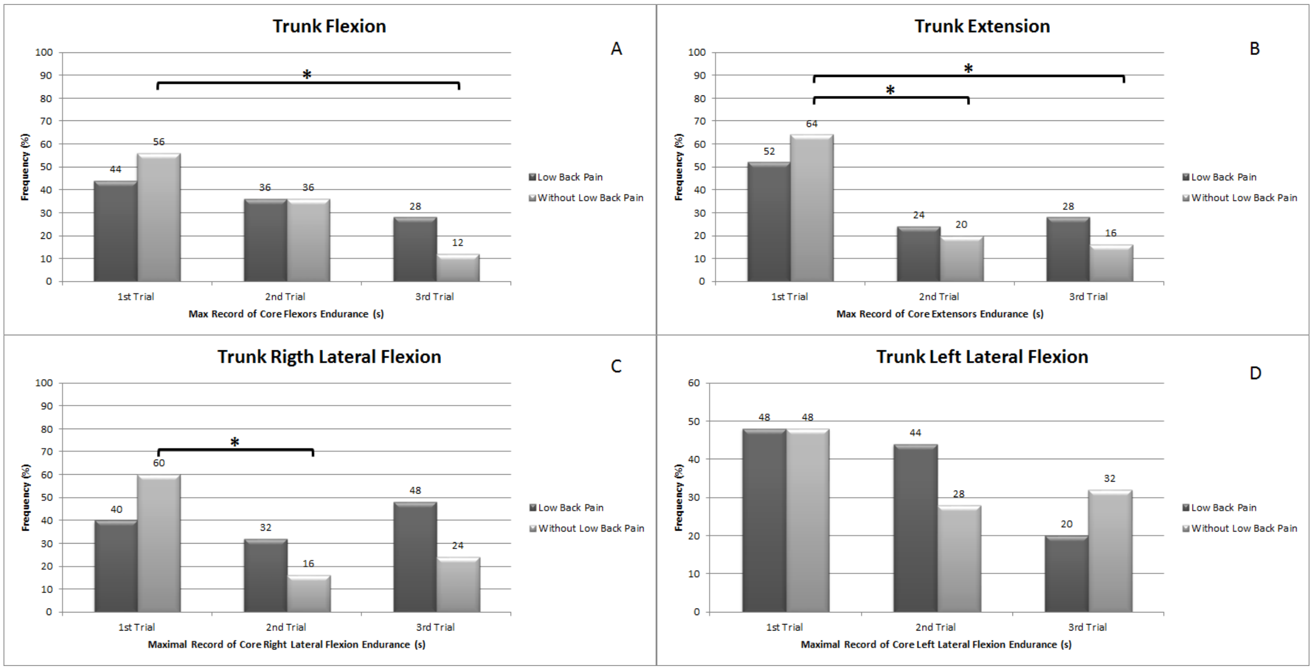

Figure 2 The frequency of recording maximal endurance in each trial for every Mac Gill test: a. flexion test, b. extension test, c. right lateral flexion test, d. left lateral flexion test

There was poor insignificant correlation between oswestry disability score and frequency of maximal record in either groups (P≥0.07, Spearman' rho coefficient of correlation≤ 0.36).

4. DISCUSSION

The purpose of this study was to determine the number of repetitions for the McGill tests to establish the core muscle endurance in healthy subjects and subjects with nonspecific low back pain. Fifty-three subjects were included in the study. The data for three subjects were not analyzed, because they had severe pain during the test and they could not complete the study protocol. According to our comprehensive search in the literature, none of the studies which used Mc Gill test to measure core muscles endurance offered proof for reporting the mean or maximal score or number of the required test repetitions.

Low back pain subjects in present study were suffering from minimal disability according to oswestry disability score (Mousavi et al., 2006). This means that "The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting, sitting and exercise (Fairbank & Pynsent, 2000). "Lack of correlation between oswestry disability score and frequency of getting maximal record in all tests may be a result of this finding.

Theoretically, endurance is correlated with the duration of sustaining a specific position (Rissanen et al., 1994). The results of the present study confirmed that the maximal score among three trials is significantly higher than the mean score in all McGill tests. Therefore, reporting the mean score may result in misinterpretation in chronic nonspecific LBP and in WLBP subjects.

There was no significant difference among the trial scores of flexion endurance and the frequency of getting the maximal flexion score in the LBP group, however, in 44% of cases, the maximal score for trunk flexion endurance was observed in the first trial. This frequency was 36% in the second trial. Therefore, it seems that the probability of obtaining the maximal score in the first two trials may be up to 80% in LBP subjects. In WLBP, the maximal flexor muscle endurance score was recorded in the first two trials in 92% of the cases and the rate of recording maximal score in first trial was significantly higher than the third one.

For the trunk extensors, the chance for achieving the maximal score in the first two trials was 76% in LBP and 84% in the WLBP group with the highest possibility for the first trial. These findings provide evidence that maybe one to two test repetitions are appropriate for reporting trunk flexor/extensor endurance using the McGill test. This reduces the overall test duration, decreases the chance of muscle fatigue and poor muscle function in following exercises and daily activities and it may also improve the subjects' self-esteem.

For the lateral trunk flexion tests, the chance of getting the maximal score was 72 and 76 percent for right trunk flexion and 92 and 76 percent for left trunk flexion in LBP and WLBP subjects respectively. The order of the McGill tests for each subject in each group was randomly assigned. About 94% of the subjects in the present study (96% in LBP and 92% in WLBP group) were right handed. Right handed subjects usually use their dominant upper extremity in daily activities and professional skilled tasks. In this case, left trunk muscles are responsible for stabilizing the torso during daily functions. Therefore, they are more often recruited than right trunk muscles. This hypothesis may explain significantly higher frequency of recording maximal scores in first couple of trials for left trunk flexion in LBP subjects

The chance of achieving the maximal score in the first couple of trials was generally 4-16% higher in the WLBP group than in the LBP group. Although this difference was not significant, the finding may imply that subjects with nonspecific chronic LBP are more prone to core muscle fatigue that subjects without LBP.

They are some limitations for the present study. Considering minimal disability in present sample of LBP subjects, it is recommended to repeat the same study with considering various disability categories according to Oswestry disability score. Our results may not be generalized to all the subjects with and without nonspecific LBP especially those who are physically active and athletes. In addition, young adults (18-25 years old) and seniors (>50 years old) may show different results.

5. CONCLUSION

It seems that the chance of recording maximum endurance decreases with further trials in all Mc Gill tests. More than 75% of subjects with or without low back pain will achieve their best records in trunk flexion and trunk extension test within first couple of trials; while the rate is a bit less, about 70%, for trunk lateral flexions. Therefore, in all Mc Gill tests, two repetitions is probably enough to reliably record core muscle endurance in subjects with and without chronic nonspecific low back pain

Authors Contributions

Conception and design: Zahra Sadat Rezaeian, Naeimeh Haddadi Esfahani, Jan Dommerholt.

Funding and obtaining financial support: Zahra Sadat Rezaeian.

Administrative, technical, or logistic support: Zahra Sadat Rezaeian.

Provision of study materials or patients: Naeimeh Haddadi Esfahani, Zahra Sadat Rezaeian, Jan Dommerholt.

Data Collection: Naeimeh Haddadi Esfahani.

Data analysis and interpretation: Zahra Sadat Rezaeian. Naeimeh Haddadi Esfahani, Jan Dommerholt.

Statistical experties: Seyyed Mohsen Hosseini, Zahra Sadat Rezaeian.

Drafting the manuscript: Naeimeh Haddadi Esfahani

Critical Revising of the Article for Important Intellectual Content: Zahra Sadat Rezaeian. Naeimeh Haddadi Esfahani, Jan Dommerholt.

Final approval of the article: Zahra Sadat Rezaeian. Naeimeh Haddadi Esfahani, Jan Dommerholt.

Integration of study protocol from design to dissemination: Zahra Sadat Rezaeian.

Role of the funding source

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Conflicting Interest (If present, give more details)

Nothing to declare. Dr.Rezaeian is an assistant professor in Isfahan University of Medical Sciences since 2011.

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