Acta of Bioengineering and Biomechanics
Vol. 26, No. 1, 2024

Original paper
DOI: 10.37190/ABB-02384-2024-02

Magnitude of changes in muscle endurance in the Biering-Sorensen test and changes in balance in subjects with LBP treated with muscle energy techniques

KATARZYNA WEGNER-CZERNIAK*, JACEK MĄCZYŃSKI,
ANNA BŁASZCZYK, MAŁGORZATA BARBARA OGURKOWSKA

Department of Biomechanics, Poznań University of Physical Education, Poznań, Poland.

Purpose: Manual therapy is used as a conservative treatment for people with low back pain (LBP). The scale of the problem encourages the search for the most effective methods to assess of manual treatment. Therefore, the aim of the study was to investigate magnitude of changes in muscle endurance using the Biering-Sorensen test (BST) and to analyse balance in patients with LBP treated with ERS and FRS muscle energy techniques (MET). *Methods*: The study included fifteen men with LBP (mean age: 42 years) working as automotive assemblers. Endurance of the biceps femoris (BF), gluteus maximus (GM) and erector spinae (ES) muscles were analysed using sEMG during the BST. The level of experienced pain, degree of disability and postural stability were also examined. Results before and after a three-week treatment cycle using MET were compared. *Results*: The MET therapy resulted in a reduction in pain ($p = 0.001$), an improvement in the degree of disability ($p < 0.001$) and an increase in the duration of the BST ($p < 0.001$). After therapy, the values of the NMFs parameter indicating the degree of fatigue increased, i.e., ES muscle endurance increased, both right ($p = 0.004$) and left ($p < 0.001$). There was also a statistically significant decrease in the centre of pressure (COP) movement velocity in balance tests. *Conclusions*: The use of MET in patients with LBP increases muscle endurance, improves postural balance, and reduces pain levels on the VAS and disability levels according to the ODI. MET appears to be a good tool for preventing LBP.

Key words: *electromyography, low back pain, muscle fatigue, posturography, osteopathic manipulative treatment*

Acronyms

MET – Muscle energy technique
LBP – low back pain
BST – Biering-Sorensen test
GM – gluteus maximus
BF – biceps femoris
ES – erector spinae
RES – right erector spinae
LES – left erector spinae
sEMG – surface electromyography
PHE – prone hip extension
VAS – visual analogue pain scale
CT – computed tomography
BMI – body mass index
MF – median frequency
SD – standard deviation
COP – centre of pressure
RGM – right gluteus maximus
LGM – left gluteus maximus
AE – area of ellipse
XR – range of movement of the COP in the *x* plane
YR – range of movement of the COP in the *y* plane
EcCb – Eyes close Close base
EoCb – Eyes open Close base
EoSr – Eyes open Single right
EoSl – Eyes open Single left

1. Introduction

Low back pain (LBP) is a common and complex problem in industrialised societies [7], [40]. The pain

* Corresponding author: Katarzyna Wegner-Czerniak, Department of Biomechanics, Poznań University of Physical Education, Poznań, Poland. E-mail: kasiawegner1@gmail.com
Received: January 12th, 2024
Accepted for publication: April 30th, 2024

is often accompanied by disability and its socio-economic impact is tremendous [19], [26]. The aetiology of LBP is not yet well understood, with the risk factors including repetitive physical and psychological stress typical of the modern lifestyle, the type of professional work and hypokinesia [1].

According to epidemiological data, there is a high frequency of LBP pain in blue-collar workers [16]. Reviews of working conditions, cyclically conducted in Europe, lead to the conclusion that a forced body position and repetitive movements rank first and foremost on the list of risk factors for overload syndromes in the work environment. Assembly line work involves repetitive forward bending and extension movements when reaching for components. This alters intervertebral disc pressures and causes backward displacement of the nucleus pulposus [23]. The adaptive capacity of the spine is usually exceeded when overloading is compounded by a deterioration of the body's capacity or health condition. This initiates functional, followed by degenerative, changes of spinal structures [32]. Individuals with LBP often have reduced strength and endurance of paraspinal muscles, which may predispose to repeat injuries and the development of LBP [31]. According to Ogurkowska [23], muscle overload affects the passive stabilisation system, i.e., ligaments and capsules of intervertebral joints, thereby increasing the shear component of the resulting force acting on the intervertebral disc causing its damage and subsequent morphological changes in the vertebral bodies and intervertebral joints. Studies show that neuromuscular disorders also affect postural balance in individuals with LBP [11], [18].

Both the deterioration of muscle endurance properties and balance disorders can exacerbate symptoms in individuals with LBP. A number of therapeutic approaches are used to improve patients' functional status. Osteopathic manipulative treatment (OMT) is commonly used in LBP. The literature confirms a reduction of pain and improvement in patients' functional status after OMT [8]. Techniques used by osteopaths include, among others, muscle energy techniques. These are soft tissue manipulation methods consisting of isometric tension initiated by the patient and resistance simultaneously applied by the therapist [3]. The biological mechanisms underlying manipulation are complex and understood only to some extent. Spine manipulation has been shown to have physiological consequences on the transmission of sensory information to the central nervous system [28]. According to the gate control theory, passive joint mobilisation and manipulation stimulate muscle and joint mechanoreceptors, which alters and inhibits afferent pain information in the posterior horn region of the spinal cord [33], [39]. This potentially reduces pain symptoms and facilitates muscle strengthening [17]. Most studies evaluating the effectiveness of MET are based on pain severity on the VAS scale and on the degree of disability measured using the ODI score, both related to the patient's subjective feelings [8].

The Biering-Sorensen Test (BST) is one of the tools used to assess the effects of LBP treatment. It analyses the endurance of back muscles while maintaining maximal isometric contraction over time. According to test authors, a shorter time in the position predisposes to the occurrence of lower back pain in the following year [2]. A more advanced muscle endurance testing techniques is the analysis of frequencies of electromyographic signals. During muscle fatigue, the median frequency of the EMG signal is observed to decrease towards lower frequencies. Kankaanpaa et al. [14] suggest that during the BST the gluteus maximus (GM) and biceps femoris (BF) muscles also show fatigue, which is closely related to the duration of the endurance test. Therefore, the aim of the study was to examine in LBP patients treated with ERS and FRS muscle energy techniques the magnitude of changes in ES, GM and BF muscle endurance using the Biering-Sorensen test (BST) in which surface electromyography was used. The patients' balance was also examined. Moreover, it was investigated whether the change in muscle endurance and postural stability after MET therapy affects the degree of disability and severity of pain.

2. Materials and methods

2.1. Participants

Participants included 15 male workers with LBP aged 41.9 ± 6.8 [years] with a BMI of 27.8 ± 2.1 [kg/m^2], working on an assembly line with an average job seniority of 22.2 ± 3.8 [years]. The work of an assembly line worker involves lifting components and remaining in the same forced body position for prolonged periods of time, most often with pelvic anteversion. The activities and body positions mentioned above are inherent to their work and they are difficult to avoid [38]. Lumbar spine overload changes in the occupational group studied were confirmed by computed tomography results. Intervertebral disc protrusion at the L1–L2 level was diagnosed in 10% of the men, L2–L3 – in 15%, L3–L4 – in 17%, L4–L5 – in 28% and L5–S1 – in 30%.

The inclusion criterion was lumbar pain of at least 7 points on the Visual Analogue Scale (VAS) lasting more than 12 weeks. It was important that the pain felt by the patient was at least severe. The intensity of pain affects the functional state of the patient [19]. Influencing, among other things, the mobility that is important in the work of an editor. Exclusion criteria: neoplastic disease, spinal fracture, lumbar spine surgery, diagnosed spondylolisthesis.

Approval no. 623/15 was granted by the Bioethics Committee of the Poznań University of Medical Sciences. All subjects submitted their written informed consent to participate in the study. All procedures were conducted according to the Declaration of Helsinki.

The study protocol consisted of an anthropometric questionnaire together with the ODI and the VAS questionnaire. The measurement part of the protocol assessed muscle fatigue using sEMG, and upright balance using stabilometric platforms. The selected men participated in two independent measurement sessions before and after a three-week MET therapy. The interval between the therapy sessions was seven days.

2.2. sEMG measurement

Patients lying in the prone position were fitted with adhesive electrodes in previously shaved and cleaned areas. Electrodes were positioned as follows: for ES – bilaterally 2 cm from the spinous processes of the L3 vertebra region; for GM – in the middle of the line connecting S2 with the greater trochanter; for BF – laterally in the middle of the line between the buttock fold and the popliteal fossa [6]. The men were given individual instruction concerning the BST. The sEMG measurement during the test was performed using a 16-channel TeleMyo 2400T G2 telemetric system. According to the SENIAM recommendations, 15 disposable, adhesive Ag/AgCl electrodes (SORIMEX, Poland, 1 cm diameter) were placed parallel to the course of the muscle fibres. Signal processing was performed with the use of the MyoResearch XP Master Edition software (Noraxon, USA) [6]. The EMG signal was sampled at 1000 Hz and then filtered (bandwidth: 10–500 Hz). Fatigue of the six muscles mentioned above was analysed.

2.3. Posturographic tests

Postural balance was tested before and after the therapy. An AccuSway stabilometric platform from AMTI with the Balance Clinic software package was used. The subjects underwent measurements for balance in four variants: standing on both feet with the upper limbs along the body, eyes open and closed, and standing on one leg – left and right – with eyes open. The men were unable to perform the single leg standing test with eyes closed. The subjects' task was to remain as still as possible for 30 s in the two feet test, and for 15 s in the single leg test. The subjects performed 3 tests for each of the four balance measurement variants. Intervals between the measurements lasted 60 s. The analysed parameters obtained in the balance test were the mean COP (centre of pressure) velocity, the ranges of motion of the COP in the frontal and sagittal planes, and the area of the ellipse comprising 95% of the measurement points. One of the three tests with the lowest COP velocity, i.e., with the best balance, was selected for statistical analysis. For the statistical analysis, the COP velocity was selected instead of the COP path due to the different test durations (15 or 30 s).

2.4. Segmental muscle energy techniques

The first phase of the therapy involved palpation of the spinous processes of the lumbar spine and the spinous process of S1. In the next phase, the osteopath performed passive rotation movements and side bends to determine the mobility deficit. The spine mobility barrier on both sides was compared to correctly identify the disorder. In the studied group, resisted contraction lasting between 3 and 7 seconds was applied according to Mitchell's guidelines [20]. The patients were asked to keep the contraction at 20% of the maximum force they could generate in a particular movement. The same osteopath diagnosed and performed the therapy on all patients. The strength of the contraction was controlled by the therapist, who sensed the muscle tension. The patients were lying in the supine position. Depending on the type of dysfunction diagnosed, two variants of mobility improvement on a given spinal segment were used. The first variant was ERS, i.e., lumbar vertebra mobility deficit during forward bending, rotation, lateral bending in the opposite direction. The second variant was FRS, i.e., lumbar vertebra mobility deficits in extension, rotation, lateral bending in the same direction [4]. Before each therapy, the same diagnostic procedure was carried out in order to select different techniques for the type of dysfunction. The current clinical condition of the patient was important. It was not suggested what kind of dysfunction was on this prior therapy. The duration of the meeting is about 30 minutes.

2.5. Biering-Sorensen test

The patients were lying in the prone position on the couch so that the anterior superior iliac spines were over the edge (Fig. 1). Based on the study by Jabłońska et al. [13], a modification was introduced, namely, fewer stabilising straps were applied (no strap in the ankle region). With hands propped on the ground, patients' lower limbs were attached to the couch with two straps at the level of the pelvis and knee joints. The test began by folding the arms across the chest and keeping the torso in a straight line at the same level as the lower limbs [2]. The test started as instructed verbally and ended at the participant's discretion or when the position of the torso was lowered, as verified by the researcher.

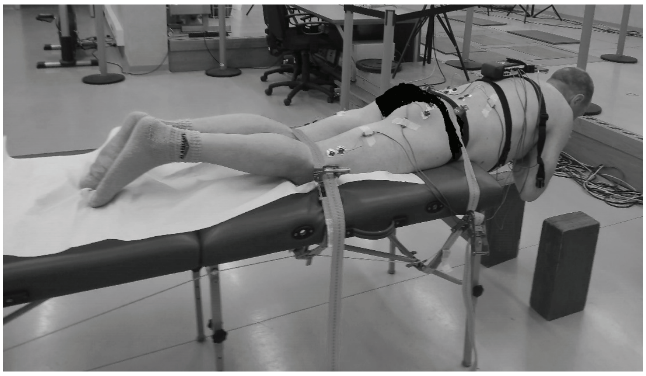

Fig. 1. SEMG measurement during the BTS test

2.6. Oswestry questionnaire

The ODI assesses the functional performance of people with back pain. The patient answers questions concerning: pain intensity, activities of daily living, lifting objects, walking, sitting, standing, sleeping, social life, professional life and travel. Each answer was scored and the maximum achievable score was 50. In interpreting the results, a percentage scale of 0–100% was used to determine the degrees of disability according to the ODI: 0–20% minimal disability, 21–40% moderate disability, 41–60% severe disability, 61–80% crippled, 81–100% bed-bound [9].

2.7. VAS pain scores

Respondents rated the intensity of their pain episodes on the ten-point Visual Analogue Scale (VAS) assessing pain intensity [12].

2.8. Numerical and statistical methods

The results are presented as mean values, standard deviations (SD), medians and quartile distributions (Q1–Q3). The median frequency (MF) of the EMG signal is a reliable parameter used for the analysis of spinal muscle fatigue [5], [30]. The relationship between MF and time is determined by applying the fast Fourier transform to the time course of the EMG signal. This relationship can be approximated in a linear regression model. The median frequency was calculated in one-second windows using the Noraxon MyoResearch XP Master software Edition 1.08.38. The calculated parameters were determined according to the formulas given in the publication by Jabłońska et al. [13]. The time interval for calculating and interpreting the frequency spectrum for all tested muscles is determined by the TE parameter (BST test duration).

Statistica software version 13.3 was used to analyze the statistical data. The Shapiro–Wilk test was used to assess the normality of the distribution of the variables. The statistical significance of differences between the mean parameters for the two dates of the study was checked using the parametric Student's *t*-test or the non-parametric Wilcoxon's *R*-signed test; correlation was tested using Pearson's or Spearman's tests, depending on the statistical distributions obtained. Calculations of the power of the parametric tests used were also performed.

3. Results

The following parameters were used for the overall evaluation of the MET therapy: TE (duration of the BST), PA (pain assessment score on the VAS scale), and ODI (Oswestry Disability Index). The TE of the BST increased on the second date (80.8 s) compared to the first date (61.0 s). A beneficial effect was obtained in therms of the PA and ODI parameters, i.e., a decrease in the medians from 5 to 2 and from 14 to 9, respectively (Table 1). The effects shown in this table are statistically significant and contribute to a positive assessment of the MET method. A high Pearson correlation was found between the PA and ODI parameters ($r = 0.704$, $p < 0.001$, $n = 30$). According to Cohen's interpretation, a large statistical effect (CES > 0.8) was obtained for the differences in the parameters given in Table 1.

Table 1. Variation in TE, ODI and PA at two testing dates, $n = 15$

Parameters	Mean (SD) Median (lower quartile; upper quartile)		*p*-value	CES
	First examination	Second examination		
TE [s]	61.0 (23.0) 61.7 (48.2; 73.6)	80.8* (25.9) 84.8 (65.9; 90.1)	<0.001	0.808
ODI	14.1 (3.1) 14 (11; 16)	7.4 (3.5) 9# (3; 10)	<0.001	2.027
PA [VAS]	5.5 (1.3) 5 (5; 7)	2.3 (1.4) 2# (1; 4)	0.001	2.369

* Significance, Student's *t*-test for dependent samples. Power of test: 0.999.

\# Significance, Wilcoxon paired rank order test.

CES – Cohen's effect size.

Electromyographic test results

EMG results obtained before and after the therapy are presented in Table 2. A highly statistically significant increase in the NMFs parameter after the therapy was obtained for the RES ($p = 0.004$) and LES muscles ($p < 0.001$). The increase in the NMFs parameter is associated, among other things, with the increase in the duration of the BST and it is indicative of less muscle fatigue after the therapy. An analogous effect (a favourable change in the NMFs parameter) was also observed for the GM and BF muscles, but it was not statistically significant. A large Cohen's *d* was obtained for the NMFs parameter and the ES muscles (CES = 1.156 for RES, 1.353 for LES).

Posturographic test results

The results of the standing balance tests are shown in Table 3. Statistically significant changes before and after the therapy were obtained for the VA parameter. A reduction in VA values was observed for all 4 positions in the balance test: EoCb ($p = 0.008$); EcCb ($p < 0.001$); EoSr ($p = 0.004$); EoSl ($p = 0.014$). Reduction in the VA parameter is indicative of improved balance after the therapy, compared to the results before the therapy. A statistically significant decrease in the XR parameter value for the EcCb position was also obtained ($p = 0.019$). Other parameter decreases, which are favourable from the point of view of the therapy evaluation, show a statistical tendency and concern the following: AE (EoCb, $p = 0.054$) and YR (EoCb, $p = 0.099$; EcCb, $p = 0.080$; EoSl, $p = 0.064$). A medium to large Cohen's *d* was obtained for the VA parameter (CES = 0.578–0.912).

In Table 4, statistically significant correlations between anthropometric parameters and the PA and ODI parameters and balance assessment parameters are shown. The data shows that, for the EcCb position, the VA of the COP movement increases together with an increase in body weight and BMI. Furthermore, as ODI increases, VA (EoCb, EcCb) and XR (EcCb) and YR (EcCb) increase as well. Furthermore, VA (EoCb, EcCb) increases together with an increase in PA.

Table 2. Electromyographic parameters for three pairs of muscles at two testing dates (mean, below SD, $n = 15$)

Testing dates / Muscles	MFi [Hz]		MFe [Hz]		$10^4 \times$ NMFs [s^{-1}]		dim [%]	
Side	R	L	R	L	R	L	R	L
I/ES	72.2 15.4	64.0 12.6	51.5 10.9	44.9 13.1	–46.2 14.0	–52.9 19.3	27.7 11.3	30.4 11.7
II/ES	73.2 15.2	67.8 13.3	54.5 14.1	51.0 13.9	–31.7* 10.9	–32.1* 10.0	25.7 12.6	25.4 10.1
I/GM	38.0 9.5	38.2 7.6	33.4 9.4	33.4 7.1	–24.4 15.2	–23.7 13.0	12.5 4.8	12.6 4.2
II/GM	34.7 5.8	37.4 5.8	30.0 6.4	32.1 5.1	–17.7 10.2	–18.7 9.1	14.2 8.6	14.0 6.2
I/BF	108.0 19.6	104.4 20.3	89.8 19.4	88.4 18.0	–29.9 17.1	–31.5 16.4	16.9 8.9	18.8 12.2
II/BF	97.0 15.5	98.5 17.9	80.3 14.5	82.2 19.8	–22.3 7.4	–27.43 17.3	17.2 7.0	22.6 17.2

* Statistical significance, Student's *t*-test for dependent samples, $p < 0.05$. Power of test R:0.893, L:0.984.

MFi (MFe) initial (final) median frequency.

NMFs normalised slope coefficient of the regression line of the median frequency.

dim normalised difference (MFi-MFe)/MFi.

R (L) right (left) muscle.

The notation $10^4 \times$ NMFs [s^{-1}] means that the correct value of the NMFs parameter is obtained by dividing the value in the table by the multiplier 10^4, used to unify the numerical entries in the entire table.

Table 3. Posturographic parameters, mean (SD), below median (lower quartile; upper quartile), $n = 15$

Position Abbreviation	XR [cm]	YR [cm]	VA [cm/s]	AE [cm^2]
First examination				
Eyes open, Closed base EoCb	1.35 (0.62) 1.18 (0.93; 1.85)	2.25^g (0.75) 2.25 (1.44; 3.05)	1.13 (0.21) 1.09^a (1.00; 1.26)	2.25 (1.19) 2.13^f (1.46; 3.24)
Eyes closed, Closed base EcCb	1.86^e (0.63) 1.86 (1.44; 2.32)	3.16^h (1.19) 2.97 (2.33; 3.72)	1.90^b (0.44) 1.96 (1.45; 2.25)	3.35 (2.48) 2.70 (1.83; 4.29)
Eyes open, Single right EoSr	2.78 (0.50) 2.68 (2.27; 3.11)	3.26 (0.71) 3.25 (2.83; 3.64)	4.41^c (0.89) 4.29 (3.80; 5.07)	6.61 (1.99) 6.40 (5.34; 7.19)
Eyes open, Single left EoSl	2.69 (0.55) 2.65 (2.17; 3.12)	3.28^k (0.84) 2.88(2.67; 3.91)	4.21^d (0.99) 4.09 (3.56; 4.48)	6.49 (2.09) 6.68 (4.86; 8.37)
Second examination				
Eyes open, Closed base EoCb	1.22 (0.42) 1.12 (0.97; 1.36)	1.84^g (0.42) 1.76 (1.48; 2.14)	0.98 (0.10) 0.95^a (0.91; 1.04)	1.57 (0.85) 1.39^f (1.02; 1.92)
Eyes closed, Closed base EcCb	1.46^e (0.40) 1.54 (1.22; 1.70)	2.59^h (0.81) 2.32 (2.19; 2.89)	1.55^b (0.40) 1.52 (1.18; 1.73)	2.53 (1.23) 2.21 (1.80; 2.98)
Eyes open, Single right EoSr	2.70 (0.54) 2.67 (2.39; 3.04)	2.92 (0.78) 2.54 (2.38; 3.35)	3.89^c (0.91) 4.02 (2.96; 4.61)	6.32 (3.00) 5.08 (4.65; 7.52)
Eyes open, Single left EoSl	2.54 (0.51) 2.50 (2.20; 2.96)	2.80^k (0.69) 2.75 (2.16; 3.12)	3.78^d (0.79) 3.69 (3.07; 4.77)	6.10 (2.44) 5.90 (4.30; 8.06)

[a] Significance, Wilcoxon paired rank order test, $p < 0.05$.
[b, c, d, e] Statistical significance, Student's t-test for dependent samples, $p < 0.05$.
Power of test b:0.996, c:0.903, d:0.743, e:0.704.
[f] Tendency, Wilcoxon paired rank order test, $0.05 < p < 0.10$.
[g, h, k] Tendency, Student's t-test for dependent samples, $0.05 < p < 0.10$.
XR (YR) – range of movement of the COP in the frontal (sagittal) plane.
VA – average speed of the COP (COP path normalised to the duration of the test).
AE – area of the ellipse in which 95% of the COP points are contained.

Table 4. Correlations of anthropometric parameters, PA and ODI with balance assessment parameters, $n = 30$

Parameters	Position	r	p-value
Body mass and VA	EcCb	0.446^P	0.013
BMI and VA	EcCb	0.473^P	0.008
ODI and VA	EoCb	0.454	0.012
and VA	EcCb	0.604^P	<0.001
and XR	EcCb	0.424^P	0.019
and YR	EcCb	0.399	0.029
PA and VA	EoCb	0.445	0.014
and VA	EcCb	0.502^P	0.005

[P] Pearson (in other cases Spearman's correlation).
Power of test: body mass and VA: 0.718, BMI and VA: 0.776, ODI and VA (EcCb): 0.959, ODI and XR: 0.667, PA andVA: 0,831.

In Table 5, statistically significant correlations of the most important electromyographic parameter NMFs with the following parameters: anthropometric (body height, body mass), posturographic (VA, YR) and ODI and PA, are shown. The NMFs parameters were obtained by averaging them for the left and right BF and ES muscles (except for the RGM muscle). The data show that as body weight and height increase, the NMFs parameter value for the BF muscles decreases, and therefore their strength decreases as well. For the ES muscles, an analogous effect of a decrease in endurance together with an increase in PA and ODI was observed. Relationships were also found between the NMFs parameter and posturographic parameters for the EoCb balance position, i.e., a decrease in the VA of the COP movement with an increase in the ES muscle endurance, and a decrease in the YR of the COP movement in the anteroposterior direction with an increase in the RGM (right gluteus maximus) muscle strength.

Table 5. Correlations of NMFs parameter with anthropometric parameters (BH, BM), posturographic parameters (VA, YR), ODI and PA ($n = 30$)

NMFs and Variable	Muscle	r	p-value
BH	BF	–0.474	0.008
BM	BF	–0.458	0.011
ODI	ES	–0.365^P	0.047
PA	ES	–0.471^P	0.009
VA (EoCb)	ES	–0.407	0.026
YR (EoCb)	RGM	–0.393	0.032

[P] Pearson (in other cases Spearman's correlation).
(EoCb) Balance position Eyes open Closed base.
Power of test: NMFs and ODI: 0.525, NMFs and PA: 0.771

4. Discussion

The most important result of the study is the confirmation of the beneficial effect of MET on muscle endurance and the improvement of postural stability after the therapy in the selected group of men. To our knowledge, electromyographic and posturographic methods have not been used to assess the effectiveness of MET. An increase in the duration of the BST is associated with less fatigue after the therapy of the muscular system and therefore an increase in its endurance [30]. This is particularly important in the case of people with chronic LBP, in whom changes in computed tomography confirm the pathobiomechanism of overload changes among the examined group of fitters. The effect of MET on the fatigue of individual muscles of the spine and lower limbs during the BST test was examined. A statistically significant improvement was obtained for the right and left ES muscles. An increase in ES muscle fatigue, and thus a decrease in the efficiency of these muscles, was generally also observed in people with high disability and pain scale. This confirms that the obtained improvement in PA and ODI parameters is related to the function of the ES muscles. This is important information, because the improvement in the muscles efficiency of active stabilizers of the spine directly translates into a reduction in the load on passive stabilizers, i.e., ligaments and joint capsules. [23]. According to Panjabi [25], the stability of the spine is the proper motor control of the trunk consisting in the interaction of passive stabilizers (osteo-ligamentous structures of the spine), active stabilizers (muscles) and the control system (central nervous system), with the latter the integration and coordination of sensorimotor information through direct control of the muscles. The nature of the work of fitters requires adopting non-ergonomic body positions, straining the musculoskeletal system. The improvement in muscle endurance achieved thanks to MET affects the stabilization of the spine. Previous studies of muscle endurance have shown the effect of increasing body weight and height on shortening the duration of BST [14], [22]. Our results also confirm that with the increase in body weight and height, the fatigue of the BF muscles also increases, acting as thigh extensors and lift the pelvis when the thigh is in a fixed position [15]. Additional load on the spine and the resulting exacerbation of overload changes was observed in overweight fitters with hypertrophy of adipose tissue mainly in the abdominal cavity [10], as a result of extending the lever arm of the center of gravity [24].

Postural stabilization is also impaired in the group of people with LBP compared to people without LBP symptoms [36]. Proprioceptive information may be reduced or distorted as a result of traumatic tissue damage and muscle fatigue [35]. Prolonged nociception leads to increased activation of the sympathetic nervous system [21], which directly innervates the muscle spindles and modulates their secretion [29]. This may be a contributing mechanism to the observed impairment of trunk proprioception in patients with LBP. The results of our study confirmed the positive effect of MET on the improvement of balance parameters, as a significant correlation was observed between ES muscle fatigue and balance. The applied manipulation of the spinal muscles could affect the sympathetic nervous system, activating the flow of information from the muscle spindles, improving the flow of proprioceptive information through the corticospinal axis [27]. A relationship was also observed between anthropometric parameters, pain intensity, degree of disability and balance parameters. High BMI and body weight increased COP movement speed. Also, an increase in PA and ODI impairs postural stability in people with LBP. In the standing position, they adopt a pain-relieving posture, thus relieving, for example, a painful lower limb [23]. The more severe the pain, the worse the posture, and thus the more difficult it is to maintain balance. Therefore, alleviating pain and improving functional status in people with LBP is crucial because it positively affects balance [24]. In their study, Vining et al. [37] used a similar design to assess biomechanical mechanisms after chiropractic treatment in soldiers with LBP. A four-week program of spinal manipulation along with education in a group of 100 people resulted in an increase in BST time by 13.9 s, improvement in balance with eyes closed, reduction in pain intensity and degree of disability. The difference between the two treatments is that the osteopath works with the neuromusculoskeletal system, among other things. Chiropractors, on the other hand, focus solely on the spine, ignoring the myofascial system. Jabłońska et al. [13] also used BST to evaluate the effectiveness of McKenzie's weekly therapy sessions in people with LBP. The therapy had the same focus as chiropractic, i.e., the spine. The BST duration also increased by 13.9 s after the seven-day therapy, compared to a 19.8 s increase after the MET therapy. The effects of the different spinal treatments may confirm the aforementioned role of the autonomic system in muscle activation. In contrast, the better results of the BST after the MET treatment can be due to the fact that these techniques act on the spine through the myofascial system. According to Szulc et al. [34], it is the myofascial limitations that affect spinal mobility and function.

The advantage of this study is indicating the correlation between subjective parameters, such as pain intensity and degree of disability, and objective measures of muscular endurance and balance. It is important to use objective research tools in this measurement to better understand the mechanism of manual treatment. This may contribute to a more precise selection of techniques in patients with LBP. Furthermore, it will make it possible to reduce a treatment time and cost, and for the patient to return faster to work. The results of our study may provide a basis for the development of evaluation protocols for other manual techniques.

5. Conclusions

The use of MET in patients with LBP increases muscle endurance, as shown by electromyographic measurements, improves postural balance and reduces pain levels on the VAS scale and disability levels according to the ODI. MET appears to be a good tool for preventing LBP, but the high prevalence of back pain should prompt a search for further research methods to verify the degree of clinical utility of manual therapy.

References

[1] BALDWIN M.L., *Musculoskeletal disorders and work disability: The role of socioeconomic factors*, Paper prepared for the National Academy of Sciences Panel on Musculoskeletal Disorders and the Workplace, 2000.
[2] BIERING-SORENSEN F., *Physical measurements as risk indicators for low-back trouble over a one-year period*, The Spine Journal, 1984, 9 (2), 106–119.
[3] CHAITOW L. et al., *Muscle energy techniques*, Elsevier Urban i Partner, Wrocław 2011.
[4] COLOTA TH., VERHEYENA M., *Practical Handbook of Osteopathic Manipulation*, Maisonneuve, 2002.
[5] COOREVITS P., DANNEELS L., CAMBIER D., RAMON H., VANDERSTRAETEN G., *Assessment of the validity of the Biering-Sørensen test for measuring back muscle fatigue based on EMG median frequency characteristics of back and hip muscles*, Journal Electromyography Kinesiology, 2008, 8 (6), 997–1005.
[6] CRAM J., KASMAN G., HOLTZ J., *Introduction to surface EMG*, Maryland: Aspen Publishing, Gathersburg, PA., 1998, 1, 336–370.
[7] DAGENAIS S., CARO J., HALDEMAN S., *A systematic review of low back pain cost of illness studies in the United States and internationally*, Journal Spine, 2008, 8 (1), 8–20.
[8] DAL FARRA F., RISIO R.G., VISMARA L., BERGNY A., *Effectiveness of osteopathic interventions in chronic non-specific low back pain: A systematic review and meta-analysis*, Complementary Therapies in Medicine, 2021, 56 (1).
[9] FAIRBANK J., PYNSEN P.B., *The Oswestry Disability Index*, Spine, 2000, 25 (22), 2940–2952.
[10] FRILANDER H., SOLOVIEVA S., MUTANEN P., PIHLAJAMAKI H., HELIOVAARA M., VIIKARI-JUNTURA E., *Role of overweight and obesity in low back disorders among men: a longitudinal study with a life course approach*, OOOOO, 2015, 5 (8).
[11] HAM Y.W., KIM D.M., BAEK J.Y., LEE D.C., SUNG P.S., *Kinematic analyses of trunk stability in one leg standing for individuals with recurrent low back pain*, Journal of Electromyography and Kinesiology, 2010, 20 (6), 1134–1140.
[12] IQBAL Z., ALGHADIR A., *Prevalence of work-related musculoskeletal disorders among physical therapists*, Occupational Medicine, 2015, 66 (4), 459–469.
[13] JABŁOŃSKA M., MĄCZYŃSKI J., FRYZOWICZ A., OGURKOWSKA M.B., *Electromyographic assessment of muscle fatigue after the Biering-Sorensen test in subjects with low back pain who underwent the McKenzie treatment*, Acta Bioeng. Biomech., 2021, 23 (3), 87–96.
[14] KANKAANPÄÄ M., LAAKSONEN D., TAIMELA S., KOKKO S.M., AIRAKSINEN O., HÄNNINEN O., *Age, sex, and body mass index as determinants of back and hip extensor fatigue in the isometric Sorensen back endurance test*, Archives of Physical Medicine and Rehabilitation, 1998, 79 (9), 1069–1075.
[15] KAPANDJI A., OWERKO C., ANDERSON A., *The Physiology of the Joints*, Vol. 2: *The Lower Limb*, Handspring Publishing, 2019.
[16] KOŁODZIEJ K., KWOLEK A., RUSEK W., PRZYSADA G., *Correlation of lower limb load symmetry index and pain intensity in patients with lumbosacral spine pain syndrome rehabilitated in a hospital*, Medical Review of the University of Rzeszów, 2005, 3, 234–236.
[17] KOPPENHAVER S.L., FRITZ J.M., HEBERT J.J., KAWCHUK G.N., PARENTET E.C. et al., *Association between history and physical examination factors and change in lumbar multifidus muscle thickness after spinal manipulation in patients with low back pain*, Journal of Electromyography and Kinesiology, 2012, 22 (5), 724–731.
[18] LEE D.C., HAM Y.W., SUNG P.S., *Effect of visual input on normalized standing stability in subjects with recurrent low back pain*, Gait and Posture, 2012, 36 (3), 580–585.
[19] LUTTMANN A., JÄGER M., GRIEFAHN B., CAFFIER G., LIEBERS F., *Preventing musculoskeletal disorders in the workplace*, Word Health Organization, Geneva 2003.
[20] MITCHELL F., MITCHELL K.G., *Muscle Energy Handbook*, Vol. 2, *Evaluation and treatment of the thoracic and lumbar spine and chest*, Met. Press, 1998.
[21] NAITO E., NAKASHIMA T., KITO T., ARAMAKI Y., OKADA T., SADATO N., *Human limb-specific and non-limb-specific brain representations during kinesthetic illusory movements of the upper and lower extremities*, The European Journal of Neuroscience, 2007, 25 (11), 3476–3487.
[22] NUZZO J.L., MAYER J.M., *Body Mass Normalization for Isometric Tests of Muscle Endurance*, Journal Strength Cond. Res., 2013, 27 (7), 2039–2045.
[23] OGURKOWSKA M.B., BŁASZCZYK A., *Distribution of Young's modulus at various sampling points in a humanlumbar spine vertebral body*, The Spine Journal, 2020, 20 (11), 1861–1875.
[24] OGURKOWSKA M.B., KAWAŁEK K., *Pathological changes in the lumbar intervertebral discs among professional field hockey players*, Journal of Sports Medicine and Physical Fitness, 2016, 56 (1–2), 85–91.
[25] PANJABI M.M., *Clinical spinal instability and low back pain*, Journal Electromyography Kinesiology, 2003, 13 (4), 371–379.
[26] PARENT-THIRION A., MACÍAS E.F., HURLEY J., VERMEYLEN P., *Fourth European Working Conditions Survey*, European Foundation for the Improvement of Living and Working Conditions, Dublin 2007.

[27] PICKAR J.G., *Neurophysiological effects of spinal manipulation*, The Spine Journal, 2002, 2 (5), 357–371.
[28] PICKAR J.G., Neurophysiological effects of spinal manipulation. The Spine Journal. 2002;2(5):357–371.
[29] RADOVANOVIC D., PEIKERT K., LINDSTRÖM M., DOMELLÖF F.P., *Sympathetic innervation of human muscle spindles*, Journal Anatomy, 2015, 226 (6), 542–648.
[30] ROSE-DULCINA K., ARMAND·S., DOMINGUEZ D.E., GENEVAY S., VUILLERME N., *Asymmetry of lumbar muscles fatigability with non-specific chronic low back pain patients*, European Spine Journal, 2019, 28 (11), 2526–2534.
[31] STEELE J., BRUCE-LOW S., SMITH D., *A reappraisal of the deconditioning hypothesis in low back pain: review of evidence from a triumvirate of research methods on specific lumbar extensor deconditioning*, Current Medical Research and Opinion, 2014, 30 (5), 865–911.
[32] STODOLNY J., *Spinal overload disease: an epidemic of our time*, ZL Natura, Kielce 2000.
[33] SUTER E., MCMORLAND G., *Decrease in elbow flexor inhibition after cervical spine manipulation in patients with chronic neck pain*, Clinical Biomechanics, 2002, 17 (7), 541–544.
[34] SZULC P., WENDT M., WASZAK M., TOMCZAK M., CIEŚLIK K., TRZASKA T., *Impact of McKenzie Method Therapy Enriched by Muscular Energy Techniques on Subjective and Objective Parameters Related to Spine Function in Patients with Chronic Low Back Pain*, Medical Science Monitor, 2015, 21, 2918–2932.
[35] TAIMELA S., KANKAANPÄÄ M., LUOTO S., *The effect of lumbar fatigue on the ability to sense a change in lumbar position. A controlled study*, The Spine Journal, 1999, 24 (13), 1322–1327.
[36] TSIGKANOSA CH., GASKELL L., SMIRNIOTOU A., TSIGKANOS G., *Static and dynamic balance deficiencies in chronic low back pain*, Journal Back Musculoskelet Rehabilitation, 2016, 29 (4), 887–893.
[37] VINING R. et al., *Effects of Chiropractic Care on Strength, Balance, and Endurance in Active-Duty U.S. Military Personnel with Low Back Pain: A Randomized Controlled Trial*, Journal of Alternative and Complementary Medicine, 2020, 26 (7), 592–601.
[38] WEGNER K., BŁASZCZYK A., ZYGMAŃSKA M., OGURKOWSKA M.B., *Evaluation of overload changes in employees of the automotive industry*, The Małopolska School of Economics in Tarnów Research Papers Collection, 2017, 3 (35), 93–103.
[39] WILLLAMS P., *The lumbo-sacral spine*, McGraw Hill, New York 1965.
[40] WU A., MARCH L., ZHENG X., HUANG J., WANG X., ZHAO J., BLYTH F.M., SMITH E., BUCHBINDER R., HOY D., *Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017*, Annals of Translational Medicine, 2020, 8 (6), 299–313.