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ORIGINAL ARTICLE

Fat infiltration in the lumbar multifidus and erector spinae muscles in subjects with sway-back posture

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Abstract

Aim Decreased activity of the lumbar stabilizer muscles has been identified in individuals with sway-back posture. Disuse can predispose these muscles to atrophy, which is characterized by a reduced cross-sectional area (CSA) and by fat infiltration. The aim of this study was to evaluate the amount of fat infiltration in the lumbar multifidus and lumbar erector spinae muscles as a sign of the muscle atrophy in individuals with sway-back posture, with and without low back pain.

Materials and methods Forty-five sedentary individuals between 16 and 40 years old participated in this study. The sample was divided into three groups: symptomatic sway-back (SSBG) ($n = 15$), asymptomatic sway-back (ASBG) ($n = 15$), and control (CG) ($n = 15$). The individuals were first subjected to photographic analysis to classify their postures and were then referred for a magnetic resonance imaging (MRI) examination of the lumbar spine. The total (TCSA) and functional (FCSA) cross-sectional areas of the lumbar erector spinae together with lumbar multifidus and isolated lumbar multifidus muscles were measured from L1 to S1. The amount of fat infiltration was estimated as the difference between the TCSA and the FCSA.

Results Greater fat deposition was observed in the lumbar erector spinae and lumbar multifidus muscles of the individuals in the sway-back posture groups than in the control group. Pain may have contributed to the difference in the amount of fat observed in the groups with the same postural deviation. Similarly, sway-back posture may have contributed to the tissue substitution relative to the control group independently of low back pain.

Conclusions The results of this study indicate that individuals with sway-back posture may be susceptible to morphological changes in their lumbar erector spinae and lumbar multifidus muscles, both due to the presence of pain and as a consequence of their habitual posture.

Keywords Multifidus · Erector spinae · Magnetic resonance imaging · Posture · Sway-back

Introduction

Sway-back posture is one among the most common deviations of sagittal alignment [16, 19, 20, 30]. Sway-back posture is clinically identified by the posterior displacement of the trunk relative to the pelvis, long thoracic kyphosis, reduced lumbar lordosis, posterior pelvic tilt, and extended hip and knee joints [14, 29, 30]. It is radiographically defined as one of four possible types of lumbar lordosis on the sagittal plane, as described by Roussouly et al. [27, 30]. This posture is considered to be passive because it depends on the passive structures such as ligaments, capsule and bone approximation to maintain an upright erect position against gravity [21]. Its passive nature has been confirmed in studies by O'Sullivan et al. [21]

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and Reeve and Dilley [26], which both document a decrease in the activity of the lumbar stabilizer muscles, such as the lumbar multifidus, internal abdominal oblique and transversus abdominis muscles, when adopting the sway-back posture rather than other postures that maintain the neutral posture of the lumbar spine, pelvis and hips. Smith, O'Sullivan and Straker [30] have identified a significant gender-based correlation between the sway-back posture and low back pain. Male adolescents with the sway-back posture are significantly more prone to low back pain lasting three or more months than are male adolescents with neutral posture. Although the relationship between low back pain and posture has been established [5, 22, 30], the contributing factors to the onset of symptoms are not yet understood. Several mechanisms have been proposed, including a possible spinal overload arising from changes in vertebral orientation [1, 18] and motor control [21, 26]. Alternatively, decreased muscle activity may lead to atrophy of the lumbar stabilizer muscles due to disuse and deconditioning. Muscle atrophy can be measured by non-invasive techniques, such as computed tomography (CT) [6, 11, 13] and magnetic resonance imaging (MRI) [3, 9, 10, 12]. MRI have been used to identify and measure alterations in the morphology of lumbar paraspinal muscles, such as reduced cross-sectional area (CSA) and fat infiltration which are thought to be critical signs of muscle atrophy [2, 15, 17]. Increased intramuscular fat deposits may affect the contractility of the muscles required for control of spinal orientation and intervertebral motion, resulting in the advent of pain and disability [7, 15]. The aim of this study was to evaluate the amount of fat infiltration measured by MRI as a sign of the muscle atrophy in symptomatic and asymptomatic sway-back subjects.

Materials and methods

Study design

Prospective and cross-sectional.

Sample

The sample consisted of 45 sedentary individuals between 16 and 40 years old. The sample was divided into three groups: symptomatic sway-back (SSBG) ($n = 15$, 9 females and 6 males), asymptomatic sway-back (ASBG) ($n = 15$, 2 females and 13 males) and control (CG) ($n = 15$, 6 females and 9 males). Age, weight, height, history of low back pain and level of physical activity were self-reported by the individuals. Low back pain complaint in the past 12 months was the inclusion criterion for SSBG. The ASBG and CG individuals denied any episodes of lumbar pain. The sedentary classification was based in the non-participation in vigorous physical activities, such as swimming, running, soccer and brisk walking, for more than 10 min/day. The exclusion criteria were lack of participation in core strengthening programs in the past 6 months, distal pain below the knee, signs and symptoms of nervous compression, previous lumbar surgery, neuromuscular diseases, systemic diseases, pregnancy and contraindications for MRI. Age and anthropometric variables such as weight, height and body mass index (BMI) were controlled and paired to compose structurally homogeneous groups (Table 1). BMI was calculated as the weight in kilograms divided by the squared height in meters. This study was approved by the Human Research Ethics Committee of the University Hospital.

Photographic imaging protocol

The individuals were selected in interviews and subjected to computerized photographic analysis to establish their sway angle in the sagittal plane. To be classified as sway-back, individuals had to exhibit an angle greater than or equal to 10° posterior to an imaginary vertical line crossing three anatomical landmarks: the lateral tip of the acromion, the midpoint of the femoral greater trochanter, and the tip of the lateral malleolus. A sway angle less than 10° was the inclusion criterion for the control group. The anatomical landmarks used in this study have been suggested in previous studies [21, 26]. The 10° value was used as the inclusion criterion for the sway-back individuals because the typical alterations of sway-back posture were clearly present in individuals with angles above or equal to 10°, based on the previous pilot study. After localization by palpation, non-reflecting markers were placed over anatomical landmarks by the same evaluator. The reliability of the localization and the angle obtained by joining these three anatomical landmarks was previously tested to assess

Table 1 Characteristics of the symptomatic sway-back, asymptomatic sway-back and control groups expressed as mean and standard deviation (SD) (significance level $p < 0.05$)

	Sway-back symptomatic ($n = 15$)	Sway-back asymptomatic ($n = 15$)	Control ($n = 15$)	p value (ANOVA)
Age (years)	28.1 ± 5.6	27.7 ± 5.5	25.4 ± 4.8	0.35
Height (cm)	173.0 ± 9.8	176.7 ± 4.5	172.5 ± 6.7	0.24
Weight (kg)	63.2 ± 12.0	71.5 ± 10.9	67.4 ± 11.1	0.14
BMI (kg/m^2)	21.0 ± 2.5	22.9 ± 3.1	22.2 ± 2.8	0.12

BMI body mass index

the intra- and inter-observer reproducibility of the values. Photographic images were obtained using a digital camera (Sony DSC-W35) placed on a tripod 100 cm high and 345 cm lateral to each individual. Lateral photographs of the left side of participants were taken in front of a non-reflective background and were photographed by the same evaluator. The participants were asked to adopt their habitual standing position and to avoid conscious postural corrections.

Magnetic resonance imaging protocol

The MRI was performed using 1.5-Tesla equipment (Magneton Vision Siemens, Germany). The individuals were placed in the supine position with a foam wedge underneath the knees to keep the hips and knees slightly flexed and to maintain a standardized lumbar position and symmetric alignment of the lower limbs. The participants were instructed to remain motionless during the scan. The parameters used for the imaging were a T2-weighted fast spin echo sequences, 8,200 ms repetition time, 120 ms echo time, 512 × 512 matrix, 280 × 280 field of view, 7 mm slice thickness, and the estimated time for full acquisition of the images was 6 min and 41 s. The upper margins of the L1 and S1 vertebral bodies were used as the upper and lower limits, respectively.

Analysis of photographic images

Digital photographs of each participant were transferred to a laptop computer and later analyzed using the ACLimagem software (version 2.1), which converted the image points to coordinate axes. Using digitally drawn straight lines, the software calculated the angle formed by markers (Figs. 1, 2). Twenty participants were recruited and evaluated twice, with a one-week interval between the first and second evaluations, to analyze the reliability of the measures. Intraclass correlation coefficients (ICC) for intra- and inter-observer reliability were rated as excellent [ICC = 0.94 (95 % CI = 0.74–0.99)] and good [ICC = 0.89 (95 % CI = 0.51–0.97)], respectively. The SPSS (Statistical Package for Social Sciences, Chicago, IL, USA, version 17.0) software was used to analyze the reproducibility of the measured angular values.

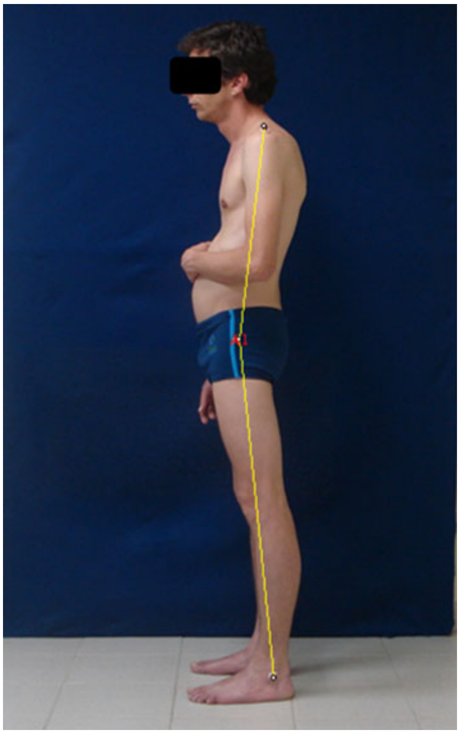
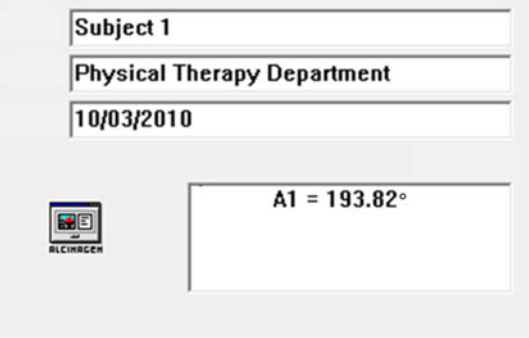


Fig. 1 Computerized photographic analysis of the individual with sway-back posture



Subject 1

Physical Therapy Department

10/03/2010

A1 = 193.82°

Fig. 2 Example of the angular measurement of the individual classified with sway-back posture (sway angle = 13.82°)

Analysis of magnetic resonance images

After scanning, the images were saved in DICOM file format before being recorded and transferred to a laptop computer. A total of 11 levels per individual, corresponding to the axial sectional planes through the upper endplate and lower endplate of each lumbar vertebra (L1u, L1l, L2u, L2l, L3u, L3l, L4u, L4l, L5u and L5l) and the upper margin of the first sacral vertebra (S1u), were selected from the scout view by the same evaluator. The images were transferred to the image-processing software (Image J software, version 1.41, National Institutes of Health, USA, available at: http://rsb.info.nih.gov/ij/) installed on a notebook computer and enlarged using a 1.5:1 zoom ratio for the better visualization. In each level, the total (TCSA) and functional (FCSA) cross-sectional areas of the combined bulk of the erector spinae muscles (iliocostalis lumborum pars lumborum, longissimus thoracic pars lumborum and lumbar multifidus) and isolated lumbar multifidus, were measured in cm^2 on both the right and left sides. The same image-processing software was used to measure the TCSA and FCSA of the abovementioned muscles. FCSA measurement has been previously suggested as a tissue segmentation method for differentiating tissues such as muscle and fat [24] because a number of studies have found that significant atrophy may occur despite preservation of the TCSA of muscles [15]. The FCSA was estimated according to the method proposed by Ranson et al. [24], with a threshold of 120 for the gray scale to exclude those pixels representing fat content from each muscular CSA. Although this method has been used to quantify the area of muscle tissue (as distinct from fat) [25], it is also possible to use this protocol to quantify fatty infiltration. The region of interest (ROI) was manually traced by a single evaluator who was blinded to the TCSA and FCSA measurements to eliminate potential bias (Figs. 3, 4). The amount of fat was calculated by subtracting the FCSA (muscle without fat) value from the TCSA (muscle and fat) value. The reliability of the CSA measure was performed using images of ten randomly selected individuals. ICC intra-rater was good and excellent for TCSA and FCSA measures for both, erector spinae [ICC = 0.92 (95 % CI = 0.89–0.94); ICC = 0.90 (95 % CI = 0.88–0.92)] and lumbar multifidus [ICC = 0.94 (95 % CI = 0.93–0.96); ICC = 0.94 (95 % CI = 0.93–0.95)], respectively. Higher values also were found for the ICC inter-rater for TCSA and FCSA measures to the erector spinae [ICC = 0.85 (95 % CI = 0.49–0.94); ICC = 0.86 (95 % CI = 0.53–0.93)] and lumbar multifidus [ICC = 0.83 (95 % CI = 0.78–0.87); ICC = 0.83 (95 % CI = 0.75–0.88)]. ICC values measurement were performed using SPSS software version 17.0.

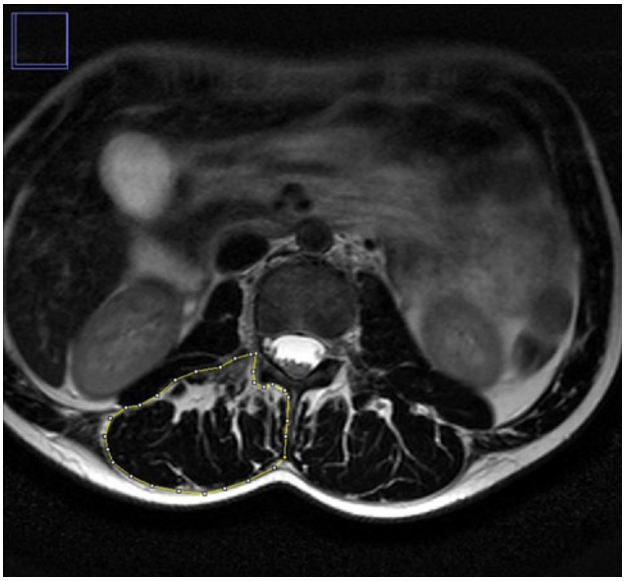


Fig. 3 Region of interest (ROI) to calculate the total cross-sectional area of the erector spinae (longissimus and iliocostalis) and lumbar multifidus

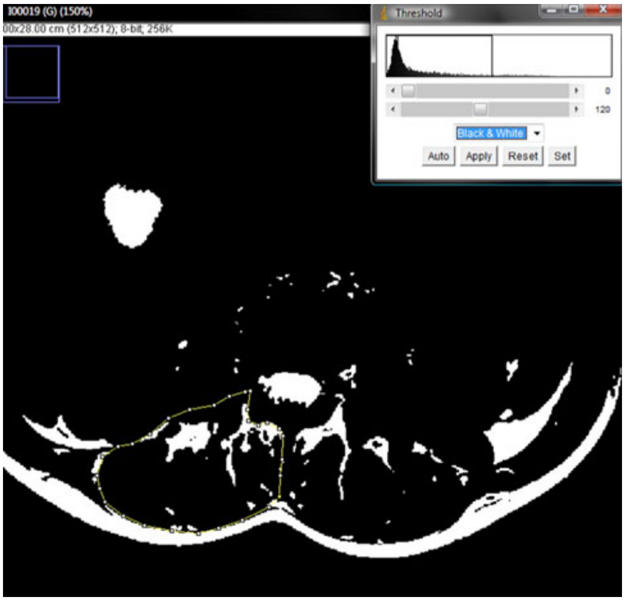


Fig. 4 Region of interest (ROI) to calculate the functional cross-sectional area (threshold 0 = minimum and 120 = maximum) of the erector spinae (longissimus and iliocostalis) and lumbar multifidus

Statistical analysis

Two-way analysis of variance (ANOVA) was used to compare the means of the age and anthropometric variables (weight, height and BMI) of the participants in this study. The Kolmogorov–Smirnov test was used to verify the normality of variables. No significant deviations from normality were identified. The two-tailed unpaired Student's *t* test was used to compare the means of the fat percentage of the symptomatic sway-back, asymptomatic sway-back and control groups. Statistical significance was established at 5 % ($p < 0.05$). Data analysis was performed using SPSS software version 17.0.

Results

Greater fat deposition was observed in the lumbar erector spinae and lumbar multifidus muscles of the sway-back posture groups (Tables 2, 3). Significant differences were observed between the symptomatic sway-back and control groups at the L1u, L1l, L2u, L2l, L3u, L4l and L5u levels on the left side and at the L1u, L1l, L2u, L2l, L3u, L4l and L5u levels on the right side for lumbar erectors spinae plus lumbar multifidus. When analyzed alone, there were statistically significant differences for the lumbar multifidus at the L1u, L2u, L3u, L4u, L4l and the L5l and L1u, L2u, L4l, L5u and L5l levels on the right and the left sides, respectively. Significant differences in the amount of fat among the symptomatic and asymptomatic sway-back groups were found only at the L1u and L1l levels for the lumbar spinae erectors together with multifidus and at the L1l level for the multifidus alone. Although a significant difference was identified at only one level, there was a greater average concentration of intramuscular fat in the symptomatic sway-back group. To some degree, pain contributed to the difference in the amount of fat between the groups with the same postural deviation. When comparing the asymptomatic sway-back and control groups, there was greater average fat infiltration in the sway-back posture individuals at the majority of the levels analyzed. There were significant differences between these groups for the right lumbar erectors spinae at the L1u, L2u, L2l, L3u, L4u and L5u levels and at the L2l, L3u and L4l levels on the left side. With regard to the right-side lumbar multifidus muscle, there were significant differences at the L1u, L2u and L4u levels, while a significant difference was found only at the L4l level on the left side. Despite the lack of significant differences at the other levels, a higher percentage of fat was consistently observed in the sway-back posture groups.

Table 2 Percentage of fat content in the lumbar erector spinae (longissimus and iliocostalis) and multifidus (of the % CSA muscle) in the symptomatic sway-back, asymptomatic sway-back and control groups expressed as mean and standard deviation (SD) (significance level $p < 0.05$)

Level	Side	Sway-back symptomatic	Sway-back asymptomatic	Control
L1u	L	7.27 ± 0.83**	4.85 ± 0.65*	3.52 ± 1.19
L1u	R	7.00 ± 1.00**	3.21 ± 0.58	3.25 ± 0.87
L1l	L	7.03 ± 0.72*	5.13 ± 0.81	3.90 ± 1.15
L1l	R	7.07 ± 0.83*	3.77 ± 0.74	3.43 ± 1.04
L2u	L	5.25 ± 0.79*	3.91 ± 0.68	2.34 ± 0.83
L2u	R	5.15 ± 0.73**	3.01 ± 0.75*	2.12 ± 0.76
L2l	L	5.27 ± 1.00*	3.90 ± 0.62*	2.53 ± 0.84
L2l	R	4.56 ± 0.73*	3.27 ± 0.45*	2.23 ± 0.69
L3u	L	4.17 ± 0.78**	3.48 ± 0.47**	1.49 ± 0.45
L3u	R	3.82 ± 0.59**	3.23 ± 0.44**	1.27 ± 0.49
L3l	L	3.11 ± 0.60	3.39 ± 0.56	2.70 ± 0.51
L3l	R	3.23 ± 0.58	2.80 ± 0.46	2.38 ± 0.55
L4u	L	2.99 ± 0.63	2.92 ± 0.47*	2.07 ± 0.44
L4u	R	2.85 ± 0.51*	4.01 ± 1.37	1.47 ± 0.39
L4l	L	3.94 ± 0.85**	5.13 ± 2.21	1.32 ± 0.49
L4l	R	3.52 ± 0.68*	3.76 ± 1.11	1.26 ± 0.53
L5u	L	5.88 ± 0.98**	4.39 ± 1.15*	2.93 ± 1.24
L5u	R	6.50 ± 1.31**	4.46 ± 1.46	2.96 ± 1.10
L5l	L	13.78 ± 2.43	9.94 ± 1.87	4.01 ± 0.89
L5l	R	11.00 ± 1.65	8.04 ± 2.15	4.24 ± 0.87
S1u	L	MNS	MNS	MNS
S1u	R	MNS	MNS	MNS

u upper end plate, *l* lower end plate, *MNS* muscle not seen at this level

* Significant difference ($p < 0.05$) between symptomatic or asymptomatic sway-back posture group and control group; ** Significant difference ($p < 0.01$) between symptomatic or asymptomatic sway-back posture group and control group

Table 3 Percentage of fat content in the lumbar multifidus (of the % total CSA muscle) in the symptomatic sway-back, asymptomatic sway-back and control groups expressed as mean and standard deviation (SD) (significance level $p < 0.05$)

Level	Side	Sway-back symptomatic	Sway-back asymptomatic	Control
L1u	L	13.1 ± 2.76*	12.3 ± 2.88*	4.5 ± 3.67
L1u	R	13.0 ± 3.53*	8.7 ± 2.48	4.4 ± 2.48
L1l	L	17.2 ± 2.36*	13.3 ± 2.80*	10.8 ± 3.12
L1l	R	15.6 ± 2.25*	7.7 ± 1.83	11.5 ± 3.07
L2u	L	9.0 ± 2.19	8.6 ± 2.61	3.4 ± 1.72
L2u	R	9.2 ± 2.29	6.5 ± 2.23	4.7 ± 2.01
L2l	L	11.0 ± 2.38	9.5 ± 2.21	6.4 ± 2.21
L2l	R	9.4 ± 1.67	9.5 ± 1.81	6.8 ± 2.19
L3u	L	6.1 ± 1.49	3.6 ± 1.35	2.3 ± 0.87
L3u	R	5.9 ± 1.41	3.9 ± 1.24	3.1 ± 0.98
L3l	L	4.3 ± 1.09	4.4 ± 1.12	2.9 ± 0.80
L3l	R	4.5 ± 1.05	4.8 ± 1.28	3.2 ± 0.88
L4u	L	5.2 ± 1.95*	3.1 ± 1.95*	1.2 ± 0.41
L4u	R	3.8 ± 1.13	3.6 ± 1.21	1.9 ± 0.59
L4l	L	6.6 ± 1.44**	4.6 ± 1.30	2.1 ± 0.92
L4l	R	6.0 ± 1.34**	4.7 ± 1.16*	1.8 ± 0.90
L5u	L	7.1 ± 1.21	5.0 ± 1.10	3.1 ± 1.28
L5u	R	7.5 ± 1.44*	4.4 ± 1.38	3.2 ± 0.97
L5l	L	10.2 ± 2.08*	7.7 ± 1.72	4.1 ± 1.11
L5l	R	11.7 ± 1.99**	6.8 ± 1.41	3.5 ± 1.10
S1u	L	7.0 ± 1.69	7.7 ± 2.02	3.6 ± 1.23
S1u	R	4.9 ± 1.17	6.7 ± 2.18	3.2 ± 0.88

u upper end plate, *l* lower end plate

* Significant difference ($p < 0.05$) between symptomatic or asymptomatic sway-back posture groups and control group; ** significant difference ($p < 0.01$) between symptomatic or asymptomatic sway-back posture groups and control group

Discussion

Muscular atrophy is characterized by a decrease in the cross-sectional area and alterations in the consistency of muscles due to fibrotic alterations, scar tissue or fat infiltration [6, 8]. Fat infiltration was identified in the lumbar erector spinae and lumbar multifidus muscles of our sample. It is known that intramuscular fat infiltration, which increases the T2 signal intensity in MRI, is strongly associated with lumbar pain in adults [17]. Using spectroscopy, Mengiardi et al. [17] observed a significant adipose content in the multifidus muscles of patients with chronic low back pain. Greater fat content in the lumbar multifidus muscle was likewise identified in the symptomatic group of our study. Kjaer et al. [15] have observed this association in 81 % of a sample of 412 adults. In our study, the L5 level of both the lumbar erector spinae and the lumbar multifidus muscles was the most affected region in the symptomatic individuals. This finding was in accordance with that found by Kjaer et al. [15], which documented greater fat infiltration at this level in individuals with low back pain. An increase in intramuscular fat may affect the contractility of muscles with stabilizing functions and make these individuals prone to segmental instability. Although the presence of pain was correlated with greater intramuscular fat deposition when comparing the groups with the same postural deviation, the sway-back individuals who did not have a history of low back pain were also predisposed to greater fat infiltration in the lumbar erector spinae and lumbar multifidus muscles than was seen in the control group. Despite the differences at several levels in both the lumbar erector spinae and lumbar multifidus muscles, it was possible to observe a consistent pattern in the fat percentage in these individuals. The disuse as consequence of the posture adopted may explain our findings. The anterior displacement of the pelvis, one of the main deviations in sway-back posture, alters the position of the gravity line, which moves backwards [21, 28]. When the gravity line is behind the lumbar vertebral bodies rather than slightly in front of the vertebral bodies of the last lumbar vertebrae, gravity tends to extend the trunk, which in turn causes a decrease in the recruitment of the lumbar erector spinae. Consequently, the abdominal muscles are increasingly recruited to impede the extension of the lumbar spine by gravity [4, 21]. Such a change in activation was observed by O'Sullivan et al. [21] when they evaluated the electromyographic activity of muscles such as the lumbar multifidus and rectus abdominis in individuals who tended to adopt a sway-back posture. In that study, however, the individuals were instructed to reproduce postures through modifications in postural alignment, while our study used individuals who spontaneously adopted the sway-back posture. Roussouly et al. [27] have found that individuals exhibiting type 1 spinopelvic alignment, that is, who adopt a sway-back posture more frequently experience symptomatic disk herniation. Morphological alterations such as those identified in our study may affect the control of segmental motion due to decreased contractility of the stabilizer muscles and a corresponding increase in the stress on vertebral structures, such as the intervertebral disk. The minimum amount of fat required to predict the onset of pain and functional limitations is not yet known. We found no literature studies that have to evaluate morphological alterations in the lumbar erector spinae and lumbar multifidus muscles in individuals with sway-back posture. Therefore, this is the first study quantifying these alterations using MRI.

Study limitations and future directions

One of the limitations of our study is the lack of a universal postural standard to evaluate quantitatively sway-back posture alterations, which in turn would help clinicians in the postural classification. We agree with some authors [29] that recognize that definitive allocation of a posture type is difficult. Future studies are necessary in order to determine the limits between different postures. Another relative limitation arises from our not having performed lateral panoramic radiographies, which may have allowed for measuring specific spinopelvic parameters of the posture analyzed. However, using photography to classify posture on the sagittal plane has been considered a valid and reliable method in previous studies evaluating sway-back posture [23, 30]. Moreover, we had to consider the ethical issues involved in exposing asymptomatic volunteers to ionizing radiation.

Conclusion

This study provides preliminary data showing that individuals with sway-back posture are susceptible to morphological alterations in the lumbar erector spinae and lumbar multifidus muscles, both due to the presence of pain and as a consequence of the posture they habitually adopt.

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Conflict of interest None.

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