

Can sacralization cause morphological changes in lumbar and abdominal muscles?

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Abstract

Purpose

Although sacralization is one of the most common congenital anomalies of the spine, its effect on surrounding muscles is still not well known. This study was conducted to determine the size of the lumbar and abdominal muscles of the individuals with sacralization and to compare with the control group.

Methods

Eighty-five participants with sacralization phenomena and fifty-six asymptomatic participants were included in this study. Sacralization was classified according to the Castellvi classification. The cross-sectional area of the multifidus lumborum, erector spinae and rectus abdominis muscles, and the section thicknesses of external abdominal oblique, internal abdominal oblique and transversus abdominis muscles were measured bilaterally on axial computed tomography images at the L1-2 and L4-5 levels.

Results

ANCOVA revealed that there is no any significant group*side interaction effect regarding muscles sizes in terms of two groups in L1-L2 and L4-L5. In addition, ANCOVA revealed a both side effect [($p = .020$; $\eta^2 p = .038$)] and group*side interaction effect [($p = .010$; $\eta^2 p = .049$)] regarding length of the L5 transverse process ($p < .05$).

Conclusions

Regardless of low back pain, muscle sizes are not associated with the sacralization phenomenon.

Introduction

Lumbosacral transitional vertebra (LSTV) is a congenital anomaly seen in approximately one out of every four people in the population, and it includes a spectrum from complete/incomplete L5 sacralization to complete/incomplete S1 lumbarization according to morphological changes [3]. Sacralization, which is one of these anomalies, is the fusion of the fifth lumbar vertebra with the first sacral vertebra in different ways and gaining the characteristic of the sacrum [5, 11]. Several authors have reported the incidence of sacralization, which is mostly found incidentally as 4.6–35.9% in the general population [6, 7, 9]. In clinical studies, it has been shown that with sacralization, mobility in the lumbar region decreases and it is asymmetrical, and may also cause early degenerative changes [12]. When mobility is reduced or asymmetrical, changes in muscle structure and size are inevitable. However, studies examining the morphology of both lumbar and abdominal muscles in LSTV anomaly are limited [4]. However, previous studies have shown that morphological changes can occur in the spine and abdominal muscles in different disorders involving the lumbar region, and that examining the anatomical structures of the musculoskeletal

system can provide information about the limits of stability [14]. In this context, it was aimed to determine the dimensions of the multifidus, erector spinae and abdominal muscles of the individuals with sacralization in the lower and upper lumbar regions and to compare them with the control group in our study.

Materials And Methods

Patient population and ethics

In our study, the images of patients aged 18–65 years, who applied to our imaging center with preliminary diagnoses such as urinary system stones, intestinal and visceral organ pathologies, and whose imaging method were computed tomography (CT), between January 2020 and December 2021, scanned retrospectively from the PACS imaging system. Images of patients with a history of surgery involving the spine, ribs or pelvis, fractures of these bones, a history of spinal cord injury, tumor or infection, and pathology such as arthrosis, spondylolisthesis, and scoliosis were excluded from the study. The images were examined by a specialist radiologist for sacralization, and they were divided into sacralization and control groups, and the body mass index (BMI weight/height²) was calculated by recording the age, gender, weight and height information of the patients. The study was approved by the local ethics committee (Registration date-no: 09.12.2021-2021/106) and conducted in accordance with the principles of the Declaration of Helsinki.

Computed tomography images and classification

Images of Abdominopelvic examinations taken in the supine position with a multi-slice computed tomography device (MSCT) (General Electric IQ™ 32-Detector Spiral MSCT) without contrast were used. The acquisition parameters are 200–320 mAS, 120 kV, average 350 mm FOV and 1.25 mm section thickness. Images were evaluated both axial and coronal on the workstation, both in the bone window and in the soft tissue window.

LSTV's were recorded as unilateral or bilateral as well as incomplete or complete classification according to Castellvi classification [6]. Type 1 shows unilateral (1a) or bilateral (1b) elongated dysplastic transverse processes, while type 2 includes incomplete unilateral (2a) or bilateral (2b) pseudo-articulation with diarthrodial joint. Type 3 exhibits unilateral (3a) or bilateral (3b) bone fusion of the transverse process. Type 4 includes a unilateral type II with a type III on the contralateral side.

Evaluation of the multifidus lumborum, erector spinae and abdominal muscles

As the first step in image processing, CT images were opened in RadiAnt, a free DICOM imaging program. CT imagings were recorded in JPEG (Joint Photographic Experts Group) format to calculate the cross-sectional area of the multifidus lumborum muscle (MM), erector spinae muscle (ES) and rectus abdominis

muscle (RA) and the section thicknesses of abdominal muscles (external abdominal oblique muscle 'EO', internal abdominal oblique muscle 'IO' and transversus abdominis muscle 'TA'). Then, all these images were displayed simultaneously in the "ImageJ" program, which can be downloaded from <https://imagej.nih.gov/ij/download.html>. An image series was created by selecting "stack→image to stack" icon under the "image" tab of the ImageJ program. Using the options in the "measurement and tools" tab on the RadiAnt program, the length of any specific spot on the image was measured. In the ImageJ program, the same spot was marked in the same section using the "straight" button. The images were calibrated using "Set Calibrate" option under the "analyze" tab of the ImageJ program [15]. In the next step, the boundaries of the MM, ES and RA muscles were determined manually by using the "Free Hand" button of the ImageJ program bilaterally in the axial images at the L1-L2 and L4-L5 levels, and the cross-sectional area was recorded in square centimeters (Fig. 1). The section thicknesses of the EO, IO and TA were recorded in millimeters on the transverse line connecting the farthest points of the abdominal wall on the right and left (Fig. 1). All these processes were performed on the CT image of each individual separately on the right and left.

Statistical Analysis

The data were evaluated using the Statistical Package for the Social Sciences 22.0 program for Windows. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk's test) to check normality. We used descriptive statistics and reported counts and proportions for categorical data and measures of distribution for continuous data. An independent t test or χ^2 test was performed to compare the baseline characteristics. To evaluate the cross-sectional areas of muscles by using CT, a 2*2 [group (participants with- and without sacralization) * side (right or left)] repeated measures ANCOVA was performed with group as a between-groups factor and side as a within-subjects factor, and with demographical measures set as the covariates. When the F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. Effect sizes were determined as partial eta squared (η^2_p). The level of significance was set at $p < .05$.

Results

A total of 141 participants with (n = 85)- and without (n = 56) sacralization were included in the study. Descriptive characteristics of the participants are presented in Table 1. There was no any significant difference between the two groups in terms of baseline characteristics except for age ($p \leq .05$). The mean of age were higher in the sacralization group ($p < .001$).

Table 1
Descriptive statistics of the participants.

Variable	Participants with sacralization (n = 85)	Asymptomatic participants (n = 56)	p
Age	55.85 ± 12.41	46.53 ± 14.66	< .001
Body mass index (kg/m ²)	26.14 ± 2.13	25.17 ± 4.34	.078
Female (%)	35 (41.17)	29 (51.78)	.231
Castelvi type (%)			
1a	13 (15.29)	-	-
1b	10 (11.76)	-	-
2a	15 (17.64)	-	-
2b	36 (42.35)	-	-
3a	3 (3.52)	-	-
3b	8 (9.41)	-	-
Independent samples t test or χ^2 test.			

ANCOVA revealed a side effect regarding cross-sectional areas of rectus abdominis muscle [(p = < .001; η^2_p = .085)] and erector spinae muscle [(p = .005; η^2_p = .055)] in terms of L1-2 measurements. But, there is no any significant group*side interaction effect regarding cross-sectional areas of muscles in terms of two groups in L1-L2 (Table 2).

ANCOVA revealed a side effect regarding cross-sectional areas of rectus abdominis muscle [(p = < .001; η^2_p = .107)], internal oblique muscle [(p = .026; η^2_p = .035)], and erector spinae muscle [(p = .003; η^2_p = .062)] in terms of L4-L5 measurements. But, there is no any significant group*side interaction effect regarding cross-sectional areas of muscles in terms of two groups in L4-L5 (Table 2).

Lastly, ANCOVA revealed a both side effect [(p = .020; η^2_p = .038)] and group*side interaction effect [(p = .010; η^2_p = .049)] regarding length of the L5 transverse process. This was higher in the sacralization group (Table 2).

Table 2

Comparison of cross-sectional areas of muscles and length of the L5 transverse process between two groups.

	Participants with sacralization			Asymptomatic participants			2 x 2 ANCOVA	
	Right	Left	p ¹	Right	Left	p ¹	Side p ² ($\eta^2 p$)	Group*Side p ² ($\eta^2 p$)
L1-L2 measurements								
Rectus abdominis muscle	5.25 ± 1.99	5.37 ± 1.91	.745	4.90 ± 1.40	5.11 ± 1.36	.322	< .001 (.085)*	.336 (.007)
External oblique muscle	5.39 ± 1.18	5.42 ± 1.18	.893	6.26 ± 1.20	6.25 ± 1.18	.956	.551 (.003)	.573 (.002)
Internal oblique muscle	6.27 ± 1.36	6.26 ± 1.34	.968	7.08 ± 1.23	7.05 ± 1.27	.875	.677 (.001)	.688 (.001)
Transversus abdominis muscle	3.66 ± 0.83	3.63 ± 0.87	.852	4.31 ± 0.84	4.32 ± 0.79	.936	.711 (.001)	.513 (.003)
Lumbar multifidus muscle	9.88 ± 2.23	9.93 ± 2.23	.905	10.88 ± 3.08	11.17 ± 2.85	.524	.203 (.012)	.367 (.006)
Erector spinae muscle	10.02 ± 2.24	9.86 ± 2.32	.711	11.29 ± 2.55	11.15 ± 2.50	.718	.005 (.055)*	.888 (< .001)
L4-L5 measurements								
Rectus abdominis muscle	5.71 ± 2.23	5.85 ± 2.16	.736	5.28 ± 1.50	5.46 ± 1.51	.436	< .001 (.107)*	.657 (.001)
External oblique muscle	5.28 ± 1.32	5.32 ± 1.31	.872	6.55 ± 1.40	6.57 ± 1.36	.924	.379 (.006)	.737 (.001)
Internal oblique muscle	6.34 ± 1.56	6.29 ± 1.52	.863	7.92 ± 1.62	7.85 ± 1.53	.772	.026 (.035)*	.700 (.001)
Transversus abdominis muscle	3.20 ± 0.94	3.19 ± 0.91	.954	4.32 ± 0.79	4.35 ± 0.74	.798	.554 (.003)	.533 (.003)
Lumbar multifidus muscle	8.89 ± 2.15	8.94 ± 2.21	.903	10.43 ± 2.21	10.30 ± 2.21	.701	.488 (.003)	.148 (.015)
Erector spinae muscle	9.49 ± 1.92	9.34 ± 1.93	.680	11.04 ± 1.92	10.95 ± 1.82	.754	.003 (.062)*	.431 (.004)
Length of the L5 transverse process	20.62 ± 4.08	22.63 ± 4.11	.001	15.00 ± 1.91	15.17 ± 2.11	.582	.020 (.038)*	.010 (.049)*
p ¹ : Independent samples t test results for within-group side comparisons; p ² : two-way repeated measures analysis of covariance with a mixed model. Figures in parentheses are effect sizes partial eta squared ($\eta^2 p$).								

Discussion

In this study, based on cross-sectional CT imaging from adults with (n = 85) and without (n = 56) sacralization, the dimensions of the multifidus (MM), erector spina (ES) and abdominal muscles at the L1–2 and L4–5 intervertebral disc levels were evaluated. The data we obtained revealed that the muscle sizes of the individuals with sacralization were similar to the muscle sizes of the individuals in the control group. In addition, according to Castellvi classification, Type 2b was the most common type of sacralization in our study at 42.35%.

Sacralization, a congenital vertebral anomaly, is a frequently encountered condition in the general population [10]. The relationship between LSTV and low back pain (LBP) is well known and studies on paraspinal muscle dimensions are quite extensive [2, 13, 16]. However, it is a known fact that the reduced muscle mass in the lumbar region not only affects the global sagittal alignment of the spine but also plays a role in the development of LBP [1, 14]. In addition, the muscles of the anterior-lateral abdominal wall play an important role in the spine stability [8]. Studies investigating the relationship between LSTV and both paraspinal and abdominal muscle sizes are limited, regardless of LBP [4]. Therefore, in our study, images of patients who applied with pre-diagnoses such as urinary system stones, intestinal and visceral organ pathologies other than LBP, were examined for sacralization, and paraspinal and abdominal muscle sizes of individuals with sacralization and those in the control group were analyzed and compared.

The presented study differs from previous studies that showed individuals with LSTV to have atrophic musculature. Our data showed that there were statistically similarity in the paraspinal and abdominal muscles between the both groups. There could be two reasons for this. First, hypomobility at the sacralization level is compensated by hypermobility of segments above this level. This hypermobility may have caused individuals with sacralization to have similar muscle sizes to the control group, contrary to expectations, as it required more muscular workload. Second, most of the studies on this subject were conducted by examining the images of patients with LBP [2, 13, 16]. Today, the importance of paraspinal muscle quality in patients with low back pain is widely accepted. Muscle atrophy itself may play an important role in the pathogenesis of LBP. Therefore, studies on images taken for LBP may not only reflect the characteristics of individuals with sacralization. However, a recent study of 46 patients with LSTV reported a reduction in muscle sizes [14].

Our study revealed a side effect regarding cross-sectional areas of RA and ES in terms of L1-2 measurements. Also revealed a side effect regarding cross-sectional areas of RA, IO and ES in terms of L4-L5 measurements. This corroborates the studies of Becker et al. showing that individuals with LSTV have a different muscle load than the control group.

Our study has some limitations. First, because it was a retrospective study, we could not analyze clinical findings such as pain, activity limitation, and spasm. This prevented us from separating symptomatic and asymptomatic individuals. Second, morphological and degenerative changes in the facet or disc and fat changes in the muscles were not analyzed.

Conclusions

In conclusion, in our analyzes of CTs taken for different reasons, independent of LBP, we determined that sacralization did not have a significant effect on the paravertebral and abdominal muscles sizes of the individual. In order to shed light on the subject, studies with wider participation, including patient symptoms, are required.

Declarations

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Author Contribution: The authors confirm contribution to the paper as follows. Study conception and design: FÇ, İU, SÇ, CK; Data collection: FÇ, İU, SÇ; Analysis and interpretation of results: FÇ, İU, SÇ, CK; Draft manuscript preparation: FÇ, İU. All authors reviewed the results and approved the final version of the manuscript.

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Figures

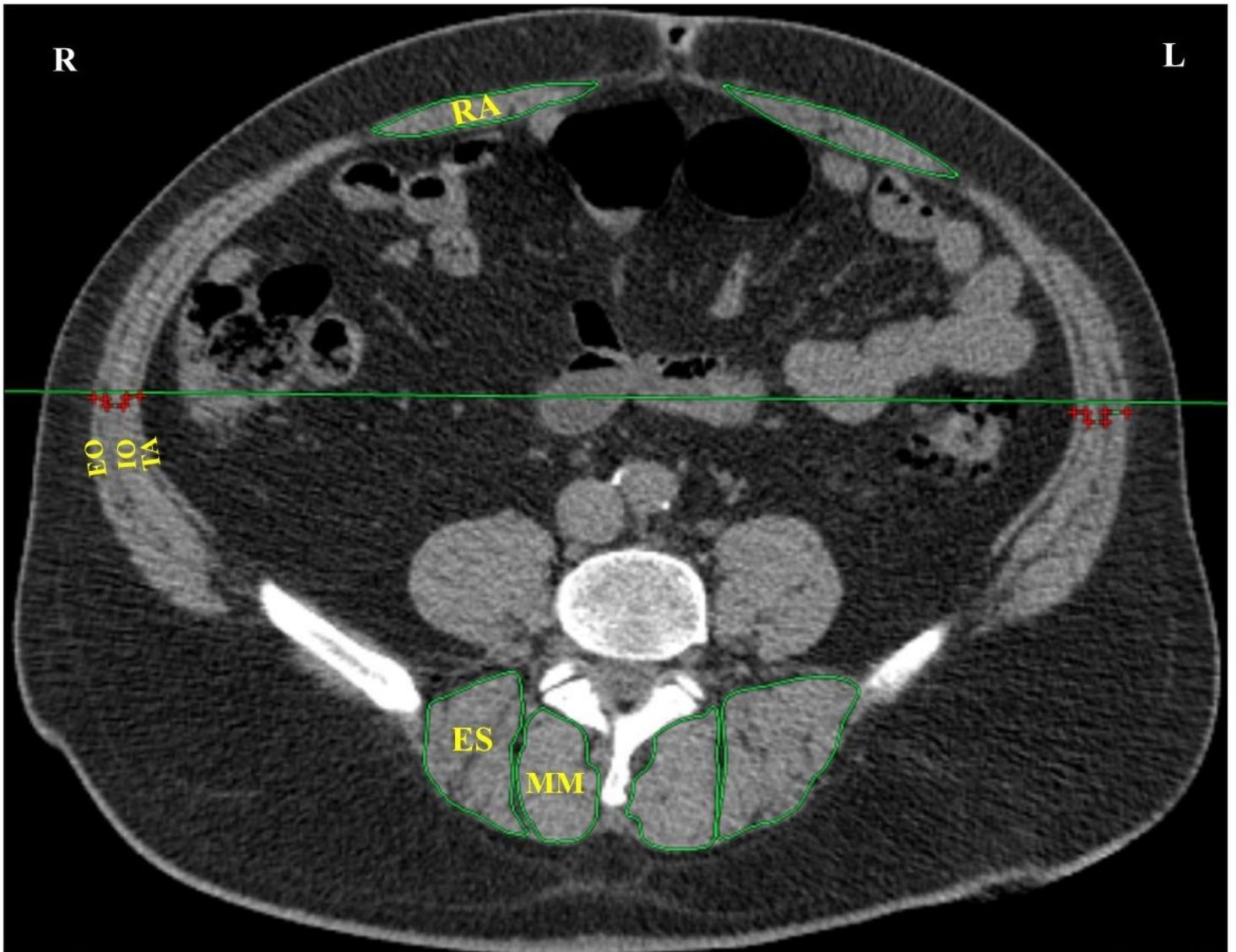


Figure 1

Measurements of muscles sizes

An axial CT image at L4-L5 level. **EO**: External abdominal oblique muscle, **IO**: Internal abdominal oblique muscle, **TA**: Transversus abdominis muscle, **RA**: Rectus abdominis muscle, **MM**: Multifidus lumborum muscle, **ES**: Erector spina muscle