CT imaging of multifidus muscles in sacralization

Authors:

Gali Dar[1,2], PhD, PT

Nathan Peled[3], MD

[1] Department of Physical Therapy, Faculty of Social Welfare & Health Studies, Haifa University, Mount Carmel, Haifa 31905, Israel;

[2] Physical Therapy Clinic, The Ribstein Center for Sport Medicine Sciences and Research, Wingate Institute, Israel;

[3] Department of Radiology, Carmel Medical Center, Haifa 34362, Israel

***Correspondence to:** Gali Dar, Department of Physical Therapy, Faculty of Social Welfare & Health Studies, Haifa University, Mount Carmel, Haifa 31905, Israel. Tel: 972-50-5662054.

E-mail: gdar@univ.haifa.ac.il, galidar@yahoo.com

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Abstract

Background: The multifidus muscles are vital for spine stability and movement. Changes in muscle morphology are considered to be related to spine problems**.** The aim of this study was to examine multifidus muscles morphology in patients with sacralization**.**

Methods: Seventy CT images were examined for the presence of sacralization phenomena, using 3-D and 2-D images on the coronal and sagittal planes. Sacralization was identified as a partial or full fusion between the L5 transverse process and the sacrum. The cross-sectional area (in mm^2) and fat infiltration (in Hounsfield units) were measured bilaterally on axial images on the L4 and L5 levels**.**

Results: Sacralization phenomena were found in 9 subjects (mean age 72 ±10.3 years). In order to age-match the controls, only 29 out of the 61 subjects were included in the analysis (mean age 69.9 ±7.9 years). Smaller cross-sectional areas of the multifidus muscles examined on both levels were observed in the sacralization group compared with the controls (not significant). The size of the muscles on the L4 level was larger than on the L5 level in the sacralization group. A significant difference ($p<0.05$) in fat infiltration was found between the L4 and L5 levels in both groups without a significant difference between groups.

Conclusion: Amongst the sacralization patients, the multifidus muscles were observed to be more active on the L4 level than the L5, although the total cross-sectional areas of the muscles were smaller compared to the controls. Fat infiltration within the muscles is not associated with the sacralization phenomena.

1. Introduction

The multifidus muscles are the short and deep muscles of the spine and are considered to play a significant role in spine stability. The multifidus function is associated with limb as well as trunk movement since they are important trunk stabilizers.[1] The size of the multifidus muscles can be assessed via imaging techniques such as magnetic resonance imaging (MRI) and computerized tomography (CT) and usually measured as the cross-sectional area of the muscle on a specific level. Moreover, since the cross-sectional area does not supply the intra architecture of the muscle, fat infiltration is one of the methods employed to assess muscle degeneration.

Whilst the multifidus muscles are vital for spine stability and movement, changes in muscle morphology were found related to spinal problems. It has been previously established that patients with low back pain develop atrophy of the multifidus muscles and that unilateral atrophy appears on the symptomatic side amongst patients with unilateral pain.[2-8] Paraspinal fat infiltration was found associated with older age, decreased range of motion and a high intensity of pain or disability.[8-11]

Sacralization is a phenomenon that might be associated with back muscle morphology and atrophy. It is a fusion of L5 vertebra to the sacrum usually by broadened and elongated transverse processes. The fusion might be full or partial and bilateral or unilateral.[12-17]

Sacralization is a common phenomenon found in the normal population with a wide prevalence reported in the literature (4-35%).[13,14,18,19] The fusion between L5-S1 causes decreased mobility in this segment, followed by increased mobility in the segment above.[20] As a result, a higher load is applied to the disc on the L4-5 levels, which might lead to disc failure (bulging, herniation, degeneration) and low back pain.[20-23]

The correlation between the multifidus muscles and low back pain was previously examined,[18,24,25] yet, the possible relationship between the sacralization and multifidus muscles is still unclear. The aim of this study was to examine the multifidus muscle morphology in patients with sacralization compared to patients without sacralization. We hypothesized that since more of a load is present on the L4-5 level and the role of the multifidus muscle is to maintain segmental stability, the cross-sectional area on the L4 level in sacralization subjects would be larger.

2. Methods

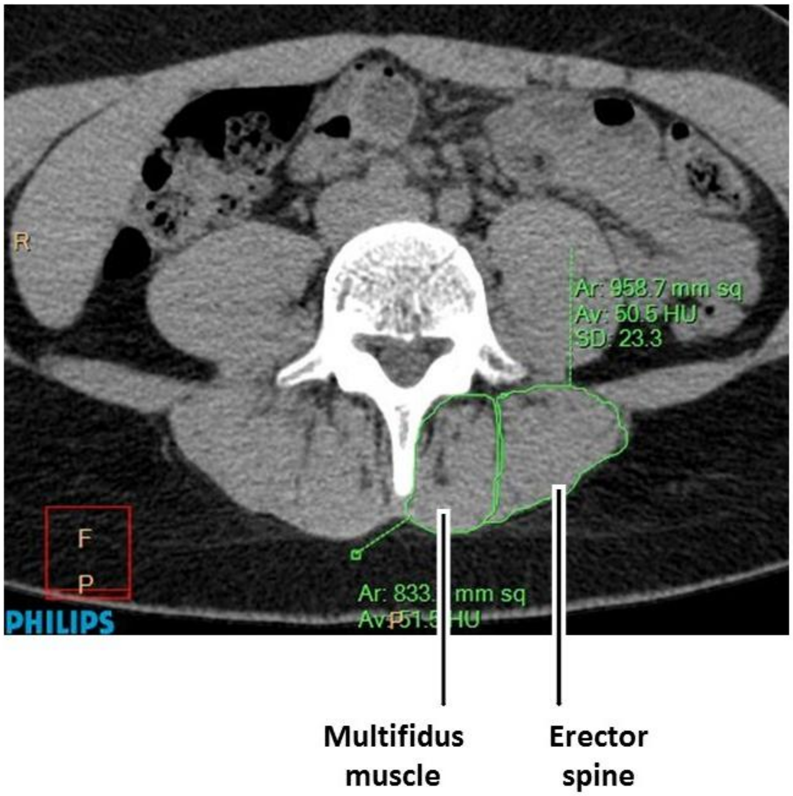
2.1 Sample study

Seventy CT images ((Phillips Brilliance 64 CT, thickness of sections: 1-2 mm, MAS: 80-250) of patients who had undergone scanning of their abdomen at the Department of Radiology, Carmel Medical Center, Haifa, Israel, were examined. The study was approved by the Institutional Review Board of the Carmel Medical Center. The images were examined for the presence of sacralization. Subsequently, the study was divided into sacralization and control groups.

2.2 Evaluation of the multifidus muscles

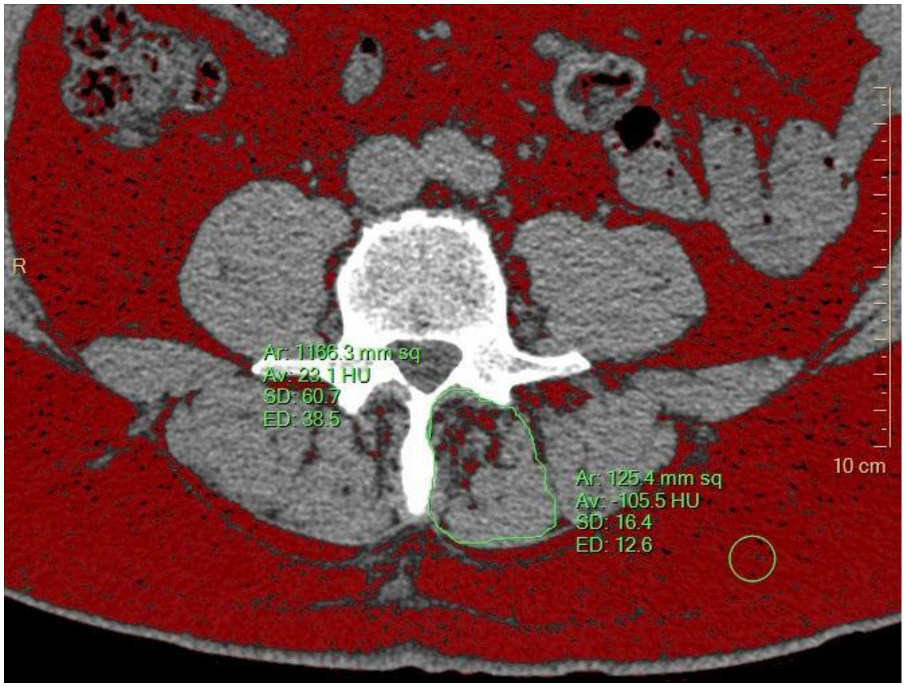
The cross-sectional area of the multifidus muscles was measured bilaterally on axial images at the L4 and L5 levels. The cross-sectional area of the multifidus muscles was assessed by manually outlining the fascial border surrounding the muscles, using an on-screen caliper. The fascial border is clearly seen at this level. The cross-sectional area was measured in square millimeters. The multifidus muscles are clearly seen on levels L4-L5 and are important for studying sacralization as it is one level above the fused vertebra and the level of fusion itself (Figure 1).

Figure 1: Cross-sectional area measurement of the paraspinal muscle



The fat infiltration in the multifidus muscles was measured on the axial images using a dedicated program located in the CT workstation and measured bilaterally in Hounsfield units (HU). Firstly, the clear fat in the outer back layer (beneath the skin) was measured and used as a reference area. A 1cm circle was marked within a homogeneous section of the center of the fat layer. Secondly, the fat infiltration was measured in the multifidus muscles using the previously marked cross-sectional area as the area of interest (Figure 2).

Figure 2: Measurement of fat infiltration in the multifidus muscles using axial CT images (red represents adipose tissue)



2.3 Sacralization identification

Sacralization was defined as full fusion between the L5 transverse process and the sacrum, identified by 3-D images via the volume rendering method (Phillips Brilliance 64 CT, thickness of sections: 1-3 mm, MAS: 80-250). 2-D images on the coronal and sagittal planes were further examined to ensure full fusion.[17]

2.4 Reliability

For intra-tester reliability, one of the authors (G.D.) re-scored 3-D images of ten individuals, three times every other week, determining the presence of sacralization. For inter-tester reliability, 3-D images of ten individuals were scored by two investigators blinded from each other. Kappa statistics were calculated for both intra- and inter-examiner reliability. A similar procedure was carried out for the metric data, calculating intra-class correlation (ICC).

2.5 Statistic analysis

Statistical analysis was performed by SAS for Windows, version 9.4. Univariate analysis was used to compare the sacralization and control groups with respect to demographic and clinical variables. Continuous variables following normal distribution were analyzed by a two-sample Student t test and reported as mean and standard deviation. Continuous variables that did not follow normal distribution were analyzed by the two-sample Wilcoxon test and reported as the median and interquartile range. Categorical variables were compared by the Pearson chi-square test. The Wilcoxon signed rank sum test evaluated the changes in the L5 and L4 measurements within each group. A p-value of 0.05 was considered significant.

3. Results

3.1 Reliability

Inter and intra-examiner reliability for the presence and location of sacralization were very good (K>0.9 for both). The inter- and intra-examiner reliability for the cross-sectional area and fat infiltration measurements were high (ICC = 0.9 and 0.87 respectively).

3.2 Study groups

Sacralization was identified in 9 subjects (4 males and 5 females), mean age 72 (±10.3) years (range 55-83 years). In order to age-match the control group to the sacralization group we included 29 subjects (14 males and 15 females) taken from the 70 examined images; mean age 69.9 (±7.9) years (range 57-82 years). Amongst the sacralization group, 5 individuals had bilateral fusion, 3 - right fusion and 1- left fusion.

3.3 Cross-sectional area

The cross-sectional area of the multifidus muscles on the right side of L4 in the sacralization and control group was 996.3 and 1016.3 mm^2, respectively. All other measurements are described in Table 1. A tendency of a smaller cross-sectional area of the multifidus muscles in the sacralization group was observed in both levels (although the differences were not significant). The differences between groups were more pronounced in level L5. The cross-sectional area was smaller in level L5 in the sacralization group compared with level L4, while in the controls, the opposite occurred (not statistically significant).

Table 1: Results of the cross-sectional areas of the multifidus muscles in the research groups (in mm^2)

Variable	**Control (N=29)**	**Sacralization (N=9)**	**P value**
CSA L4 right (median, Q1,Q3)	1016.3(900.2,1196.0)	996.3(935.5,1077.4)	0.82
CSA L4 left (mean, SD)	1018.0 (±256)	935.4 (±198.4)	0.38
CSA L5 right (mean, SD)	1064.7(±208.5)	907.2(±198.1)	0.05
CSA L5 left (mean, SD)	1050.1(199.6)	906.1(203.7)	0.07

3.4 Fat infiltration

The results of the fat infiltration measurements are summarized in Table 2. No significant difference was found between groups for each measurement in both levels. A significant difference ($p<0.05$) in fat infiltration was found between the L4 and L5 levels in both groups with no significant difference between groups, thus, implying that fat infiltration was higher in the L5 level regardless of the sacralization phenomena.

Table 2: Fat infiltration in the multifidus muscles in the research groups (in Hounsfield units)

Variable	Control (N=29)	Sacralization (N=9)	P value
Fat L4 right (median, Q1,Q3)	41.3(29.4,52.7)	29.4(15.0,45.7)	0.29
Fat L4 left (median, Q1,Q3)	28.9(8.9,87.5)	32.2(23.0,37.4)	0.42
Fat L5 right (median, Q1,Q3)	92.5(43.9,135.1)	85.8(82.7,96.5)	0.99
Fat L5 left (median, Q1,Q3)	87.7(54.7,144.2)	70.6(38.2,82.9)	0.29

4. Discussion

The aim of the current research was to examine the association between the sacralization phenomena and morphological characteristics of the multifidus muscles. The study was conducted via CT images as they are considered the best imaging technique used to identify sacralization.[26] Analyzing CT images can provide essential information on muscle morphology and characterizations by utilizing two parameters usually used to assess muscle degeneration: the cross-sectional area and fat infiltration.[5]

The main findings of the current research were: a) a smaller cross-sectional area of the multifidus muscles in the sacralization group compared with the control group (although not significantly); b) a smaller cross-sectional area on level L5 compared with L4 level in the sacralization group, whereas in the control group, the opposite occurred; c) a higher fat infiltration on the L5 level in both groups.

These findings show a difference in the size of the multifidus muscle in the sacralization group. As in sacralization, fusion of the L5 to the sacrum leads to a loss of movement in this segment, thus, it is reasonable to assume that the multifidus muscle would be smaller at this level. During this fusion, an extra load is transferred to the L4-L5 segment.[20,21,26] One could assume that the multifidus muscle would compensate for this extra load by increasing the muscle size.

Our research does not completely support this hypothesis as the multifidus size on L4 level in the sacralization group was also found to be smaller than in the controls. Yet, the size of the muscles on the L4 level were larger than on the L5 level in the sacralization group (in contrast to the control group), thus implying that the multifidus muscles are more active at the L4 level compared with the L5 level in the sacralization group.

Most studies on back muscle size and low back pain have found that patients with low back pain have a smaller cross-sectional area, especially at the lowest two vertebral levels.[4,5,7,27-29] The association of sacralization with low back pain has been debated in several studies[18,21,23]. It is possible that the observed changes in the cross-sectional area of the multifidus muscles in the current study are further related to the loss of movement rather than to the pain.

Dysfunction of the back muscles results in pain inhibition which can eventually lead to fatty infiltration of the multifidus muscles.[10] As a result, fat infiltration in the paraspinal muscles is believed to be associated with low back pain.[10,29-31] The association between fat infiltration and other spinal pathologies was found in spinal stenosis, ankylosing spondylitis and scoliosis patients.[32,33,34]

Kalichman et al. (2009)[35] conducted a CT imaging study examining paraspinal muscle density, finding that paraspinal muscle density decreases with age, increases with BMI and in some levels, is associated with other spinal pathologies such as spondylolisthesis, disc narrowing and facet joint arthritis. No association was found between paraspinal muscle density and low back pain. This was a very large study investigating the association between back muscles and spinal abnormalities yet, sacralization was not included.

The current study did not find an association between fat infiltration and the sacralization phenomena but did find differences between levels (a higher fat infiltration on level L5 compared to level L4) in both groups. We might suggest that fat infiltration in the paraspinal muscles is further associated with other factors such as aging or trunk load on the vertebra and not necessarily to spine pathologies.

Study limitation

The main limitation of this study is the small number of subjects included in the sacralization group. Our findings suggest that a larger sample study should be conducted. In addition, this was a retrospective study based on CT images and as such, no correlation to low back pain was examined.

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