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The Spine Journal 7 (2007) 338–344

THE SPINE JOURNAL

Back muscles biometry in adolescent idiopathic scoliosis

Gnahoua Zoabli, PhD[a,b], Pierre A. Mathieu, PhD[a,b,*], Carl-Éric Aubin, PhD[a,b]

[a]Institute of Biomedical Engineering, Department of Physiology, Pav. Paul G. Desmarais, 2960 Chemin de la tour, Montreal, Quebec H3T 1J4 Canada
[b]Research Center, Sainte-Justine University Hospital Center, 3175, Chemin de la Côte-Ste-Catherine, Montreal, Quebec, H3T 1C5 Canada

Received 13 December 2005; accepted 5 April 2006

Abstract

BACKGROUND CONTEXT: Many studies have been devoted to the role of back muscle activity in the development of scoliosis. While an imbalance in the electromyographic (EMG) activity has often been detected at the skin surface, very little information is available on the mechanisms by which such an imbalance could take place. To gain insight into those mechanisms, an important step could be the collection of anatomical data on the volume of the erector spinae muscle on both sides of the spine as well as on the skin and subcutaneous fat (skinfold) thickness separating those muscles from the body surface. For this purpose, the use of magnetic resonance (MR) imaging is appropriate.

PURPOSE: To collect anatomical information on the erector spinae muscles and skinfold thickness along the spinal deviations of scoliotic patients.

STUDY DESIGN: In an observational retrospective study, MR images of scoliotic patients treated in a pediatric hospital in the last 5 years were analyzed.

PATIENT SAMPLE: Images were obtained from adolescent idiopathic scoliosis patients.

METHODS: For 15 patients (Group I), three clinical acquisition protocols were used. Five investigators were asked to grade the contrast of the images obtained with each protocol. All the assessments were carried on the same monitor without any change in its settings. For the MR sequence providing the best contrast, 25 fully imaged scoliotic deviations were obtained from 17 patients (Group II). A manual segmentation with an image processing software package was done on the erector spinae muscle on both sides of the spine on each of the available images in order to determine their volume. Skinfold was also measured; first at regular intervals from C7 to L3 over the erector spinae muscle and then at sites centered over the apex of each curve.

RESULTS: For Group I, the spin echo (SE-T1) was found to provide the best contrast to identify the contour of individual muscle. With this sequence, the analysis of the fully imaged scoliotic curves (Group II) revealed that back muscle volume was found larger 14 times on the concave side and 11 times on the convex one. When the length of each curve was normalized and then divided into three equal regions, muscle volume was larger 11 times at the apex (6 times on concave side), 7 times above and 7 times below (4 times on the concave side for both positions). From C7 to L3, the mean skinfold thickness of each patient ranged from 7.3 mm to 16.3 mm. On average, this thickness was <10 mm between T3 and T12 but became larger at L3 level. At the apex of each scoliotic deviation, skinfold thickness was always larger on the concave side, and the difference decreased progressively as the distance from the apex increased.

CONCLUSION: A larger back muscle volume in adolescent idiopathic scoliosis patients was slightly more frequent on the concave than on the convex side. The differences were more frequent at the apex of the curve. Skinfold thickness was always greater on the concave side at the apex region.

Keywords: Adolescent idiopathic scoliosis; Magnetic resonance imaging; Back muscle biometry; Skinfold thickness

FDA device/drug status: not applicable.

This work was supported by NATEQ of Quebec and NSERC of Canada (Grant 156144-04). No funds were received from a commercial entity related to this manuscript.

* Corresponding author. Institut de génie biomédical (dépt. physiologie), Université de Montréal, Pav. Paul G. Desmarais, Montréal H3T 1J4, Canada. Tel.: (514) 343-6369; fax: (514) 343-6112.
E-mail address: mathieu@igb.umontreal.ca (P.A. Mathieu)

1529-9430/07/$ – see front matter
doi:10.1016/j.spinee.2006.04.001

Introduction

Scoliosis affects mainly adolescent girls, and its initial cause is known only in 15–20% of the cases. For the other patients, classified as idiopathic, various factors are suspected such as genetic defects, uneven growth of the vertebrae, hormonal effects, abnormal muscular activity [1], postural problems [2], or a mix of some of these elements [3]. Because muscles are essential to maintain or modify the position of the spine, many studies have been devoted to this factor and in adolescent idiopathic scoliosis, a larger electromyographic (EMG) signal has often been observed on the convex side of the curves [4,5]. It is still not known whether the presence of a muscle imbalance could be at the origin of scoliosis or should be considered a consequence of the mechanical deformation of the spine. Unknown also are the mechanisms that could explain how an EMG asymmetry can take place around a scoliotic deviation. While it could be associated with an imbalanced neural input [6], the presence of a larger muscle volume on one side of the deviation or an unequal skin and subcutaneous fat (skinfold) thickness separating muscles from the skin surface can also be considered.

In order to shed light on the distribution of muscle mass along scoliotic curves and to facilitate the interpretation of EMG signal that can be collected over the back muscles of adolescent idiopathic scoliosis patients, we initiated an observational retrospective study based on magnetic resonance (MR) images acquired from adolescent idiopathic scoliosis patients. Among the MR sequences used with these patients, our initial goal was to identify which one seemed to offer the best contrast between the anatomical structures. From the images acquired with this sequence, our second goal was to collect anatomical dimensions of the erector spinae muscles and skinfold thickness along the spinal deviations.

Materials and methods

A MR databank of adolescent idiopathic scoliosis patients from the scoliosis clinic of Sainte-Justine University Hospital Center (Montreal, Canada) over a 5-year period was retrospectively analyzed (Table 1A). Among the 88 patients, it was found that for 15 of them (Group I), the same three acquisition sequences have been successively used. Five observers evaluated the contrast obtained for each of those 45 series of images. These observers were individually introduced to MR image contrast analysis during a 1-hour session, and verification was made that they could rate similarly the contrast of a few selected images. They were then asked to assess the contrast between subcutaneous fat and muscle tissue, between healthy muscle fibers and infiltrated fat, between adjacent muscles, and between the spine and back muscles. Using the same monitor where the zooming factor and gamma correction were kept constant, each observer rated the contrast on each image of the three sequences from 1 (blurred) to 5 (excellent), and one sequence was identified as providing the best contrast for muscle segmentation.

Table 1A
Magnetic resonance sequence parameters identified in the databank (field strength 2T). The most frequently used appears on the top and the least used at the bottom

Pulse sequence	Sequence parameters			
Name	TR (ms)	TE (ms)	Pixel dimension (mm)	Slice thickness (mm)
Spin echo (SE-T1)	450–750	20	0.72–1.00	1–10
Fast spin echo (FSE-T2)	3500–4000	90–126	0.75–1.00	3–5
Gradient recalled echo (GRE-T1)	25	5	1.87–1.88	9

The databank was searched a second time to identify patients for whom that sequence had been used and where the entire span of the scoliotic deviation had been imaged. Seventeen patients (Group II, 4 boys and 13 girls, 11.6±3.2 years) with 25 scoliotic curves in total were found. To facilitate comparison between those patients, the lower and upper inflexion points (end vertebrae spinal marrow centroids) of each scoliotic curve were respectively considered as 0% and 100% of the curve and the apex position (α) was referenced to this scale. As can be seen in Figure 1, the value of the curvature cord ρ is given by:

$$\rho = \left\| \overrightarrow{I_1 A_p} \right\| \cdot \sin(\theta) \quad (1)$$

where θ is the angle between the directions I_1I_2 and I_1A_p. In the frontal plane, the offset of the cord (ρ_f) is the distance between A_p and the segment composed of the inflexion points I_1 and I_2: The offset of the deviation (ρ) at the apex was expressed in percentage of the distance between the two inflexion points.

The normalized curves were divided in three equal lengths (Fig. 1) to study muscle volume distribution. Image processing was done with a specialized software package (Tomovision, Montreal, Canada). On each slice, a manual segmentation minimizing operator errors [7] was used to obtain the contour of the anatomical structures of interest. With small slice thickness (<4 mm), muscle boundaries were assumed to be constant within each slice and the volume of a muscle was obtained by multiplication of its cross section area (CSA) with the slice thickness. Left and right muscle volume was assessed over three equal sections located above the apex, at the apex, and below the apex of the normalized curve (Fig. 1). The difference in muscular volume between the convex and concave sides was measured with a muscle difference index (MDI) defined as:

$$MDI(\%) = \frac{1}{N}\sum_{i=1}^{N}\left[1 - \frac{Volume_{\mathrm{concave\_}i}}{Volume_{\mathrm{convex\_}i}}\right] \times 100 \quad (2)$$