International Journal of Industrial Ergonomics 49 (2015) 108–115

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Morphological investigation of low back erector spinae muscle: Historical data populations

Celal Gungor [a, b, *, 1], Ruoliang Tang [a, c], Richard F. Sesek [a], Kenneth "Bo" Foreman [d], Sean Gallagher [a], Gerard A. Davis [a]

[a] Occupational Safety and Ergonomics Program, Department of Industrial and Systems Engineering, Auburn University, 3301 Shelby Center, Auburn, AL 36849-5346, USA
[b] Department of Forest Industrial Engineering, Izmir Katip Celebi University, Cigli Ana Yerleskesi, Balatcik, Cigli, Izmir 35620 Turkey
[c] Department of Occupational Science and Technology, University of Wisconsin-Milwaukee, 2200 E. Kenwood Blvd., Milwaukee, WI 53211, USA
[d] Motion Analysis Facility, Department of Physical Therapy, University of Utah, 520 Wakara Way, Salt Lake City, UT 84108, USA

ARTICLE INFO

Article history:
Received 9 June 2014
Received in revised form
15 December 2014
Accepted 2 February 2015
Available online 21 February 2015

Keywords:
Erector spinae
Biomechanics
Low back modeling

ABSTRACT

Accurate and reliable low back morphological data such as the cross-sectional area (CSA) of the erector spinae muscle (ESM) is vital for biomechanical modeling of the lumbar spine to estimate spinal loading and enhance the understanding of injury mechanisms. The objective of the present study is to enhance the current database regarding ESM sizes by studying with larger sample sizes, collecting data from live subjects, using high resolution MRI scans, using computerized, reliable, and repeatable measurement techniques, and analyzing data from three inter-vertebral disc (IVD) levels for both genders. A total of 163 subjects (82 males and 81 females) were included in the study. CSAs of both right and left ESMs were measured from axial-oblique MRI scans using architectural design software. The average CSA of the ESM was 23.50, 24.22, and 24.33 cm^2 for females and 30.00, 28.28, and 24.60 cm^2 for males at the L3/L4, L4/L5, and L5/S1 levels, respectively. Results agree with some studies, but generally larger than most previous studies, possibly due to differences in sampling (sample size, subject characteristics: age, anthropometrics, cadavers, etc.), measurement techniques (scanning technology, scanning plane, scanning posture, different IVD levels), or muscle definitions.

Relevance to industry: Lifting tasks are very common in occupational settings and associated with low back pain. Accurate and reliable low back muscle size data is of importance to produce more efficient low back biomechanical models to better understand the loading mechanism in lifting tasks and to minimize low back pain risk regarding the lifting task. However, available low back muscle size data are quite limited. This study fills part of this gap by providing data from a large sample population of live subjects, multiple levels, both genders, high resolution MRI scans, reliable and repeatable measurement technique. The updated low back muscle size data presented in this paper can be used by biomechanical modelers to improve current low back biomechanical models.

1. Introduction

Low Back Pain (LBP) is highly prevalent in the United States. More than 44.4 million healthcare visits were due to back pain in 2006 (BMUS, 2011). Improved biomechanical modeling of the lumbar spine may allow better evaluation of LBP risk. Accurate biomechanical model inputs such as the cross-sectional area (CSA) of the erector spinae muscle (ESM) are required to calculate forces exerted/created by muscles, and forces acting on the spine. Several studies have been conducted to investigate low back muscle morphologies. Some of them, however, had limitations such as having small sample sizes: Bogduk et al., 1992 (9 males); Delp et al., 2001 (2 males and 3 females); Guzik et al., 1996 (16 males); Han et al., 1992 (6 males and 4 females); Lin et al., 2001 (8 males). McGill et al., 1988 (13 males); McGill et al., 1993 (15 males); Parkkola

* Corresponding author. Occupational Safety and Ergonomics Program, Department of Industrial and Systems Engineering, Auburn University, 3301 Shelby Center, Auburn, AL 36849-5346, USA.
E-mail address: czg0012@tigermail.auburn.edu (C. Gungor).
[1] Department of Forest Industrial Engineering, Izmir Katip Celebi University, Cigli Ana Yerleskesi, Balatcik, Cigli, Izmir 35620 Turkey.

http://dx.doi.org/10.1016/j.ergon.2015.02.001
0169-8141/

et al., 1992 (11 males and 1 female); Tsuang et al., 1993 (5 males); and Tveit et al., 1994 (6 males and 5 females). Studying with limited sample sizes could decrease the power of statistical tests that make inferences about a population from the sample. Delp et al. (2001) studied cadaveric subjects, which may limit results to be extrapolated to live subjects. Several previous studies quantified ESM size at a single level (i.e., at the L3/L4 (Seo et al., 2003), at the L4 (Cooper et al., 1992), at the L4/L5 (Lee et al., 2006; McGill et al., 1988; Parkkola et al., 1992; Wood et al., 1996), at the L5 (Lee et al., 2011), at the L5/S1 (Lin et al., 2001; Tracy et al., 1989)) or provided an average number for several levels (Delp et al., 2001; Reid and Costigan, 1985). However, having lumbar data from several vertebrae or inter-vertebral disc (IVD) levels may provide better understanding of the muscle structure on the low back region. The objective of this present study is to provide morphological data to current literature regarding musculature for low back biomechanical models by including larger sample sizes, collecting data from live subjects, using high resolution MRI scans, using computerized, reliable, and repeatable measurement techniques, and analyzing data for three IVD levels for both genders. The present study also investigates the effect of gender, measurement location (IVD level), and measurement side.

2. Methods

2.1. Subjects

A total of 163 symptomatic subjects (82 males and 81 females) who had previously undertaken an MRI scan of the lumbar spine at the University of Utah Hospital in Salt Lake City, Utah to help medical doctors explore whether they had any medical abnormalities in their lumbar spinal region. It is unknown whether such abnormalities were associated with the spine itself or to nearby tissues. Researchers were blinded to patient medical history.

MRI scans were reviewed by an expert with experience analyzing spinal MRI scans and holding a Doctor of Philosophy degree in Anatomy. Patients with (1) degenerative changes in their lumbar spines (e.g., crushed vertebral body, trauma, etc.) and/or in the erector spinae muscle (e.g., atrophy), (2) obvious spinal deformities, and (3) any known pathology relevant to and likely to alter the low back geometry (e.g., scoliosis, tumor) were excluded (apprx. 10% of all scans) from the study. The research protocol for this study was approved by the Institutional Review Boards (IRBs) at both the University of Utah and Auburn University.

It should be noted that the number of subjects included in the study is 163; however, some subjects were missing some measurements at some levels. Of 163 subjects, there were 155 subjects whose MRI scans were good enough for morphological investigation at the L3/L4 IVD level. The reasons for exclusion are that either MRI scans had low resolution at this IVD level or there was not any axial-oblique scan available at this IVD level. There were more missing scans at lower IVD levels. The number of MRI scans was 136 at the L4/L5 level and 108 at the L5/S1 level.

Subject demographics (gender and age) and anthropometrics (height and weight) were previously recorded in the picture archiving and communication system (PACS) embedded in the MRI scans. Researchers were unfortunately restricted to the data available. For example, some stature measurements were not recorded in PACS. Therefore, researchers could not access those stature data. Since BMI is a function of subject's height, it could not be calculated for those subjects. Out of 155 subjects who were included in the L3/L4 level muscle measurements, only 107 of them had stature data available. 96 subjects out of 136 and 80 subjects out of 108 subjects had stature and BMI data at the L4/L5 and L5/S1 levels, respectively.

2.2. Data collection

2.2.1. Device and recording

Magnetic Resonance Imaging (MRI) technology was used to study the low back architecture. MRI scans were performed on a 1.5 T MRI scanner (MAGNETOM Avanto, Siemens AG, Erlangen, Germany) at the University of Utah Hospital. Subjects were placed in the open-bore MRI machine and in a head-first-supine (HFS) posture while their arms placed on their sides and knees were slightly flexed with a cushion under the legs. T2-weighted MRI

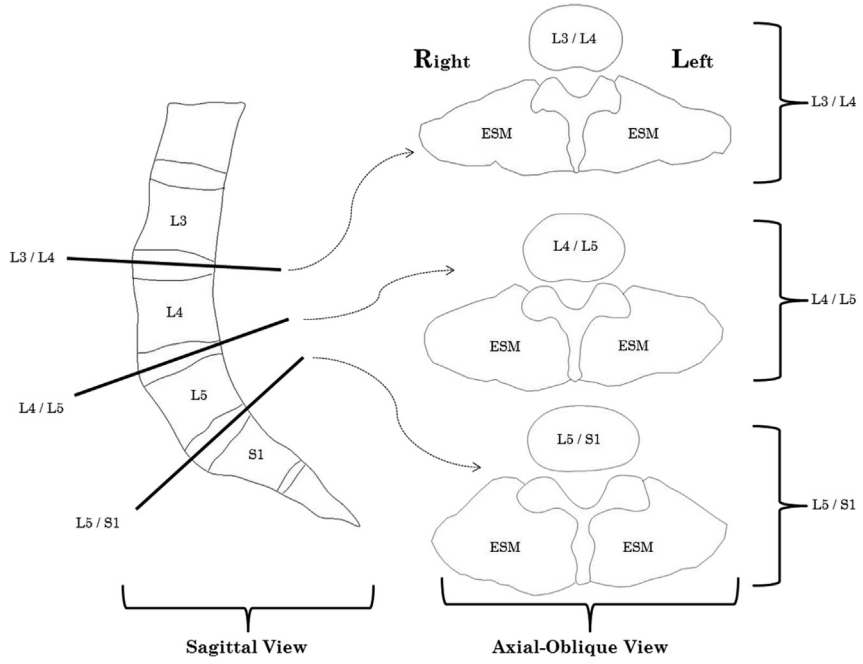

Fig. 1. Axial-oblique scans of the erector spinae muscle (ESM) at three inter-vertebral disc (IVD) levels.