A COMPLETE AND COHERENT MUSCULO-SKELETAL DATASET FOR THE HUMAN SPINE

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INTRODUCTION

There has been a considerable increase in the number of musculo-skeletal models of the spine in the last decade. Some models were even applied in clinical practice [1]. However, the credibility of such models is largely dependent on the accuracy of the anatomical data they incorporate.

Previous studies showed that models are very sensitive to the spinal geometry and muscle attachment sites [2]. Moreover, morphological muscle parameters such as fiber length, sarcomere length, optimum fiber length, tendon length, pennation angle, mass, and physiological cross-sectional area can affect muscle and joint force estimations considerably [3]. Implementing these parameters in an accurate and consistent manner will facilitate more realistic simulation of the muscle contraction dynamics and, therefore, will increase models' credibility.

Earlier anatomical investigations on the spine primarily focused on the cervical and lumbar regions. Attachment sites and the morphological parameters of the neck muscles were measured from a single cadaver [4]. Other studies measured some of the morphological parameters and presented anatomical drawings to illustrate muscle attachments sites [5]. There is, however, no anatomical dataset which enables the development of a complete and coherent musculo-skeletal model for the entire human spine. The lack of such coherent dataset requires models piecing together data from several cadavers. This approach then necessitates scaling between the skeletal geometries of the cadavers and their muscle architectures. As a consequence, models using combined datasets may not be anatomically realistic. A musculo-skeletal dataset measured from a single body will enable a consistent model of the spine and is, therefore, a better approach for use in clinical practice [6]. Thus, the aim of this study was to obtain a complete and coherent anatomical dataset for the entire human spine.

METHODS

We obtained an embalmed body of a 79 years-old male (height: 154 cm, mass: 51 kg). We dissected muscles of the spine from the right side of the body and measured positions of muscle attachments at origin and insertion by using the NDI Hybrid Polaris Spectra tracking system. We also measured via points and wrapping surfaces for muscles with curved lines-of-action. Before dissection, we divided the muscles into a number of muscle-tendon elements to improve the simulation of the muscles' function. Finally, we measured fiber length, tendon length, sarcomere length (by using the laser diffraction method, Figure 1c), optimal fiber length, pennation angle, mass, and physiological cross-sectional area (PCSA) for each element [7].

RESULTS AND DISCUSSION

In total, we measured 49 muscles using 321 elements. All bones with muscle lines-of-action are shown in Figure 1d. Total muscle PCSAs ranged from 0.09 cm^2 for sternothyroid muscle to 18.50 cm^2 for longissimus thoracis muscle. Mean sarcomere lengths ranged from 2.10 µm for sternothyroid muscle to 3.91 µm for semispinalis cervicis muscle. Mean optimal fiber lengths ranged from 0.6 cm for rectus capitis lateralis muscle to 25.1 cm for rectus abdominis muscle. Mean tendon lengths ranged from 0.4 cm for sternohyoid muscle to 20.5 cm for psoas major muscle. Morphological muscle parameters we measured fit with the range of data reported in literature.

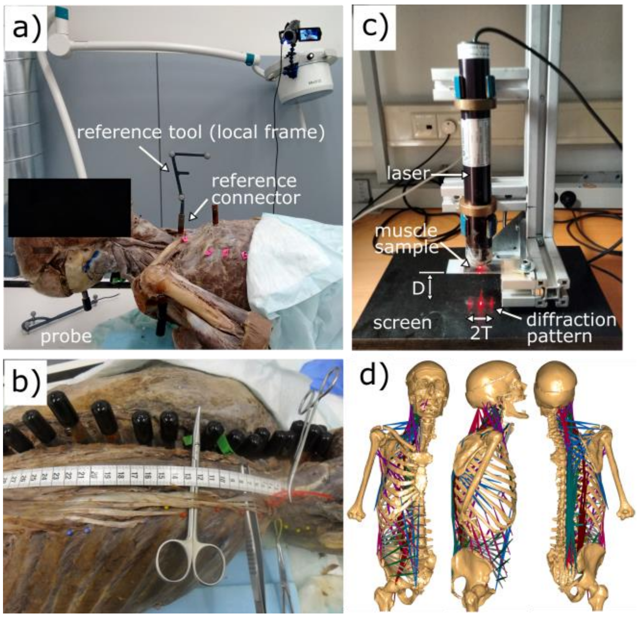
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Figure 1: a, b, c: Experimental set-ups. d: The muscles measured in this complete dataset are highlighted.

CONCLUSIONS

In this study, we obtained a complete and coherent anatomical dataset for the entire human spine. This dataset includes segmented bone surfaces (in STL file format), three-dimensional coordinates of muscle attachment sites, and the morphological muscle parameters from a single male human cadaver. This dataset is freely available through http://www.utwente.nl/ctw/bw/research/projects/TwenteSpineModel.

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