HOW VALID ARE LEFT-RIGHT SYMMETRICAL MUSCULO-SKELETAL MODELS?

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Introduction

Musculo-skeletal (MS) models of the spine provide clinical insights into the *in vivo* functioning of the spine and allow us to answer "what if" questions [1]. Current musculo-skeletal models combine data from different dissection studies [2] and make assumptions about missing data. A musculo-skeletal model based on a complete and coherent dataset, obtained from one specimen, would further improve our understanding of the human spine significantly and is therefore a better approach for use in clinical practice [3]. With the aim of building such a complete and consistent model of the entire spine, we recently started a detailed-dissection project. In this specific study, we compare morphologic parameters for the left and right sternocleidomastoid muscle to assess the validity of making a left-right symmetrical model.

Methods

We obtained the left and right sternocleidomastoid muscle (SCM) from an embalmed body of a 79 year-old male (height: 154 cm, mass: 51 kg). Prior to resection, we divided the muscles into smaller muscle-tendon elements to represent the muscle function more accurately (figure 1, left). Elements 1 and 2 originated from the sternum, 3 and 4 from the clavicle. Resected muscles were stored in 2% formaldehyde solution to prevent decay and drying of the tissues. We measured several morphologic parameters: fiber length, tendon length, sarcomere length, optimum fiber length, pennation angle and physiological cross sectional area (PCSA), using the protocols described by Breteler et al. [4]. From each element, we isolated six to ten single muscle fibers for sarcomere length measurements with a He-Ne laser using the method of Cross et al. [5] (figure 1, right).

Results

Clear differences were seen between the left and right SCM muscle (table 1). For example, although the fiber lengths were similar between the left and right SCM, optimum fiber lengths were higher in the left muscle due to different contraction state of the sarcomeres. The total tendon length of the sternal part was also higher in the left SCM. The total PCSAs were 32% and 25% larger in the right for the sternal and clavicular parts, respectively. This results in maximum force differences of 47 and 29 Newton assuming a specific muscle tension of 90 N/cm2, which translates into equally large maximal force differences in MS models.

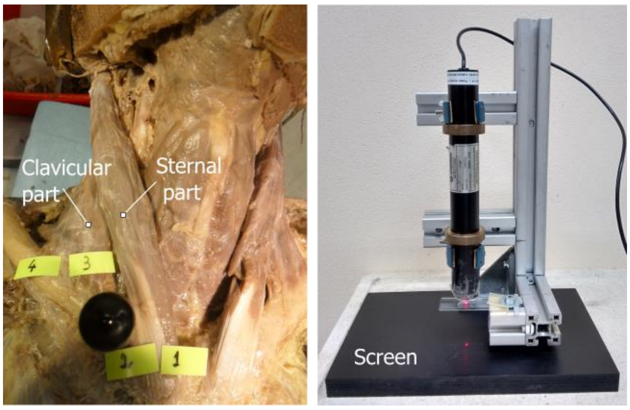

Figure 1: Left: sternocleidomastoid muscle in situ. Right: laser diffraction set-up.

	left				right			
element #	1	2	3	4	1	2	3	4
fiber length	13.0	14.1	8.1	11.1	12.7	11.9	8.0	11.3
fiber length SD.	2.9	1.2	1.0	0.6	3.1	1.1	1.3	0.6
sarcomere length	2.75	2.77	2.44	2.68	2.96	2.90	2.90	2.99
sarcomere length SD.	0.68	0.39	0.44	0.20	0.16	0.34	0.48	0.22
optimum fiber length	12.8	13.8	9.0	11.2	11.5	11.0	7.4	10.2
tendon length	9.0	6.6	6.0	5.5	4.9	8.7	6.1	5.5
pennation angle	0	0	0	0	0	0	0	0
mass	16.96	5.45	8.97	4.04	13.76	12.00	10.30	3.15
PCSA	1.25	0.37	0.95	0.34	1.13	1.03	1.32	0.29

Table 1: Comparison of left and right SCM muscle. Fiber and tendon lengths in cm, sarcomere length in µm, mass in grams, and PCSA in cm^2.

Discussion

Symmetry is usually assumed when building MS models. However, the data presented here indicated muscular imbalance for sternocleidomastoid muscle. Erroneous force estimations will emerge in MS models if the presented differences are neglected. Although we measured one muscle in this study, similar-anatomical variations are anticipated for other muscles of the spine.

References

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Acknowledgements

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