MUSCULAR BIOMETRY OF THE UPPER LIMB USING MRI: COMPARISON WITH DATA COLLECTED FROM DISSECTIONS

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ABSTRACT

Anatomy knowledge used to be obtained through dissections performed on cadavers. With modern techniques however, as magnetic resonance imaging (MRI), such information can also be obtained from living persons. When segmentation of muscles is carried on those images, length, weight, surface and volume of various muscles can be estimated. It is possible to illustrate the relative position of muscles within the limb and to reproduce in vivo muscle shapes. As a validation of this approach, images of the upper limb of six normal subjects were processed and results compared to data obtained from cadavers. Some of the measurements obtained from MRI meet those obtained by dissection. Further improvements in MRI are necessary before segmentation can routinely be used as a substitute to muscular dissections.

INTRODUCTION

Up to recent years, cadaver dissections were the main approach to collect information on human anatomy. When muscles are studied, measures such as physiologic cross-sectional area (PCSA) are often reported [1,2]:

$$\text{PCSA } (\text{cm}^2) = \frac{\text{Muscle\_mass} \bullet \cos(\alpha)}{\rho(\text{g}/\text{cm}^3) \bullet L_f \text{ (cm)}} \qquad (1)$$

where ρ is muscle density (ρ1.056 g/cm^3) [3], α surface pennation angle, and L_f muscle fibre length. To get a reliable PCSA, muscle mass has to be measured on fresh cadaver which is a condition considered most equivalent to a living person. Such experimental requirements restrict collection of anatomical data that could be very useful in many research activities. However, with the development of modern imaging modalities, alternative approaches are available and anatomical data can be obtained from living persons.

MRI is the modality of choice to study soft tissues such as skeletal muscles. With this technique, tissue properties, such as proton density, relaxation rate, flow, chemical shift, diffusion, and perfusion, contribute to the contrast between soft tissue and adjacent structures [4]. However, due to magnetic field inhomogeneity, there is no specific numeric pixel value associated with each tissue: one tissue can appear different within the same slice and more so from slice to slice. In such situation, automatic segmentation would not be reliable. When an interactive approach is considered, identification of boundaries from MRI is usually accomplished by anatomist experts. Their availability can be a restriction to anatomical data collection. However, when segmentation is performed in axial, sagittal and coronal planes (i.e. 3D segmentation), the procedure takes more time but could be realized by a non-expert person [5].

Our purpose is to illustrate how information on mu scle surface and volume can be obtained with this segmentation approach. Measurements from two muscles of the arm of healthy volunteers will be presented and compared to data collected from dissections.

MATERIAL AND METHODS

MRI from the right arm of normal subjects (3 men and 3 women: 30.5±6.7 years; BMI[1]: 21.8±1.8) were acquired using a 3D gradient recalled echo imaging technique[2]: A checkout questionnaire was filled to make sure the subjects were free of any paramagnetic implant. To reproduce the experimental conditions of an electromyography acquisition protocol, an angle of 140^o was maintained between the arm and the forearm and a non-magnetic weight of 2kg held in the right hand. A series of 70 images were obtained for each subject and 3D segmentation was accomplished with a commercial software[3]. With the chosen field of view (FOV) and slice thickness, the voxel dimensions (x, y, z) were respectively 1.41 x 1.41 x 1.50 mm. An ethic committee approved the protocol and a consent form was signed by the subjects.

Cross-sections of each muscle are obtained by multiplying the number of pixels included within its segmented surface by the pixel size in the plane. Muscle shape being regular, its boundaries are assumed to be constant when slice thickness is < 4 mm [5]. Area of each segmented region is considered to be the surface of an equivalent disk. Muscle length is obtained from the slice thickness and the number of slices where the muscle is detected. Muscle volume is obtained by summing the volume of each cylinder (cross-section x slice thickness). Weight is estimated considering an average muscle density of 1.056 g/cm^3 [3]. For each of the subjects, measurements were made for the biceps and two sections of the triceps (i.e. long head alone while medial and lateral heads were grouped together). Since muscle fibre length and pennation angle could not be obtained from MRI, values available in the literature [1,2] were used to obtain our PCSA.

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[1] Body mass index BMI= weight(kg)/(height(m))^2
[2] Centre hospitalier universitaire de Montréal (CHUM)
[3] http://www.tomovision.com

RESULTS

Table 1: Mean values (± standard deviation) of biceps and triceps length, weight and PCSA. Results obtained from our segmented images are compared to data collected from people diseased many weeks before [1] and to measurements made on fresh cadavers [2].

	Biceps brachii		**Triceps brachii**		
	long head	short head	medial head	lateral head	long head
Length (cm)					
MRI (n=6)	20.5±3.1		21.7 ±3.1		23.1 ±2.4
[1] (n=10)	not available		20.7±0.6	22.8±0.5	26.9±1.0
[2] (n=10)	21.6±4.5	23.4±4.2	not available	29.1±5.2	35.6±7.6
Estimated mass (g)					
MRI (n=6)	195±93.0		217.4±103.0		231.7±101.4
[1] (n=10)	not available		294.1±58.3		
[2] (n=10)	not available				
PCSA (cm^2)					
MRI (n=6)	12.8±6.1		77.7±10.7		60.3±7.4
[1] (n=10)	not available		39.2±2.4		
[2] (n=10)	4.6±1.1		not available	10.5±5.2	4.3±1.8

In Table 1, mean length, mass and PCSA obtained from our subjects are compared to data collected from cadavers [1,2]. The mean humerus length of our subjects (30.1±2.4 cm) is similar to those of [1] (31.9±1.4 cm) and [2] (32.0±1.4 cm). Mean circumference was 28.7±3.8 cm in our case and 25.8±10.6 for [2] (no value is given in [1]). From these measures, all these persons seem to share similar arm morphology. As for biceps length, our values are similar to those of [2] (no data provided in [1]). For the triceps, our values are in the same range of [1] but differences occur with the results of [2]: their measurements are larger than ours, especially for the long head. Only the mass of the triceps is reported and it is appreciably smaller than our results. As for PCSA, our estimations are many times larger than those in [1] and [2].

DISCUSSION

Measures obtained from MRI are co mpared to data collected through dissection. While arm morphology of the subjects was similar in the three experiments, some of our results were not similar to those published. Considering the flexion of 140° produced by our subjects, biceps length may be somewhat reduced and this could explain the small difference with [2]. At the same time, triceps should be elongated but its length is smaller than values of [1] and much smaller than in [2]. Such differences may be associated with an inadequate evaluation of muscle-tendon boundaries with MRI (specially with the triceps).

Differences in PCSA may partly be linked to differences in the pennation angle and density we used compared to those in [1,2] and [3], respectively. When published data are compared, differences are also observed: lateral and long heads of the triceps are shorter in [1] than in [2] but PCSA in [1] is larger than in [2]. Some characteristics of fresh cadavers may be different from persons deceased since few weeks.

Variation in skin and fat thickness may also be involved. Two of our male subjects shared a similar BMI but their skin+fat thickness was 6.5 and 13.5 mm. With arm circumferences (26.0 vs 30.0 cm), and humerus length (34.2 vs 30.8 cm) respectively, subject with smaller fat thickness had larger muscle mass than the other person (220.0 vs 182.9 g for the biceps and 309.9 vs 179.3 g, for the long head of the triceps). Then, humerus length and arm circumference alone may not be sufficient to establish valid comparison between different studies.

Since tendons are not well identified in our MRI images, there is a need to identify new acquisition sequences to get enhanced contrast; that could also facilitate the segmentation process. Experimentation with a muscle-specific contrast agent could also be considered. Without indication of skin+fat thickness, comparison between studies may be misleading.

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