Automated whole body muscle quantification based on a 10 min MR-exam

Anette Karlsson[1,2], Olof Dahlqvist Leinhard[2,3], Anna Vallin[2], Thobias Romu[1,2], and Magnus Borga[1,2]
[1]Department of Biomedical Engineering, Linköping University, Linköping, Sweden, [2]Center for Medical Image Science and Visualization (CMIV), Linköping University, Linköping, Sweden, [3]Depts of Radiation Physics, Linköping University and Radiation Physics, UHL County Council of Ostergotland, Linköping, Sweden

INTRODUCTION:
In sports and rehabilitation medicine the current standard method for determination of muscle mass and distribution is dual energy x-ray absorptiometry. This method has two obvious drawbacks as it only enables analysis of two-dimensional projections of the body and that ionizing radiation is used for image acquisition. MRI offers superior soft tissue contrast in muscle tissue and using fat/water separation techniques detailed characterization of fat and muscle tissue volume can be done. However, at our knowledge, no MRI-methods for quantification of whole body muscle mass and muscle fat have been previously presented. We have, however, previously developed robust methods for phase sensitive water/fat separations on 3D data using the inverse gradient method [1-3] which have made it possible to perform quantification of visceral adipose tissue [4]. The same approach described in [4] has now also been implemented for segmentation of whole body muscle volume.

Fig 1: A - Water image of the target volume, B - Water image of the prototype volume, C - The water image of the deformed prototype, and D – Deformed muscle mask overlaid on target's water + fat image in orange color. The arrows show the errors from the automatic segmentation.

METHOD:
The volumes were acquired using a 1.5 T Philips Achieva scanner (Philips Medical Systems, Best, the Netherlands) with a 3D gradient echo sequence with out-of-phase and in-phase echo times of 2.3 ms and 4.6 ms respectively. The repetition time was 6.58 ms and the flip angle was 10 º with a reconstructed resolution of 3.5x3.5x3.5 mm. The whole body volumes were acquired in approximately 10 minutes. A volume of a male, born 1983 were used as the prototype volume, see Fig.1B. The prototype volume was non-rigidly registered on to a target volume, Fig 1A, using the morphon technique [5], and a deformed volume shown in Fig. 1C was acquired. The manually segmented muscle mask of the prototype was deformed according to the deformation fields acquired from the registration, which resulted in an automatic segmentation of the target's muscles, see Fig. 1D. The registration was performed on 26 subjects and the result was either approved or discarded by visually looking at the result. Minor faults (marked in Fig. 1D with arrows) were ignored and the volume was approved. Volumes with larger errors, as major leakage into the abdominal or not segmented muscles, were discarded. The results from the shoulders and up were excluded in the approval/discarding process due to a non-consistent placement of the arms during the data acquisition. The quantification was performed by integrating the deformed mask, shown in Fig. 1D and comparing it with a manually segmented result. Here, all the information above the shoulders again was included.

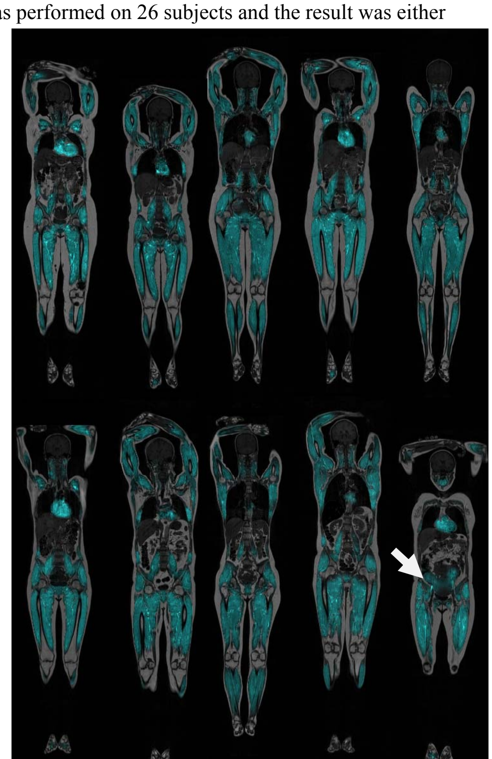

Fig 2: Automatic muscle segmentation results overlaid on water + fat images in blue color in ten subjects. The bottom right was discarded due to leakage in the abdominal (arrow). The other nine were approved.

RESULT:
From the 26 subjects evaluated, 24 were considered approved and 2 were discarded. See Fig. 2 for examples of 9 approved registrations and one that was not approved. Quantification was performed on the target volume shown in Fig. 1 and the muscle volume was estimated to 22.0 liter for the manually segmented mask and 22.8 liter for the automatic segmentation.

DISCUSION AND CONCLUSION:
Manual segmentation of whole body muscle volume is very time consuming. We show a very satisfying result from an automatic 3D whole body segmentation also in cases where the target volumes that differs significantly from the prototype image, compare for example Fig. 1A and Fig. 1B. The difference between our automatic method and the manually segmented volume used as a reference shows a difference below 1 liter in muscle volume. However, further evaluations are needed in order to evaluate the quantification process further. The result from these early investigations however shows promising results in the step for an automatic registration/segmentation that gives very accurate quantification results.

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