Modelling the external shape of the gastrocnemius muscle

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Summary (150 words)

This study aimed to adapt and improve the general framework for medical image registration of an external muscle structure from Otake et al. 2018 [1]. The smoothing of the segmented scans, rigid registration function selection and parameter set-up, and B-spline grid spacing were all investigated and optimised. Then, instead of using a generic template model obtained from cryosections of cadaveric muscles, a template was selected from the most statistically central case (derived from rigid registration metrics) from within a group of muscles obtained from magnetic resonance imaging (MRI) scans of humans in vivo. Shape variation and similarity was assessed between the template muscle and the other muscles in the group. Finally, a B-Spline non-rigid registration framework detailed in [1] was used to generate coefficients to describe the muscle shape and its variance from the template muscle. The method can now be used to characterise muscles in different anatomical positions.

Introduction

It is important to understand the relationship between the internal structure and external shape of a muscle for many reasons. In understanding if there are characteristics of the external shape that could be used to predict the internal structure, we can reduce the need for invasive assessments or computationally expensive scanning processes to detect muscle injury or pathology. This will aid injury and pathology identification and improve rehabilitation and general training protocols. To achieve this, it is important to establish a mean shape and then to understand the variability that exists between subjects and when anatomical factors are changed. This first study established the mean shape of the Gastrocnemius muscle and quantified variability.

Methods

To firstly establish the mean shape of the Gastrocnemius muscle and complete an assessment of its shape variability, a basic framework of image registration was taken from Otake et al. 2018 [1]. Otake, detailed the gathering of scans, a basic initial rigid registration followed by a B-spline non-rigid registration method.

Once the MRI scans were collected and segmented, a pre-processing step was added to improve on Otake's method. This ensured the images were as smooth as possible, avoiding "stair-casing". Then, four rigid registration methods were assessed with and without an adjustment for shank length to find the one that aligned the scans with the least root mean squared error (RMSE) but wasn't computationally time intensive. A shank length adjustment was necessary since size isn't a factor of shape difference, and including the adjustment improved the method's performance. Once the method was chosen (Iterative Closest Point (ICP)), the parameters for the method's function in MatLab were tuned to increase computational efficiency. Finally, the BSpline method was improved by finding the most optimal grid spacing to ensure the best description of shape difference.

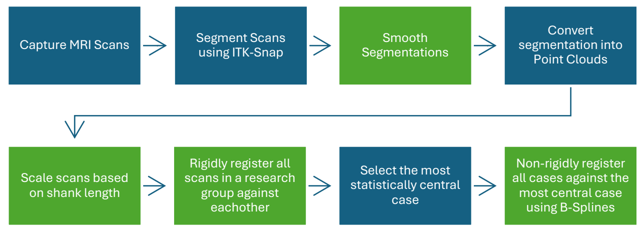

Figure 1: Framework for shape comparison using image registration. The optimised steps are highlighted in green.

Results and Discussion

When this optimised framework was applied to the training dataset [3] it was shown that the main body of the gastrocnemius muscle is largely uniform across all muscles.

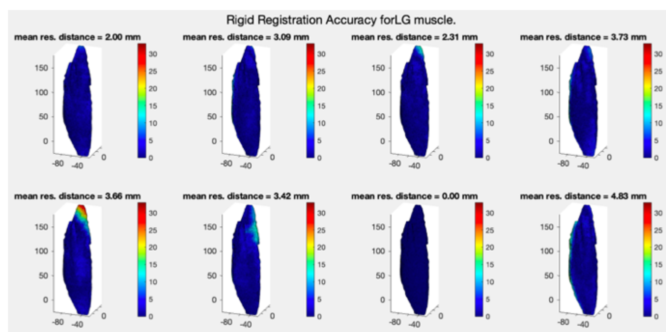

Figure 2: Rigidly Registered Lateral Gastrocnemius muscle head muscles showing minimal shape variation in the muscle body but some variation at the attachment points.

Conclusions

The framework was successful in determining a central case with BSplines showing the shape variation. The next step is to apply this to a group of muscles with varying ankle positions.

Acknowledgments

MRI scans were taken from Bolsterlee 2016 [2] and 2018 [3].

References

[1] Otake et al (2018) *MICCAI Conference* 703-710
[2] Bolsterlee et al (2016) *PLoS One*, **11**(6), p.e015727
[3] Bolsterlee et al (2018) *PeerJ*, **6**, p.e461