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Can thigh circumference predict thigh muscle volume? -Analysis using deep learning-

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Abstract

Atrophy of thigh muscles significantly affects patients with hip diseases, thus quantifying the muscle volume can play an important role. Thigh circumference measurement has been used to predict thigh muscle volumes and atrophy. However, the validity of the measurement level, impact of error, and the relationship between each thigh muscle volumes at each measurement level remain not fully evaluated. In this study, we aimed to clarify the relationship between thigh circumference and the cross-sectional area (CSA) of each muscles using the deep learning model for automatic segmentation of the skin and muscles from CT images.

Using 3D models, the thigh circumference and the CSAs of each muscle were measured at 0 cm to 20 cm above the superior aspect of the patella with 1 cm increment. evaluate the correlation between thigh circumference and CSAs.

Thigh circumference tends to increase from distal to proximal, and for muscle’ s CSA to increase as well. A strong correlation between muscle CSA and thigh circumference was observed above 5-10 cm, with a maximum correlation observed with the entire thigh muscle at 12 cm. Similar correlations were also observed around the level of maximum correlation. The correlation coefficients suggest that the measurement level should be adjusted for individual muscles. The correlation coefficients near the level of maximum correlation were almost equal, indicating that the influence of measurement level error is likely minimal.

1 Introduction

Patients with hip diseases often suffer from hip pain and restricted mobility, resulting in the atrophy of thigh muscles [1]. Previous studies have shown that the amount of muscle atrophy significantly affects the recovery after total hip arthroplasty. Thus, quantifying the muscle volume in the preoperative period can play an important role in predicting the recovery after surgery.

While the accurate volumetric measurement of the thigh muscles is difficult, previous studies have utilized and reported the efficacy of the thigh circumference in predicting thigh muscle volume and atrophy [2, 3]. However, the validity of measurement level on predicting the muscle volume and the relationship between each muscle volume and the thigh circumference at each measurement level have yet to be fully evaluated. To this end, we aimed to clarify the relationship between the thigh circumference and the thigh muscles by altering the measurement level.

2 Material and method

Seventy-seven patients (22 males and 55 females, mean age: 38.2± 14.9 years) who underwent a hip CT scan for preoperative planning were retrospectively analyzed in this study. First, the skin and each thigh muscle were automatically segmented from the CT images using a Bayesian U-net, a deep learning model for semantic segmentation [4] (Fig. 1A). Then, the segmented labels were used to measure the thigh circumference and the muscle's cross-sectional area (CSA) at each measurement level (Fig. 1B). The measurement level was altered from 0 cm to 20 cm above the superior aspect of the patella with 1 cm increment, resulting in a total of 21 analyses for each patient. (Fig.1)

Correlations between the thigh circumference and the CSAs were analyzed using Pearson correlation coefficients for each muscle (biceps femoris, vastus lateralis & vastus intermedius, vastus medialis, and rectus femoris) and also for all muscles that were included in each measurement level (i.e., muscles indicated in both gray and black in Fig. 2B). All simulation analyses were performed automatically using MATLAB (R2022a).

3 Results

When the measurement level was altered from 0 cm to 20 cm, thigh circumference gradually increased from 35.5 ± 2.6 cm to 48.2 ± 4.9 cm. Similarly, the total area of the muscles (CSA-all) increases as the measurement level was altered from 0 cm to 20 cm (Fig 2A).

When the correlation between thigh circumference and thigh muscle CSAs were analyzed for each muscle and for all muscles, the correlation coefficient was the strongest at 9 cm level for vastus medialis ($r=0.73$), 11 cm for biceps femoris ($r=0.71$), 12 cm for vastus lateralis & vastus intermedius ($r=0.83$), 17cm for rectus femoris ($r=0.72$), and 12 cm for total thigh muscles ($r=0.82$). Statistical significance was found for all CSAs (all $p<0.01$). Only limited changes in the correlation coefficient were found when the measurement levels were altered ± 2cm from the level with the strongest correlation (Fig 2B).

4 Discussion

This study evaluated the relationship between thigh circumference and each thigh muscle by altering the measurement level. We found a strong correlation coefficient between thigh circumference and each

CSA around 10 cm above the superior aspect of the patella and confirmed the validity of predicting thigh muscle volume from the thigh circumference at that level.

Previous research by Wade et al. and Housh et al. reported a strong correlation between thigh circumference and thigh muscle CSA at the mid-thigh [5, 6]. On the other hand, Yoshii et al. showed a significant correlation between thigh circumference and quadriceps CSA (r=0.73) at the 5 cm level, which was not significant at the 5 and 15 cm level (r=0.31, and 0.42, respectively) [7], indicating the importance of the measurement level in predicting the muscle volume. In this study, the CSAs of the vastus medialis, vastus lateral & vastus intermedius, and all muscles revealed a strong correlation with thigh circumference at 10 cm above the patella (r>0.68), supporting the clinical routine performed at hospitals. On the other hand, the rectus femoris muscle displayed the strongest correlation at a more proximal level, indicating the necessity for arranging the measurement level if quantifying its volume.

5 Conclusions

Thigh circumference and thigh muscle CSAs exhibited strong correlations around the 10 cm level above the patella for the biceps femoris, vastus lateralis & vastus intermedius, vastus medialis, and total volume. On the other hand, the rectus femoris muscle displayed the maximum correlation at the 17 cm level, indicating the necessity of predicting its volume at a different level. As the correlation between thigh circumference and the muscles did not change substantially with the ± 2cm alternation of the measurement level, it is likely that predicting the thigh muscle volume from thigh circumference could be effective if the same measurement level is consistently applied.

References

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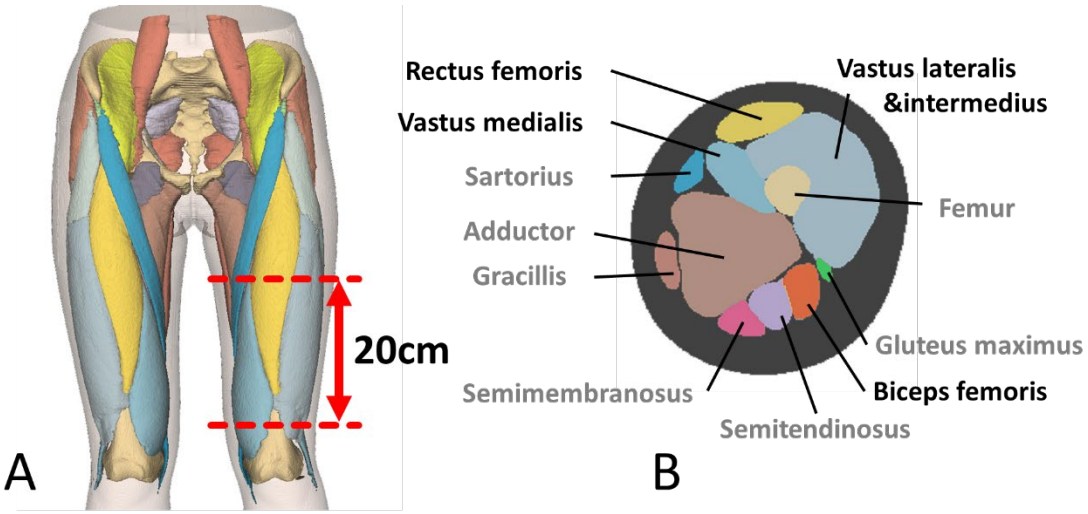

Figure 1 (A) The 3D model of thigh skin and muscles created using Bayesian U-net. (B) The example of thigh cross-section at 20cm level above the superior aspect of the patella. Muscles with black letters were correlated to thigh circumference at each measurement level.

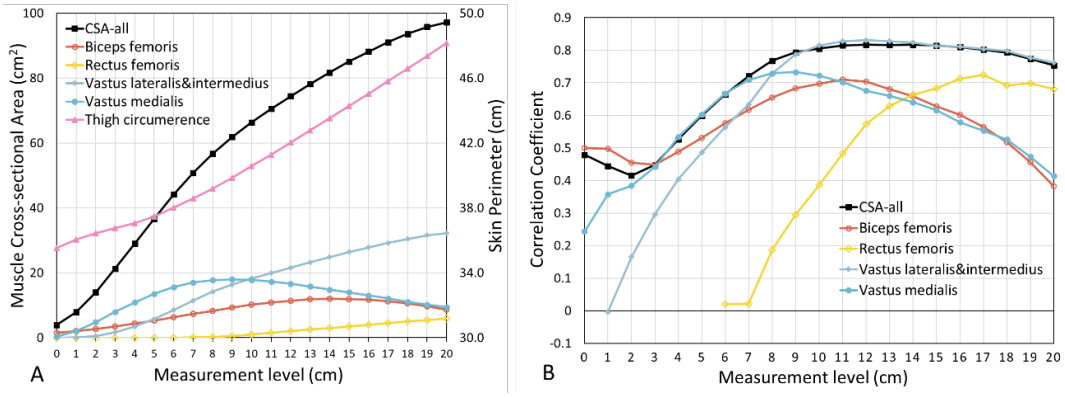

Figure 2 (A) Variation in thigh muscle cross-sectional area (CSA) (cm^2) and circumference (cm) at the designated measurement level. (B) Changes in the correlation coefficient between thigh muscle CSA and circumference when the measurement level was altered.