BRIEF NOTE

# Anthropometric equations to estimate the thigh muscle cross-sectional area by magnetic resonance imaging in young men

## Équations anthropométrique pour estimer la section transversale du muscle de la cuisse mesurée par imagerie de résonance magnétique chez de jeunes hommes

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**Summary**
*Introduction.* — It is difficult to establish the best anthropometric equation to estimate muscle cross-sectional area (CSA). The aim of this study was to determine the best anthropometric equation to estimate thigh muscle/lean CSA by magnetic resonance imaging (MRI) in young men.
*Summary of facts and results.* — Forty-four adult men underwent MRI to determine the thigh lean and muscle CSA, as well as circumference and skinfold assessment. Five anthropometric equations were solved and statistically compared with MRI. Mean values of anthropometric equations were different from the mean values of MRI ($P < 0.05$). All anthropometric equations, except the Heymsfield et al., showed low precision and/or low accuracy. Thus, the Heymsfield et al. equation seems to be the best choice to determine CSA in young men.
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**MOTS CLÉS**

Anthropométrie ;
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Prédiction

**Résumé**

*Introduction.* — Il est difficile d'établir la meilleure équation anthropométrique pour estimer la section transversale musculaire (CSA). L'objectif de cette étude était de déterminer la meilleure équation anthropométrique pour estimer la CSA des muscles de la cuisse telle qu'elle peut être déterminée par imagerie de résonance magnétique (IRM) des sujets jeunes de sexe masculin. *Synthèse des faits et résultats.* — Quarante-quatre hommes adultes ont réalisé une IRM pour déterminer la CSA de la cuisse ainsi que l'évaluation de la circonférence de la cuisse et les plis cutanés. Cinq équations anthropométriques ont été calculés et statistiquement comparées à l'imagerie par résonance magnétique. Les valeurs moyennes des équations anthropométriques étaient différentes des valeurs moyennes de l'IRM ($p < 0,05$). Toutes les équations anthropométriques, sauf celle de Heymsfield et al., se sont avérées imprécises ou peu précises. En conclusion nous obsevons que l'équation de Heymsfield et al. est la meilleure pour déterminer la CSA de sujets jeunes de sexe masculin.

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## 1. Introduction

Advancements in technology have provided sophisticated equipment (i.e. magnetic resonance imaging (MRI)) that performs precise and accurate measurements of the amount of skeletal muscle. However, high operating costs and low applicability of this equipment have impaired the practical application of such measures [1—6]. Alternatively, anthropometry equations to estimate thigh cross-sectional area (CSA) (muscle and lean) are well-accepted, simple, non-invasive and low operating cost techniques for measuring the skeletal muscle CSA [1—6]. However, as the equations' errors are based on the variability of the study's sample, principles and simplifications used in the original study and also intra and inter-examiner errors, the equations' errors cannot be compared among the studies. It is difficult to establish the best anthropometric equation to estimate muscle CSA. Therefore, the aim of this study was to compare prediction errors (precision, accuracy and concordance) of five anthropometric equations used to predict thigh CSA by MRI.

## 2. Methods

### 2.1. Subjects

Forty-four young men [convenience sample, age: $22.0 \pm 2.5$ years (18—30 years), weight: $73.0 \pm 11.7$ kg, height: $172.0 \pm 5.0$ cm] who were apparently healthy participated in this study (No. 1984, approved by the local Ethics Committee).

### 2.2. Anthropometric assessments and equations, and magnetic resonance imaging

All anthropometric measures were carried out by a single experienced examiner, in triplicate, and in the morning (between 7:00 and 9:00). The median value was recorded (technical error < 5%). The anterior thigh skinfold thickness (TST) were evaluated (adipometer Lange®) on the right and left leg (88 thighs assessed) of the body [2]. The midthigh circumference (MTC) was measured using an inextensible tape (precision of 1 mm) [2]. Three measurements were performed on each MTC and TST (distance between the inguinal ligament and the superior pole of the patella) in standing position and the mean value was taken [2].

The predictive equations for estimation of thigh CSA are Baumgartner et al. {thigh lean CSA = [MTC - π. TST (cm)/2]$^2$/4. π}, Heymsfield et al. {thigh lean CSA = [MTC - π. TST (mm)]$^2$/4. π}, Tothill and Stewart {thigh lean CSA = [(MTC - π. TST) - 2. π. ST (cm)]$^2$/4. π}, Fuller et al. {thigh muscle CSA = [MTC$^2$/4. π]−[MTC. TST (cm)/2] - 6 and Housh et al. {thigh muscle CSA = [4.68. MTC]−[2.09. TST (mm)] - 80.99} [2—6].

The procedures of magnetic resonance imaging were performed as described by Barcelos et al. (2015) [7]. Ten cross-sectional images (at midfemur level) were initially obtained of the thighs (the first four and the last five were discarded) to analyze the midthigh CSA.

### 2.3. Statistical analysis

Total muscle and muscle plus bone (lean) CSA were compared to corresponding values from MRI using Passing-Bablok regression analysis and concordance correlation coefficient (precision × accuracy). Slope B (proportional differences between the two methods) and intercept A (systematic differences between the two methods) of Passing-Bablok regression were calculated with their 95% confidence interval.

## 3. Results

All predictive equations showed a high precision (values $\geq 0.80$), except for the Tothill and Stewart ones (values = 0.33). Only the Heymsfield et al. equation showed high accuracy (values $\geq 0.80$). Therefore, only the Heymsfield et al. equation showed high levels of agreement (Table 1) (Fig. 1).

Although Heymsfield et al. equation showed the best result, intercept A showed that the values obtained by the Heymsfield et al. equation were constantly different from MRI values in 20.2 cm$^2$. The slope B showed that the values obtained by the Heymsfield et al. equation are

**Table 1** Precision, accuracy, and concordance correlation coefficient between the cross-sectional area values of the thigh muscle and estimates obtained from the Heymsfield et al., Baumgartner et al., Fuller et al., Housh et al. and Tothill et al. equations, and regression analysis Passing-Bablok between the cross section area values of the thigh muscle and estimates obtained from the Heymsfield et al., Baumgartner et al., Fuller et al., Housh et al. and Tothill et al. equations.

| Equations Thigh Lean Cross-Sectional Area | Precision | Accuracy | Concordance Correlation Coefficient |
|---|---|---|---|
| Heymsfield et al. | 0.88 | 0.84 | 0.74 (0.66; 0.81) |
| Tothill et al. | 0.33 | 0.25 | 0.08 (0.03; 0.14) |
| Baumgartner et al. | 0.87 | 0.51 | 0.45 (0.35; 0.53) |
| Thigh Muscle Cross-Sectional Area | | | |
| Fuller et al. | 0.84 | 0.70 | 0.59 (0.49; 0.67) |
| Housh et al. | 0.79 | 0.60 | 0.48 (0.37; 0.57) |
| Equations Thigh Lean Cross-Sectional Area | Intercept A | Slope B | Standart Deviation of Residue |
| Heymsfield et al. | 20.23 (1.07; 36.56) | 0.83 (0.74; 0.93) | 11.70 |
| Tothill and Stewart | 93.65 (48.45; 114.56) | 0.76 (0.56; 1.10) | 26.32 |
| Baumgartner et al. | 45.05 (27.04; 59.69) | 0.63 (0.55; 0.71) | 12.00 |
| Thigh Muscle Cross-Sectional Area | | | |
| Fuller et al. | 5.78 (−21.34; 28.57) | 0.85 (0.73; 0.99) | 13.73 |
| Housh et al. | −66.98 (− 108.35; − 32.43) | 1.66 (1.41; 1.97) | 17.41 |
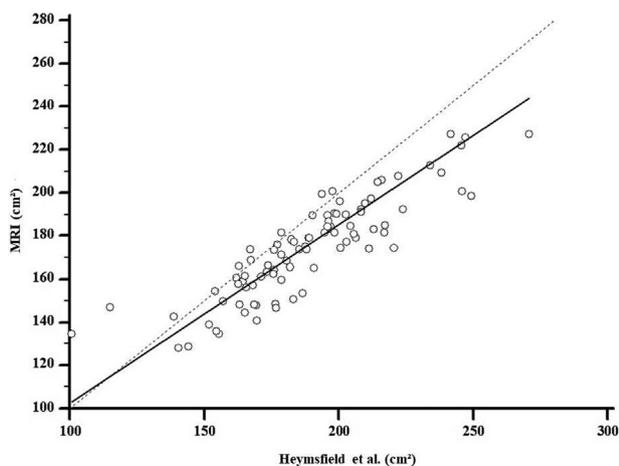


**Figure 1** Comparison of cross-sectional areas obtained by prediction equation (Heymsfield et al.) and magnetic resonance imaging. Legend: The solid line represents the line of regression. The dashed line is the line identity (Y-axis = X axis).

proportionally different from the MRI values in 27%. Each value in the predictive equation was 83% (slope B = 0.83) of the MRI value added to the constant value of intercept A. Thus, higher levels of thigh lean CSA obtained by the Heymsfield et al. equation are less accurate (technical limitation) (Table 1) (Fig. 1).

## 4. Discussion

The major findings from this study suggest that the Heymsfield et al. equation seems to be the best choice to determine the thigh lean CSA in young men. While the Heymsfield et al. equation was corrected and validated in 93 people of different ages (20—-70 years) and different health conditions (healthy and malnourished) [6], the other equations were validated in specific and small size samples [2]. In our study, although slope B and intercept A showed a difference between the Heymsfield et al. equation and MRI, the Heymsfield et al. equation showed lower dispersion values (residual), higher precision (0.88) and it was the only equation with acceptable accuracy (> 0.80). Because the precision and accuracy values of the Heymsfield et al. equation were borderline (~0.80), the concordance value was relatively low (< 0.80). However, the Heymsfield et al. equation showed a higher concordance value than other equations. Therefore, collectively, the Heymsfield et al. equation seems to be the best choice among the equations analyzed in this current study.

Based on our findings, Heymsfield's equation may be the most adequate for sports coaches and other professionals to use in practical and clinical routines. An adequate anthropometric equation may be used to monitor muscle mass changes during an intervention (i.e. training and rehabilitation).

## 5. Conclusion

Our results suggest that the Heymsfield et al. equation seems to be the best choice to determine CSA in young men.

## Disclosure of interest

The authors declare that they have no competing interest.

## Acknowledgments

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