Validation of a shape-based volume prediction method in thigh muscles

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Introduction

Relevance of muscle volume assessment

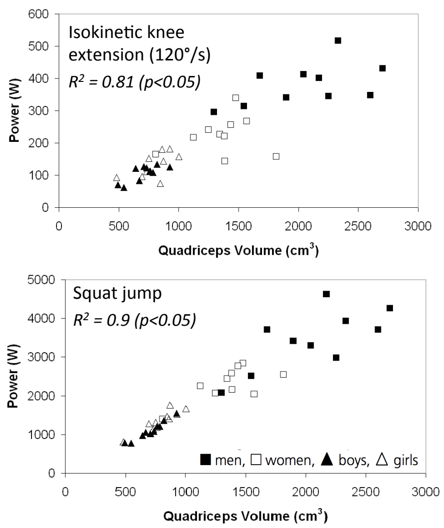


Fig.: O'Brien et al. (2009). Exp Physiol, 94: 735. (modified)

- Key feature of muscle morphology
- Determinant of muscle power
  Sleivert et al. (1995), O'Brien et al. (2009)
- Necessary for *in vivo* PCSA assessment (predictor of muscle force)
  Powell et al. (1984), Lieber & Fridén (2000)

Crucial parameter to…

→ investigate **muscle morphological changes**

→ differentiate **mechanisms** of increased or decreased **muscle force** or **power**

Introduction

Relevance of muscle volume assessment

Fields of research

- Maturation & ageing
  O'Brien et al. (2010)
  Morse et al. (2005)
- Mechanical loading
  Folland et al. (2007)
- Unloading & immobilization
  Adams et al. (2003)
  Oates et al. (2010)
- Pathology
  Zoabli et al. (2008)
  Hiba et al. (2011)
  Ji et al. (2013)

Time consuming

Expensive

Volume prediction using easily measurable parameters
Albracht et al. (2008)

Introduction

Volume prediction method

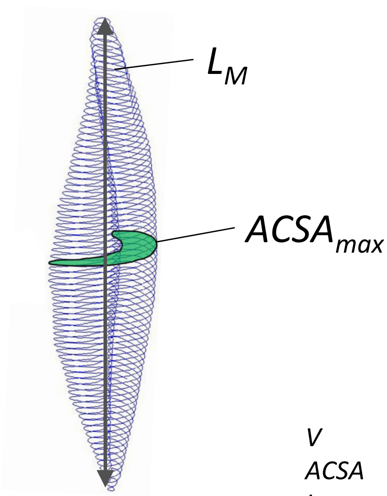
$$V = \int_0^{L_M} ACSA(z)\, dz$$

$$V = \overline{ACSA} \cdot L_M$$

$$V = p \cdot ACSA_{max} \cdot L_M$$

Shape factor

$$p = \frac{V}{ACSA_{max} \cdot L_M}$$



V	muscle volume
$ACSA$	anatomical CSA
L_M	muscle length

Introduction

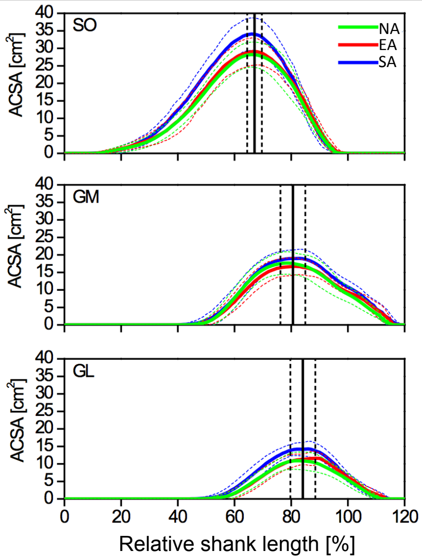
Scientific evidence

✓ Predictive **validity** established for **triceps surae muscles**
Albracht et al. (2008), Mersmann et al. (2014)

✓ **Independence of** muscle **shape** from **muscle dimensions**
in male strength-, endurance and non-athletes
Mersmann et al. (2014)

? Applicability to **other muscles**

? **Effect of sex**



Aim

Purpose and hypotheses

Purpose

- to develop and validate the volume prediction method for the **Mm. quadriceps vastii**
- to analyse potential **effect** of **sex** on muscle shape
- to determine the **precision** of the prediction method in **longitudinal designs**

Hypotheses

→ Effect of sex on muscle dimensions, but not shape

→ High determination and precision of the prediction, especially for longitudinal analyses

Methods
Participants

Peer group

- 37 athletes, **wide range of body dimensions** (i.e. height 166 - 203cm) **& training volume**

	Female (n=20)	**Male** (n=17)
Age [yrs]	31 ± 17	32 ± 16
Height [cm]	179 ± 6	193 ± 5
Mass [kg]	70 ± 7	91 ± 13

$$p = \frac{V}{ACSA_{max} \cdot L_M}$$

? **Effect of sex & muscle**

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Independent application group

- 18 adolescent athletes (9 female, 9 male), **before and after 2 of years athletic training**

	Baseline	**Follow-up**
Age [yrs]	16 ± 06	18 ± 11
Height [cm]	189 ± 7	190 ± 8
Mass [kg]	77 ± 10	80 ± 13

n=21

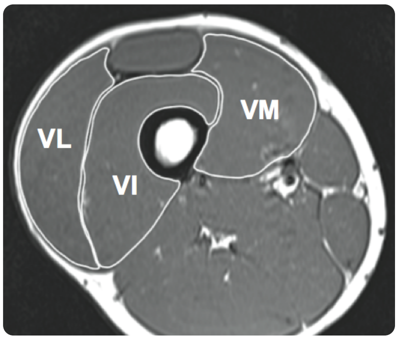
$$p = \frac{V}{ACSA_{max} \cdot L_M}$$

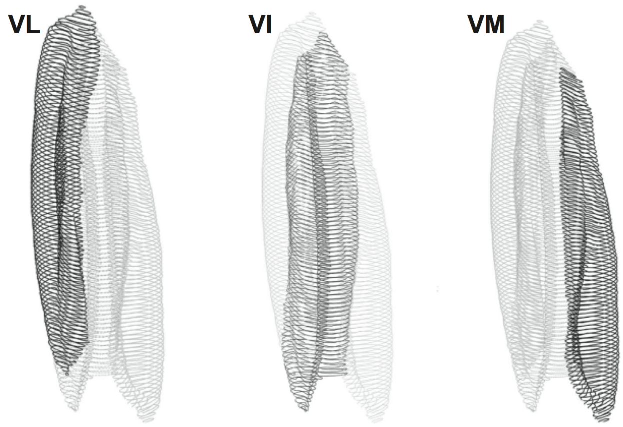
Prediction

$$V = p \cdot ACSA_{max} \cdot L_M$$

Methods

Imaging and segmentation





- T1 weighted, 4 mm slice thickness, 0.8 mm inter-slice gap
- Manual segmentation in *Osirix 4.0 64bit*, reconstruction in MATLAB

Methods

Data analysis | Statistics

Data analysis

- **Volume calculation**:

$$V = \int_0^{L_M} ACSA(z)dz$$

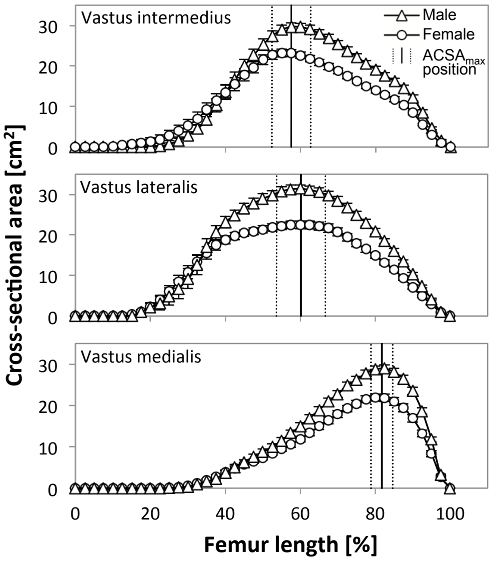
- **Femur** length *(caput femoris – epicondylus medialis)* as **reference for the ACSA$_{max}$ position**

Statistics

- **Peer group**
  RM ANOVA: Effect of sex *(between-subject factor)* and muscle *(within-subjects factor)* on muscle dimensions and shape
- **Application group**
  RM ANOVA: Effect of method, muscle and time *(within-subjects factors)* on muscle volume
- Alpha level 0.05

Results

Peer group: Muscle shape & dimensions



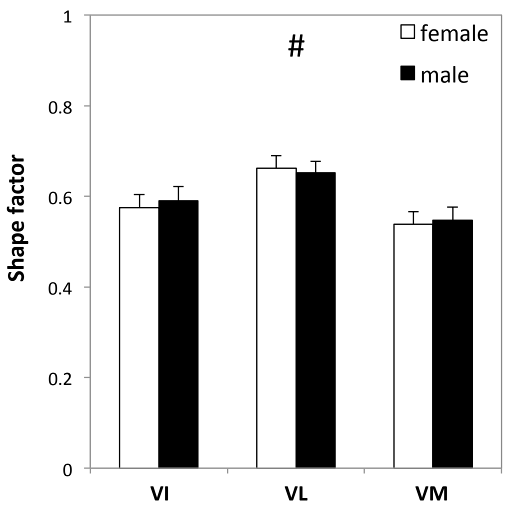
Effects of sex and muscle

- Significant effect of sex and muscle on muscle dimensions
- No effect of sex on shape factors and $ACSA_{max}$ position

	Volume	Length	$ACSA_{max}$	$ACSA_{max}$ position	Shape factor
Sex	♂ > ♀	♂ > ♀	♂ > ♀	-	-
Muscle	VL > VI > VM	VI > VL > VM	VI & VL > VM	VI & VL < VM	VI 0.582 VL 0.658 VM 0.543

Results

Peer group: Muscle shape & dimensions



sign. effect of muscle (p<0.05)

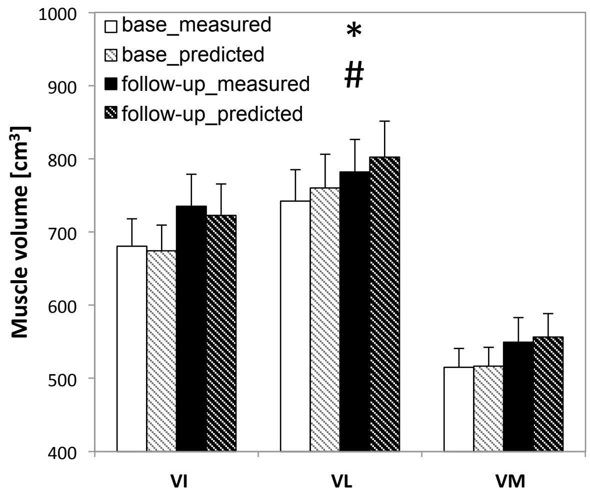
Effects of sex and muscle

- Significant effect of sex and muscle on muscle dimensions
- No effect of sex on shape factors and $ACSA_{max}$ position

	Volume	Length	$ACSA_{max}$	$ACSA_{max}$ position	Shape factor
Sex	♂ > ♀	♂ > ♀	♂ > ♀	-	-
Muscle	VL > VI > VM	VI > VL > VM	VI & VL > VM	VI & VL < VM	VI 0.582 VL 0.658 VM 0.543

Results

Independent group: Longitudinal changes



* sign. effect of time (p<0.05); # sign. effect of muscle (p<0.05)

→ **No significant effects of method**

→ **No interactions**

Significant effects of time

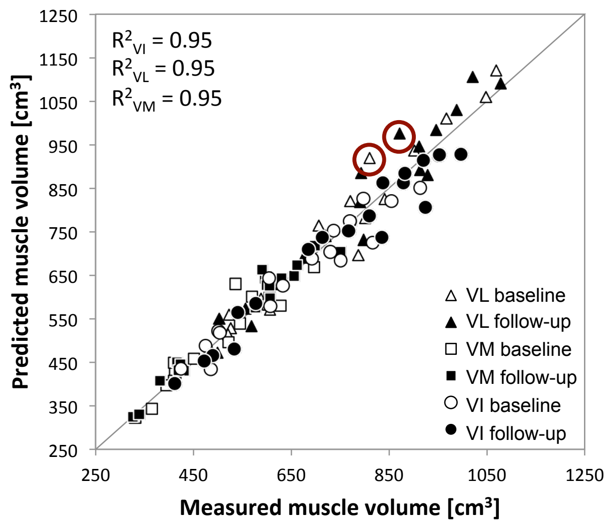
- $ACSA_{max}$

No significant effects of time

- Shape factors
- Position of $ACSA_{max}$
- Muscle length

Results

Independent group: Volume prediction

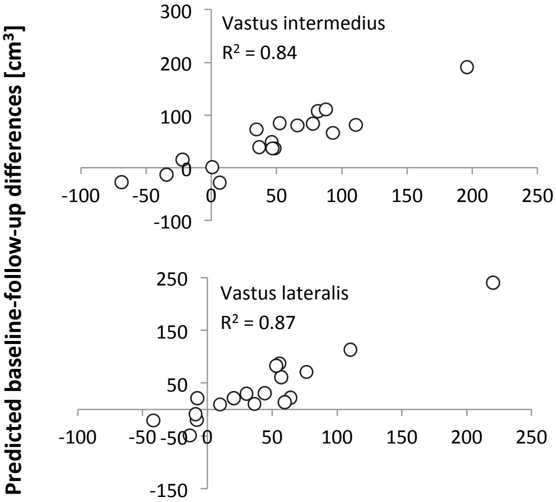


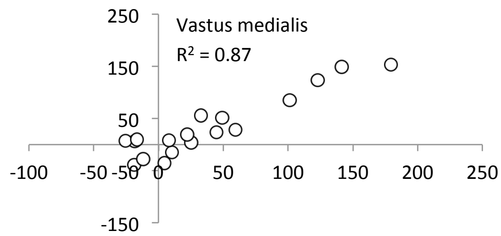
Precision

- RMS differences:
  VI 5%, VL 6%, VM 5%

Results

Independent group: Volume prediction





Measured baseline-follow-up differences [cm³]

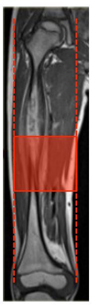
Precision 2-year changes

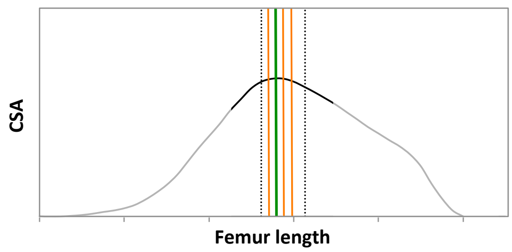
- RMS Δ differences:
  VI 4%, VL 3%, VM 3%

Discussion

Muscle shape consistency

- **No effect of sex on muscle shape** in contrast to whole-body muscle mass distribution (Abe et al., 2003) or tissue structure (Galbán al., 2005)
- **Relatively constant positions of $ACSA_{max}$**
  Scans of 26%, 20% or 11% (VI, VL, VM) of thigh length suffice to capture $ACSA_{max}$ in 95% of cases





Discussion

Muscle volume prediction

- **Precision of volume prediction ~ 5-6 % in quadriceps femoris vastii**
  Aging 11% (Suetta et al., 2009)
  Pathology 22% (Ji et al., 2013)

- **Greater precision in longitudinal designs**
  Moderate volume increases were detected; RMS Δ differences 3-4%
  Hypertrophy 10-12% (Aagaard et al., 2001; Tracy et al., 1999)
  Atrophy 10-19% (Alkner & Tesch, 2004)

→ Potential to **reduce time & costs** of MRI based muscle volume assessments

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