Correlation between Intra-myocellular Lipids and a Structural Parameter in Human Calf Muscles by ^{1}H MRSI

P. Vermathen[1], R. Kreis[1], C. Boesch[1]

[1]Dept.Clinical Research, University & Inselspital, Berne, Switzerland

Introduction

The concentration of intra-myocellular lipids (IMCL) is correlated with muscle fiber-type composition. Type I (slow) fibers contain three times more IMCL than type II (fast) fibers (1;2). Accordingly, MRS found higher IMCL content in muscles with a larger fraction of slow fibers compared to those with fast fibers. However, the IMCL differences cannot be explained by different fiber types alone. In addition to fiber-type composition, fiber orientation also leads to variations in the way a muscle is used. This MRSI study aimed at correlating IMCL in different calf muscles with fiber orientation, obtained from the same data using the orientation dependent dipolar coupling of Creatine and Taurine resonances. A correlation might indicate that IMCL and fiber orientation are directly related to functional muscle properties.

Methods

MRSI: Thirty measurements were performed on the calf of ten subjects (1.5T system, SIGNA, GE) using a 2D-MRSI sequence with PRESS volume pre-selection (transverse orientation, Matrix: 36x36, FOV: 22 or 20cm, slice thickness 15mm, TR=1600 or 1200ms, TE=35ms).

Processing: After spatial zerofilling, apodization, and Lipid Extrapolation (3) the spectra were fitted using “TDFDFIT” (4) employing prior knowledge as previously described (5). The metabolites and fiber orientation of each voxel were assigned to one of ten muscles using segmentation.

Results

Average IMCL content (relaxation time corrected area ratio to Creatine in soleus, IMCL/Cr_{SM}) and IMCL distribution (area ratio to IMCL in soleus, IMCL/$IMCL_{SM}$) in different muscles are listed in Table 1. Significant IMCL differences between some muscles were obtained with high values in soleus and 2-3 times lower values in tibialis anterior, tibialis posterior, or gastrocnemius muscles. Table 1 also lists average muscle fiber orientations with respect to B_0. A significant correlation between fiber orientation and IMCL content was found using the individual values of all measurements in different muscles and controlling for muscle as covariate (R=0.79, p<0.0001, Fig. 1). In addition, after averaging the 30 measurements for each muscle and plotting these average IMCL contents versus fiber orientation a significant correlation was obtained (R=0.89, p<0.001, Fig. 2).

Discussion

Qualitatively, the results are in agreement with morphometric studies: Soleus muscle comprises a high percentage (~88%) of type I fibers and, therefore, is expected to have high IMCL levels. In contrast, tibialis anterior comprises ~70% type I fibers and gastrocnemius, or extensor digitorum muscles only ~50%. However, these relatively small differences in fiber type composition can account only for parts of the IMCL differences between muscles. The significant correlation between IMCL and fiber orientation suggests that both, IMCL levels and fiber orientation, may be correlated to different muscle tasks, requiring different force and velocity.

	TA	TP	SL	SM	GL	GM	ED	PB	FDL	FHL
IMCL/Cr_{SM}	2.2±0.9	2.6±0.8	5.5±1.7	7.2±2.7	2.1±1.1	2.4±1.1	2.9±1.2	3.1±1.6	2.9±0.9	4.3±1.3
IMCL/$IMCL_{SM}$	0.31±0.11	0.38±0.9	0.79±0.19	1.00(Ref)	0.29±0.11	34±0.14	0.40±0.14	0.43±0.17	0.45±0.9	0.62±0.13
Fiber orientation [°]	9±4	27±5	38±5	45±3	22±4	24±5	15±7	23±4	23±4	32±6

Table1: Mean values (± 1sd) of IMCL / $IMCL_{SM}$, IMCL / Cr_{SM}, and fiber orientation in different muscles of the calf. TA, TP: m. tibialis anterior and posterior, SM, SL: m. soleus medialis and lateralis, GM, GL: m. gastrocnemius medialis and lateralis, ED: m. extensor digitorum, PB: m. peroneus brevis, FDL: flexor digitorum longus, FHL: m. flexor hallucis longus.

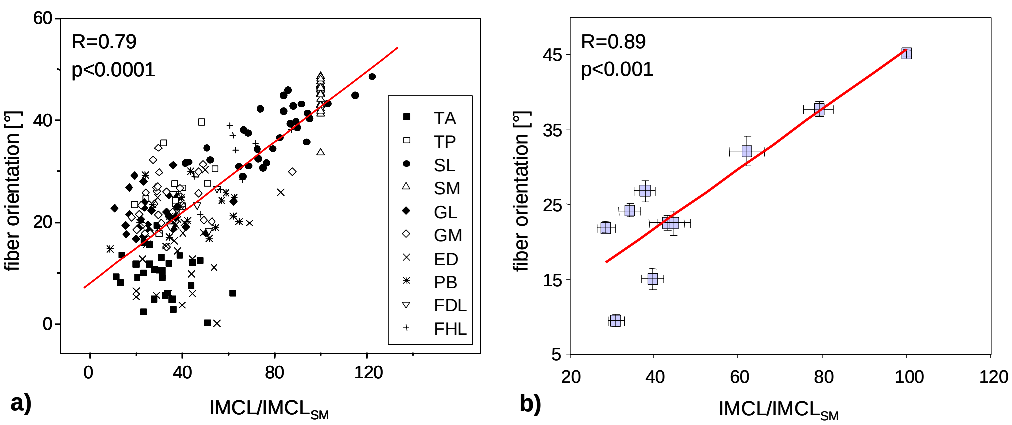

Figure 1: Correlation between IMCL/$IMCL_{SM}$ and fiber orientation.
a) Individual values for all subjects
b) Averaged values for each muscle
Different symbols in a) denote different muscles. Abbreviations as in the Table 1

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