

# Vastus lateralis/vastus medialis cross-sectional area ratio impacts presence and degree of knee joint abnormalities and cartilage T2 determined with 3T MRI – An analysis from the incidence cohort of the Osteoarthritis Initiative

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**Introduction:** Osteoarthritis (OA) is a multi-factorial degenerative joint disease and a leading cause of disability worldwide. A number of risk factors associated with development of OA have been identified. Among these, lower extremity muscle strength has been shown to influence loading and dynamic stability of the knee joint (1). In particular, quadriceps weakness has been shown to precede the onset of knee OA and is associated with increased risk of OA development (2, 3). However, the role of each individual muscle within the quadriceps muscle group in OA remains unclear and there is a paucity of data regarding the implication of vastus lateralis and vastus medialis balance in the development of OA. In this study we aim to study the role of vastus lateralis and vastus medialis balance in preclinical knee OA using cartilage T2 mapping technique (4) and 3 Tesla MRI morphological analyses in non-symptomatic subjects selected from the OAI incidence cohort, which represents a large population of individuals who would potentially benefit from early intervention for prevention of OA.

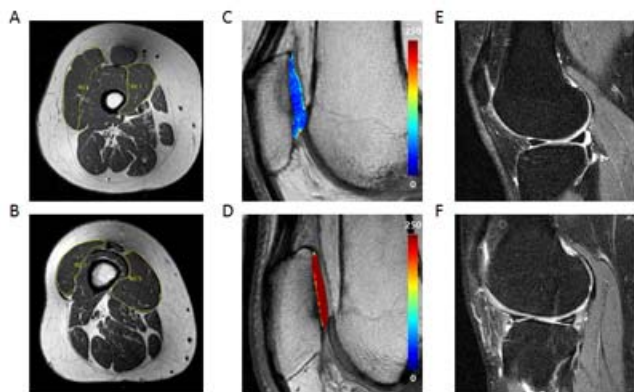
**Methods:** 178 non-symptomatic individuals with risk factors for OA were selected from the OAI incidence cohort. Inclusion criteria were: 1) baseline WOMAC pain score of zero for both knees, 2) age range: 45–55, and 3) BMI of 19–27. Semi-quantitative analysis of right knee morphological abnormalities using 3T MRI was performed using a modified whole-organ magnetic resonance imaging score (WORMS) system. Using a semi-automatic, standardized segmentation technique, knee cartilage T2 maps and cross-sectional area of vastus medialis and vastus lateralis were obtained. Physical activity levels were determined using PASE scale (range 0–400). Statistical significance was calculated using Student's t-test, ANOVA, Pearson and Spearman correlation coefficient test, and multiple regression models.

**Results:** We identified a very significant gender difference in cross-sectional area of vastus lateralis and vastus medialis with males having larger muscle size. Both male and female subjects with larger muscle size demonstrated enhanced physical performance including higher muscle strength. We next calculated the vastus lateralis to vastus medialis cross-sectional area ratio (VL/VM ratio) and found a wide variability in this ratio (Figure 1A and B). We found a highly significant difference in combined mean T2 values of all knee cartilage compartments between subjects with low VL/VM ratio and those with high VL/VM ratio (mean  $45.09 \pm 2.62$  versus  $44.10 \pm 2.19$ ,  $p = 0.0039$ , Figure 1C and D and Table 1). Linear and second degree regression analyses of cartilage mean T2 by vastus lateralis/medialis ratio also generated significant p values of 0.0301 and 0.0327 respectively (Figure 2). Subjects with higher VL/VM ratio were found to have less morphological abnormalities (Figure 1E and F) and significantly lower WORMS scores (mean  $4.21 \pm 3.92$  versus  $3.12 \pm 3.41$ ,  $p = 0.0248^*$ ).

**Conclusion:** There is a significant gender difference in cross-sectional area of vastus lateralis and vastus medialis. Larger muscle size was associated with enhanced physical performance and higher muscle strength in both male and female subjects. Subjects with relatively larger vastus lateralis compared to vastus medialis, i.e., higher vastus lateralis to medialis cross-sectional area ratio, have significantly lower cartilage T2 values and less morphological lesions detected by MRI. Our data supported the notion that cartilage T2 could potentially be used as a biomarker for preclinical OA, and suggested that vastus lateralis/medialis balance may play an important role in the pathogenesis of early or preclinical knee OA.

## References:

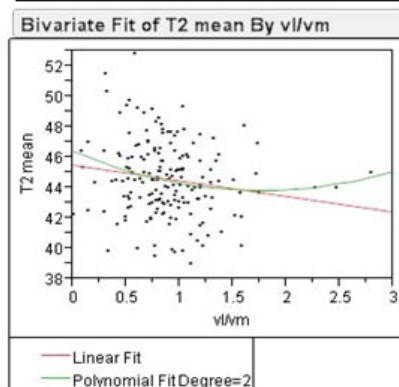
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**Figure 1.** Representative images of subjects with significant difference in vastus lateralis volume/vastus medialis volume ratio showing difference in muscle volume (A, B), cartilage T2 color map (C, D), and MR morphological abnormalities (E, F). A, C, and E are from a subject with high vastus lateralis/medialis ratio (1.72) whereas B, D, and F are from a subject with low vastus lateralis/medialis ratio (0.58). Note that relatively normal morphology is demonstrated in E, whereas tear of the posterior horn of the lateral meniscus and lateral femoral condyle cartilage are observed in F.

**Table 1.** Comparison of cartilage T2 values of different knee cartilage compartments between subject groups with low VL/VM ratio and those with high VL/VM ratio.

	Patella	Trochlea	Medial femoral	Lateral femoral	Medial tibial	Lateral tibial	Combined Mean T2
Low VL/VM	44.81 ± 3.94	46.17 ± 3.42	51.25 ± 3.77	49.24 ± 3.83	39.60 ± 2.90	39.68 ± 3.41	45.09 ± 2.62
High VL/VM	43.17 ± 3.69	44.75 ± 3.87	50.88 ± 3.40	48.32 ± 3.30	38.86 ± 2.74	38.61 ± 3.24	44.10 ± 2.19
<i>p</i>	0.0025*	0.0056*	0.2439	0.0466*	0.0434*	0.0170*	0.0039*



**Figure 2.** Bivariate linear and second degree polynomial regression analysis of mean cartilage T2 (all compartments combined) by vastus lateralis/medialis ratio. *P* value for linear fit is 0.0301; *p* value for second degree polynomial fit is 0.0327.