Introducing the Paraspinal Muscle Quality (PMQ) Score: A Novel T2-MRI Based Intensity Parameter for Assessing Spinal Sarcopenia

Ali Eren Guven, Paul C Köhli[1], Marco Burkhard[2], Jan Hambrecht, Gisberto Evangelisti, Erika Chiapparelli Harb[1], Koki Tsuchiya, Jiaqi Zhu, Krizia Caterina Amoroso, Lukas Schönnagel[1], Jennifer Shue[1], Andrew A Sama[1], Frank P Cammisa[3], Federico Pablo Girardi[1], Alexander P Hughes[1]
[1]Hospital For Special Surgery, [2]Hospi, [3]HSS

INTRODUCTION:

Recent research establishes the integrity of the paraspinal muscles (PM) as crucial for spinal health, with atrophy of the posterior PM linked to degenerative spine conditions, chronic back pain, and poor postoperative outcomes in spine patients. However, the parameters typically examined for spinal sarcopenia are limited to fatty infiltration (FI) and functional cross-sectional area (fCSA) that disregard the quality of the lean muscle. Raised muscle T2 on MR-imaging is proposed as a marker for muscle aging due to its association with age and reduced muscle function. We are proposing a novel paraspinal muscle quality (PMQ) score, which normalizes T2 intensity of the lean muscle to that of the cerebrospinal fluid (CSF) and aim to establish its correlation with key demographics, conventional muscle atrophy parameters, and functional status.

METHODS: Patients who underwent spinal fusion for degenerative lumbar disease from December 2014 to July 2023 were analyzed. Data collected included age, sex, BMI, smoking status, hypertension, diabetes, ASA score, vertebral bone mineral density (BMD), and functional status as assessed by the Oswestry Disability Index (ODI) and its subsections. Erector spinae and multifidus muscles were segmented at the L4 upper endplate level on axial T2-weighted MRI scans. Using signal intensity thresholding, pixels were identified as fat or muscle, allowing for the separate calculation of lean muscle and fat areas within the total muscle area. The fCSA was defined as the lean muscle area and was normalized to the patient's height squared. Percentage FI was defined as the fat area divided by the total muscle area. A region of interest (ROI) was set at the same axial level at the cerebrospinal fluid (CSF). If this was not possible due to stenosis, the ROI was set at the closest axial level. The PMQ score was defined as the average intensity of the lean muscle divided by the average CSF intensity within the ROI, resulting in a score ranging from 0 to 1 (Figure 1). Right and left muscle measurements were averaged prior to analysis. Interclass correlation coefficient (ICC) was used to assess interrater agreement between two raters of PMQ in randomly selected 46 patients. Spearman's correlation was used to analyze parameter relationships. Proportional odds models with ordinary outcomes were used to assess the relationship between multifidus PMQ and the ODI-subsection pain intensity, adjusting for age, sex, BMI, and FI.

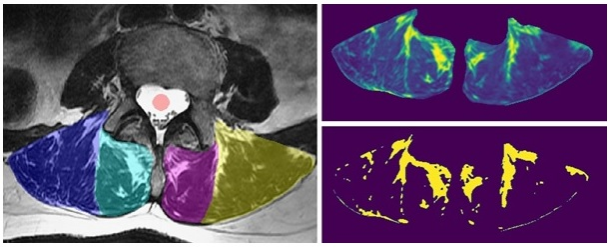
RESULTS:

A total of 481 patients (53.4% female) with a median age of 66 years (IQR: 58 - 72) and a median BMI of 28.7 kg/m^2 (IQR: 25.2 - 33.1) were included. PMQ had a highly significant positive correlation with age, female sex, BMI, ASA score, hypertension, and percentage FI as well as a negative correlation with vertebral BMD and fCSA (Table 1). Multifidus PMQ significantly predicted pain intensity with an odds ratio of 4.39 (95% CI: 1.13 – 17.08, p = 0.033). The interrater reliability for PMQ was high for both muscle groups, with an ICC estimate of 0.867 (95% CI: 0.720 to 0.932) for erector spinae and 0.874 (95% CI: 0.767 to 0.931) for multifidus.

DISCUSSION AND CONCLUSION:

The novel PMQ score which normalizes T2-signal intensity of lean paraspinal muscle mass to that of CSF correlates with age, female sex, BMI, comorbidities, and predicts low back pain. High PMQ is a likely indicator of paraspinal muscle aging and might be useful to quantify muscle edema caused by denervation or inflammation. This parameter has a high interrater reliability and can be integrated into future paraspinal muscle research as a tool for assessing muscle quality and aging, in addition to other muscle atrophy parameters such as FI and fCSA.

Figure 1:



Left image displays the segmentation of cerebrospinal fluid (red), erector spinae (blue, and yellow), and multifidus muscles (cyan and magenta) on axial T2-weighted MRI. Right upper image shows the image intensity scale. Right lower image displays the fat area identified by the automated thresholding method.

Table 1. Spearman correlation between PMQ and patient characteristics

Parameters	Erector spinae PMQ	Multifidus PMQ
Age (years)	rho = 0.30 *(p < 0.001)* *	rho = 0.36 *(p < 0.001)* *
Female sex	rho = 0.07 *(p = 0.103)*	rho = 0.16 *(p <0.001)* *
BMI (kg/m^2)	rho = 0.16 *(p < 0.001)* *	rho = 0.13 *(p = 0.005)* *
ASA	rho = 0.15 *(p < 0.001)* *	rho = 0.15 *(p < 0.001)* *
T2DM	rho = 0.04 *(p = 0.342)*	rho = 0.03 *(p = 0.533)*
Hypertension	rho = 0.14 *(p = 0.002)* *	rho = 0.12 *(p = 0.007)* *
Smoking history	rho = 0.04 *(p = 0.348)*	rho = 0.06 *(p = 0.230)*
Vertebral BMD (mg/cm^3)	rho = -0.23 *(p < 0.001)* *	rho = -0.28 *(p < 0.001)* *
Corresponding muscle atrophy		
fCSA (mm^2/m^2)	rho = -0.10 *(p = 0.037)* *	rho = -0.12 *(p = 0.006)* *
FI (%)	rho = 0.50 *(p < 0.001)* *	rho = 0.52 *(p < 0.001)* *

BMI = Body mass index, ASA = American Society of Anesthesiologists, T2DM = type II diabetes mellitus, BMD = bone mineral density. *Significant.