

Article

Association of Thigh Muscle Strength with Texture Features Based on Proton Density Fat Fraction Maps Derived from Chemical Shift Encoding-Based Water–Fat MRI

Michael Dieckmeyer ^{1,*}, Stephanie Inhuber ², Sarah Schläger ¹, Dominik Weidlich ³, Muthu R. K. Mookiah ⁴, Karupppasamy Subburaj ⁵, Egon Burian ^{1,3}, Nico Sollmann ^{1,6,7}, Jan S. Kirschke ^{1,6}, Dimitrios C. Karampinos ³ and Thomas Baum ¹

- ¹ Department of Diagnostic and Interventional Neuroradiology, School of Medicine, Klinikum rechts der Isar, Technical University of Munich, Ismaninger Str. 22, 81675 Munich, Germany; sarah.schlaeger@tum.de (S.S.); egon.burian@tum.de (E.B.); nico.sollmann@tum.de (N.S.); jan.kirschke@tum.de (J.S.K.); thomas.baum@tum.de (T.B.)
- ² Department of Sport and Health Sciences, Technical University of Munich, Georg-Brauchle-Ring 60, 80992 Munich, Germany; stephanie.inhuber@tum.de
- ³ Department of Diagnostic and Interventional Radiology, School of Medicine, Klinikum rechts der Isar, Technical University of Munich, Ismaninger Str. 22, 81675 Munich, Germany; dominik.weidlich@tum.de (D.W.); dimitrios.karampinos@tum.de (D.C.K.)
- ⁴ VAMPIRE Project, Computing (SSEN), University of Dundee, Nethergate, Dundee DD1 4HN, UK; mrk2k2@gmail.com
- ⁵ Pillar of Engineering Product Development, Singapore University of Technology and Design, 8 Somapah Road, 487372 Singapore; subburaj@sutd.edu.sg
- ⁶ TUM-Neuroimaging Center, Klinikum rechts der Isar, Technical University of Munich, Munich, Ismaninger Str. 22, 81675 Munich, Germany
- ⁷ Department of Diagnostic and Interventional Radiology, University Hospital Ulm, Albert-Einstein-Allee 23, 89081 Ulm, Germany
- * Correspondence: michael.dieckmeyer@tum.de; Tel.: +49-89-4140-4561; Fax: +49-89-4140-4563

Citation: Dieckmeyer, M.; Inhuber, S.; Schläger, S.; Weidlich, D.; Mookiah, M.R.K.; Subburaj, K.; Burian, E.; Sollmann, N.; Kirschke, J.S.; Karampinos, D.C.; et al. Association of Thigh Muscle Strength with Texture Features Based on Proton Density Fat Fraction Maps Derived from Chemical Shift Encoding-Based Water–Fat MRI. *Diagnostics* **2021**, *11*, 302. <https://doi.org/10.3390/diagnostics11020302>

Academic Editor: Sven Nebelung

Received: 22 January 2021

Accepted: 11 February 2021

Published: 13 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

Table S1. Mean and standard deviation (SD) of proton density fat fraction (PDFF), analyzed texture features, and measured MVIC, separately for knee extensors (quadriceps) (EXT) and knee flexors (ischiorcrural muscles) (FLEX) and grouped by sex (male, n = 15; female, n = 15). Significant differences ($p < 0.05$) between males and females are marked in bold.

Parameter	Male		Female		<i>p</i>
	Mean	SD	Mean	SD	
Age [years]	30.5	4.9	29.9	7.0	0.789
BMI [kg/m^2]	27.9	3.1	26.4	1.8	0.113
PDFF_{EXT, left}	3.46	1.51	3.15	1.28	0.084
PDFF_{EXT, right}	2.48	1.68	2.31	1.17	0.057
PDFF_{FLEX, left}	3.44	1.64	4.53	1.71	0.544
PDFF_{FLEX, right}	3.16	1.78	4.71	2.43	0.750
Variance(global)_{EXT, left}	336.34	45.26	284.61	36.74	0.002
Variance(global)_{EXT, right}	339.57	44.02	289.64	31.94	0.001
Skewness(global)_{EXT, left}	-0.77472	0.79763	-0.60771	0.74569	0.558
Skewness(global)_{EXT, right}	-0.77117	0.78302	-0.61101	0.73123	0.567
Kurtosis(global)_{EXT, left}	6.1126	1.6234	6.0131	1.2137	0.851
Kurtosis(global)_{EXT, right}	5.7449	1.5898	5.6851	1.0074	0.903
Energy_{EXT, left}	0.00233	0.00164	0.00216	0.00062	0.707
Energy_{EXT, right}	0.00180	0.00151	0.00152	0.00037	0.491
Contrast_{EXT, left}	139.39	43.17	132.65	25.07	0.605
Contrast_{EXT, right}	142.54	38.61	148.33	23.87	0.625
Entropy_{EXT, left}	10.197	0.530	10.185	0.337	0.941
Entropy_{EXT, right}	10.436	0.598	10.524	0.269	0.610
Homogeneity_{EXT, left}	0.32457	0.03967	0.31982	0.02384	0.694
Homogeneity_{EXT, right}	0.29668	0.04234	0.29194	0.01801	0.693
Correlation_{EXT, left}	0.66785	0.03279	0.66556	0.03663	0.858
Correlation_{EXT, right}	0.67012	0.03517	0.67093	0.03399	0.950
SumAverage_{EXT, left}	0.00237	0.00030	0.00223	0.00028	0.194
SumAverage_{EXT, right}	0.00237	0.00036	0.00227	0.00021	0.376
Variance_{EXT, left}	0.00520	0.00137	0.00498	0.00085	0.607
Variance_{EXT, right}	0.00536	0.00130	0.00565	0.00081	0.462
Dissimilarity_{EXT, left}	6.3276	0.9477	6.3293	0.6011	0.996
Dissimilarity_{EXT, right}	6.7383	1.0788	6.9069	0.5666	0.596
Variance(global)_{FLEX, left}	151.20	25.97	131.30	23.86	0.037
Variance(global)_{FLEX, right}	152.61	24.38	131.73	23.91	0.025
Skewness(global)_{FLEX, left}	-0.72612	0.79944	-0.04485	0.72210	0.021
Skewness(global)_{FLEX, right}	-0.53888	0.68579	0.05623	0.89315	0.049
Kurtosis(global)_{FLEX, left}	4.7946	2.3472	3.9210	1.2507	0.214
Kurtosis(global)_{FLEX, right}	4.3439	1.9087	3.9012	1.4120	0.476
Energy_{FLEX, left}	0.00111	0.00037	0.00109	0.00040	0.837
Energy_{FLEX, right}	0.00120	0.00046	0.00107	0.00021	0.340
Contrast_{FLEX, left}	213.62	42.24	194.74	30.04	0.169
Contrast_{FLEX, right}	201.45	29.13	184.90	26.03	0.112
Entropy_{FLEX, left}	11.000	0.384	11.073	0.351	0.591
Entropy_{FLEX, right}	10.963	0.458	11.055	0.264	0.505
Homogeneity_{FLEX, left}	0.26793	0.02528	0.26039	0.02216	0.393
Homogeneity_{FLEX, right}	0.27107	0.02961	0.26380	0.01326	0.393
Correlation_{FLEX, left}	0.67865	0.04887	0.69873	0.03854	0.222
Correlation_{FLEX, right}	0.68513	0.04441	0.71334	0.05416	0.130
SumAverage_{FLEX, left}	0.00252	0.00028	0.00219	0.00028	0.004

SumAverage _{FLEX, right}	0.00239	0.00023	0.00220	0.00027	0.049
Variance _{FLEX, left}	0.00839	0.00160	0.00817	0.00137	0.686
Variance _{FLEX, right}	0.00814	0.00164	0.00829	0.00163	0.810
Dissimilarity _{FLEX, left}	8.2982	0.8591	8.3651	0.7246	0.819
Dissimilarity _{FLEX, right}	8.1726	0.9328	8.1498	0.4629	0.933
MVIC _{EXT, left [Nm]}	236.92	50.95	146.57	24.35	0.000
MVIC _{EXT, right [Nm]}	245.36	36.75	157.65	27.73	0.000
MVIC _{FLEX, left [Nm]}	111.51	19.15	74.65	12.28	0.000
MVIC _{FLEX, right [Nm]}	113.71	19.01	69.54	13.44	0.000