# White matter integrity of motor tracts in professional musicians and soccer players

**Poster No.:** C-1431  
**Congress:** ECR 2013  
**Type:** Scientific Exhibit  
**Authors:** D. Kaufmann¹, I. Koerte¹, M. Muehlmann¹, E. Hartl¹, M. F. Reiser¹, N. Makris², Y. Rathi², M. Shenton², B. B. Ertl-Wagner¹; ¹Munich/DE, ²Boston, MA/US  
**Keywords:** Neuroradiology brain, MR-Diffusion/Perfusion, Comparative studies  
**DOI:** 10.1594/ecr2013/C-1431

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited. You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

[www.myESR.org](http://www.myESR.org)
Purpose

The aim of this study was to characterize white matter (WM) integrity in professional musicians compared to professional soccer players using advanced MR diffusion tensor imaging (DTI) techniques.
Methods and Materials

Participants

Sixteen male professional musicians (24.8 ± 2.4 years of age) and seventeen age- and gender-matched professional soccer players from soccer clubs in Germany (24.4 ± 2.5 years of age) were included in the study. All subjects were right-handed and practiced for their profession since childhood. The mean total duration of playing soccer was 18.8 ± 2.6 years (10.1 ± 4.1 hours of training per week). Musicians played instruments that require sequential finger movements such as the piano, the guitar, the bass guitar and the cello. The mean total duration of playing an instrument in the musicians group was 15.4 ± 3.2 years (11.3 ± 8.4 hours of training per week). None of the participants had a documented history of any neurological or psychiatric disease. None of the musicians played soccer on a regular basis and none of the soccer player played any musical instrument.

MR imaging protocol

All data were acquired on a 3T MR scanner with a 12-channel head coil array. Anatomical sequences consisted of 3D magnetization prepared rapid-acquisition gradient echo (MP-RAGE) acquired in a sagittal orientation and motion insensitive 3D T2-Blade acquired in a transversal orientation. Diffusion weighted imaging was performed in a DTI-sequence with 3 averages and 20 non-colinear diffusion directions, TR 11500ms, TE 107ms, FOV 250mm, voxel size 1.95x1.95x2.2mm, b-value=0 and 1000s/mm² in 65 slices.

Data analyses

MR imaging datasets were examined for image quality. The diffusion-weighted volumes were aligned to their corresponding non-diffusion-weighted (b0) image with an affine transformation to minimize image distortion from eddy currents and to reduce motion artifacts. Then, non-brain tissue and background noise were removed from the b0 image using the Brain Extraction Tool. The diffusion tensor for each voxel was estimated by the multivariate linear fitting algorithm, and the tensor matrix was diagonalized to obtain its three pairs of eigenvalues (#1, #2, #3) and eigenvectors. Voxelwise summary parameters including fractional anisotropy (FA), radial diffusivity (RD) [# = (#2 + #3)/2], axial diffusivity (AD) [# = #1], and trace [#1 + #2 + #3] were calculated. Group analyses were performed using tract-based spatial statistics (TBSS) as well as tractography.

A. Tract-Based Spatial Statistics

Whole-brain tract-based spatial statistics (TBSS), a voxel-based standard space group analysis, was performed. The skeletonized FA, RD, AD, or trace data were used in the
voxel-wise statistics analysis, which is based on a non-parametric approach utilizing permutation test theory. The testing was performed by the FSL randomise program and random permutations were set at 5000. Group statistics were carried out on the FA, RD, AD and trace data. To exclude that any observed difference of diffusion measures between groups was caused by age-related changes, age was entered into the analysis as a covariate. For all analyses threshold-free cluster enhancement (TFCE) was used to obtain the significant differences between two groups at p<0.05, after accounting for multiple comparisons by controlling for family-wise error (FWE) rate.

B. Tractography

To trace fiber paths of the entire brain, we used the Unscented Kalman filter-based two-tensor tractography algorithm 1, 2. Each voxel was randomly seeded 10 times and each fiber was traced from seed to termination, with the termination criteria of FA<0.15 for the primary tensor component. Subsequently, regions of interest (ROIs) were drawn individually on the diffusion maps with respect to the color-coded DTI maps using 3DSlicer. Based on the TBSS results the following white matter tracts were chosen: Corticospinal tract (CST), corpus callosum (CC), and superior longitudinal fasciculus (SLF). Tractography of the left and right CST was performed by placing an ROI in the precentral gyrus and another in the ipsilateral, anterior part of the pons. In order to obtain the callosal tracts, a ROI covering the entire CC was placed in a mid-sagittal slice. The left and right SLF were defined according to the method described by Catani et al. 3, 4. Once ROIs were defined, fibers connecting the defined ROIs were extracted. The obtained tracts were analyzed regarding FA, RD, AD, and trace. We tested for group differences using the Mann-Whitney U test. A p-value<0.05 (two-sided) was considered statistically significant. All statistical analyses were performed with SPSS®20.0.0.1.
Results

Conventional MR sequences did not demonstrate visible morphological abnormalities in either group.

TBSS of 17 soccer players and 16 musicians revealed differences between the two groups with increased fractional anisotropy (FA) and decreased radial diffusivity (RD) values in musicians (p<0.05; TFCE-corrected). Compared to soccer players, musicians demonstrated higher FA values and lower RD values in the right precentral region. This region contains pathways of the corpus callosum (CC), the right superior longitudinal fasciculus (SLF), and the right corticospinal tract (CST). The spatial distribution of the brain region showing increased FA and decreased RD in the musicians is presented in Figure 1a and b, respectively. Note that there is almost complete overlap between FA and RD changes. No significant differences were found for AD and trace.

In accordance to the TBSS findings, tractography revealed significantly higher FA and significantly lower RD values in the right SLF in the musicians when compared to the soccer players. The right SLF additionally showed a significant decrease in trace values in musicians. Significantly higher FA and significantly lower RD values were also found in the left SLF in the musicians group when compared to soccer players. AD values did not differ significantly between both groups. Figure 2 shows a representative example of the SLF of both hemispheres, the mean, and p-values as well as the scatter plot in order to provide a visual depiction of the results and the standard error of the mean.

No significant differences were neither found for the CC nor the CST in either hemispheres. Figure 3 and 4 show an example of the CSTs and the CC, respectively.
Fig. 1: Results of the tract-based spatial statistical analysis (a-b) and respective scatter plots of subject measures (c-d). Voxels highlighted in red demonstrate significantly increased FA (a) and decreased RD values (b) in musicians compared to soccer players. Voxels are thickened into local tracts and displayed on the group mean FA image. Images are shown according to radiological convention (right = participants’ left). Compared with soccer players, musicians showed higher values for FA (median [IQR] 0.61445 [0.01643] vs 0.56139 [0.03129], respectively) and decreased values for RD (0.00040 [0.00001] vs 0.00045 [0.00001], respectively).

© PNL Boston, Harvard Medical School, Boston, MA, USA 2012
Fig. 2: FIG. 2. Tractography of the superior longitudinal tract (SLF) of both hemispheres (a) and respective scatter plots of subject measures (b). Tracts were obtained using the Unscented Kalman filter-based 2-tensor tractography algorithm to trace fiber paths of the entire brain 1, 2. Fibers of the SLF were separated according to the method described by Catani et al. 3, 4. Fig. 2a displays a representative result of the SLF of both hemispheres. Fig. 2b shows the respective scatter plots of subject measures, the mean and p-values, as well as the stand error of the mean.

© PNL Boston, Harvard Medical School, Boston, MA, USA 2012
Fig. 3: FIG. 3. Tractography of the callosal tract. Tracts were obtained using the Unscented Kalman filter-based 2-tensor tractography algorithm to trace fiber paths of the entire brain 1, 2. Fibers of the CC were separately filtered through a ROI covering the entire CC in a midsaggital slice. Fig. 3b shows the respective scatter plots of subject measures, the mean and p-values, as well as the stand error of the mean.

© PNL Boston, Harvard Medical School, Boston, MA, USA 2012
Fig. 4: FIG. 4. Tractography of the corticospinal tract of the left and right hemisphere. Tracts were obtained using the Unscented Kalman filter-based 2-tensor tractography algorithm to trace fiber paths of the entire brain 1, 2. Fibers were separately filtered through the precentral gyrus and the anterior pons for each side.

© PNL Boston, Harvard Medical School, Boston, MA, USA 2012
Conclusion

Advanced DTI methods revealed white matter differences between musicians and soccer players indicating that long-term motor training leads to different patterns of white matter organization. Significant results were especially found within the SLF. The SLF connects parietal and auditory cortex areas and is purported to be a key component of visuospatial orientation and higher order motor function. High FA, low RD and low trace values are known to be associated with thicker myelin sheaths and axon diameter. The obtained group differences in white matter integrity may therefore be due to neuroplastic changes in musicians due to intensive bilateral training of higher order motor skills since childhood. Here it has to be mentioned that also contrary results have been published by Imhof et al., showing a training induced increase in diffusivity and decreased FA values. In the light of current studies on white matter changes in soccer players by Koerte et al our findings may also be due to repetitive mild traumatic brain injury, i.e. by heading a soccer ball, within the group of soccer players. Further studies are needed to elucidate the origin of these changes.
References


Personal Information

David Kaufmann MD, Institute for Clinical Radiology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany, and Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, Boston, MA, USA

Inga K Koerte MD, Institute for Clinical Radiology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany, and Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, Boston, MA, USA

Marc Mühlmann, Institute for Clinical Radiology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany

Elisabeth Hartl MD, formerly Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, Boston, MA, USA, currently Department of Neurology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany

Maximilian F Reiser MD, Prof. Dr. Dr. h.c. FACR/FRCR, Director of the Institute for Clinical Radiology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany

Nikos Makris MD/PhD, Associate Professor at Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, and Associate Director of the Center for Morphometric Analysis, Department of Neurology at Massachusetts General Hospital, Boston, MA, USA

Yogesh Rathi PhD, Assistant Professor at Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, Boston, MA, USA

Martha E Shenton PhD, Professor and Director at Psychiatry Neuroimaging Laboratory, Brigham and Women’s Hospital, Harvard University, Boston, MA, USA

Birgit Ertl-Wagner MD, Prof. Dr., Institute for Clinical Radiology, University Hospitals Munich, Ludwig-Maximilians-University Munich, Germany