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DEEPER SULCI, THICKER GYRI, DOES MUSIC TUNE BRAIN MOTOR REGIONS?

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ABSTRACT

The human brain has an exceptional capacity to reorganize neural pathways and alter cortical patterns in response to environmental context. Early intensive musical training has a significant impact on brain development. Beginning at a young age, musicians integrate multiple functions (e.g., auditory, motor, visual, and cognitive tasks) comprehensively during a musical performance, requiring the activation of multiple brain regions. In this study, I investigated the effect of musicianship on cortical thickness and sulcal depth in 15 musicians and 15 age-matched non-musicians. Image analysis was conducted using surface-based morphometry (SBM). The results indicate that musicians have increased cortical volume in multiple brain regions, including the motor and visual regions. These regions are part of the visual-motor coupling network, indicating that long-term practice may lead to GM adaptation in visual-motor-related regions, thereby enhancing spatial attention and senso-motor transformation.

Keywords: musicians, motor, visual, sulcal depth, cortical thickness, surface-based morphometry (SBM)

1. INTRODUCTION

During musical performances, musicians frequently engage in multifunctional processes involving the integration of auditory, motor, and cognitive demands. Research on music perception and musicians with high-level aptitude is an excellent method for examining brain plasticity [1–6]. A unique model that involves genetic predisposition, environmental experience, and training-induced plasticity has been proposed to characterize a musician's brain [7].

Differences in brain anatomy between musicians and non-musicians may reflect changes in response to intensive and early initiation and continuous long-term practice,

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including the repetition of musical abilities. Multiple studies demonstrated anatomical differences between musicians and non-musicians. It has been shown that musicians have a larger corpus callosum (CC) [8–10]. Greater GM density and more WM integrity have been revealed in musicians compared to non-musicians in different brain regions [11–17]. In addition, GM volume was larger in professional musicians than in non-musicians in different brain regions [18–27]. Several diffusion tensor imaging (DTI) studies exhibit a pattern that corresponds well with results from previous studies. Arcuate fasciculus, the tract that connects motor and auditory regions, demonstrates greater white matter organization in musicians compared to non-musicians [28–33].

Using passive listening tasks, functional magnetic resonance imaging (fMRI) studies revealed that musicians, compared to non-musicians, had larger activations in various brain regions including; temporal regions associated with enhanced auditory processes [34–39], motor regions, and in language processing regions, such as Broca's area [36–39], in parietal regions, specifically the supramarginal gyrus, which has been linked to syntax processing and selective attention in response to musical stimuli [35, 37, 40]. Using an electroencephalogram (EEG) and magnetoencephalogram (MEG) musicians exhibit a greater amplitude of brain-generated electrical and magnetic potential in the frontal cortex than non-musicians [21, 41–43], and greater mismatch negative responses in auditory regions [44].

2. MATERIALS AND METHODS

2.1 Subjects

Datasets were collected from 15 musicians (10 males and 5 females) and 15 matched-age non-musician subjects (11 males and 4 females) (the mean age: was 37 years (SD = 16.62). All participants of this study signed an informed consent form before data collection

2.2 Image Acquisition

Whole-head 3D anatomical datasets were obtained using a 1.5 T Symphony scanner (Siemens, Erlangen, Germany). MP-RAGE sequence was used with the following parameters; (176 slices, TR/TE= 1660/3.05 ms; 2 averages; flip angel = 8°, matrix size 256 x 256; voxel size = $1 \times 1 \times 1$ mm^3). The duration of scanning time was 14 minutes and 11 seconds.

2.3 Data Analysis

The anatomical T1 data of each subject was aligned with the ACPC plane using Statistical Parametric Mapping software (SPM12: http://www.fil.ion.ucl.ac.uk/spm) running in Matlab (R2020b, update 7). The Computational Anatomy Toolbox (CAT12: http://www.neuro.uni-jena.de/cat), an extensive toolbox SPM12 was used to derive morphometric measures of the whole brain by calculating the differences in cortical thickness and sulcal depth between musicians and non-musicians. The pre-processing steps were performed following the default settings of the fully automated surface-based morphometry (SBM) method, as described in the CAT12 manual. The GM-WM boundary for each hemisphere was determined using the SBM method, and the cortical thickness and central surface were calculated using the projection-based thickness (PBT) method [45]. The cortical thickness and sulcal depth maps were then resampled and smoothed with a 12-mm FWHM Gaussian kernel in template space.

3. RESULTS

3.1 Sulcal depth measurements

Figure 1 depicts the t-statistic maps of the sulcal depth difference between musicians and non-musicians. In various regions, such as the superior portion of the left and right postcentral sulci, the left intraparietal sulcus, the left lunate sulcus, the left central sulcus, the left precentral sulcus, and the left inferior temporal sulcus, the cortex was significantly deeper in musicians as shown in Table 1. In contrast, all sulci were not significantly deeper in non-musicians compared to musicians.

Table 1 *P* values cluster size, and MNI coordinates of cluster peak regions of sulcal depth measurements.

Cluster peak region	**Voxels**	$\mathbf{Z}_{max}$	$\mathbf{P}_{uncorr.}$	$\mathbf{x}_{mm}$	$\mathbf{y}_{mm}$	$\mathbf{z}_{mm}$
Left Postcentral Sulcus (superior part)	35	3.85	0.000	-38	-35	63
Left Intraparietal Sulcus (superior part)	35	3.82	0.000	-19	-60	63
Left Lunate Sulcus	21	3.82	0.000	-31	-93	-7
Left Central Sulcus (superior part)	35	3.68	0.000	-51	-17	46
Left Precentral Sulcus	12	3.45	0.000	-47	-1	34
Right Postcentral Sulcus (superior part)	7	3.25	0.001	17	-40	71
Left Inferior Temporal Sulcus	3	3.15	0.001	-49	-56	-13

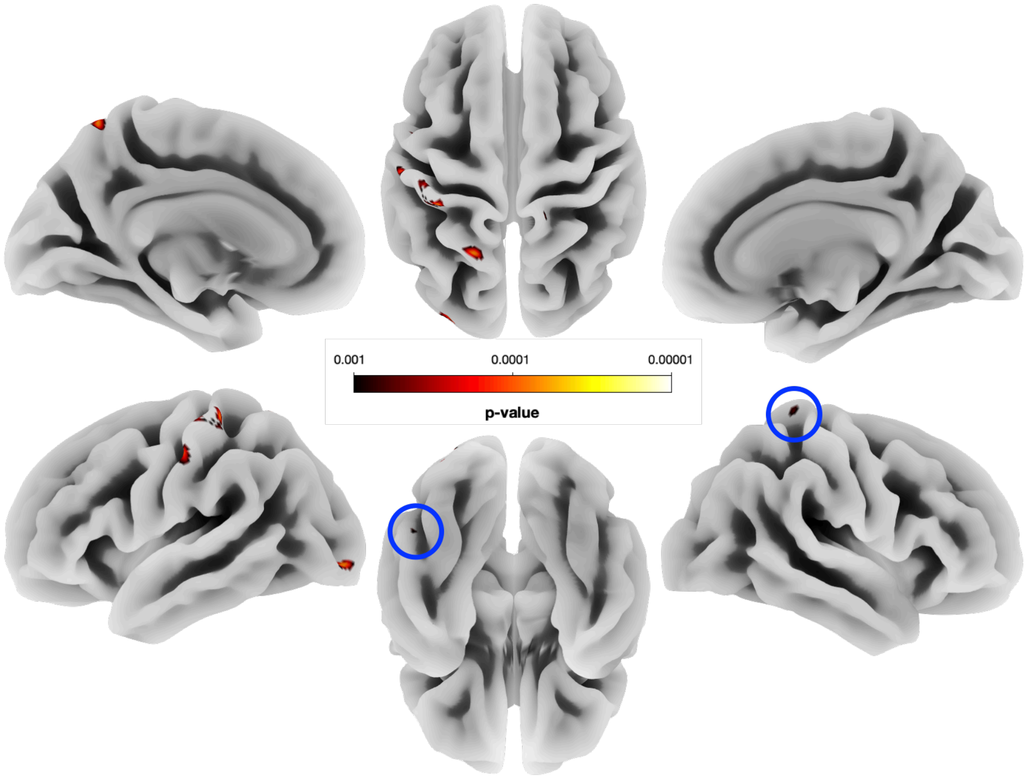

Figure 1 Statistical parametric map (extent threshold $P_{uncorr.} = 0.001$) showing clusters with statistically significant increased sulcal depth in musicians.

3.2 Cortical thickness measurements

Musicians had thicker cortex in the left superior occipital gyrus and the left occipital pole as shown in Figure 2 and Table 2. In addition, the interior and posterior portions of the left fusiform gyrus were thicker in musicians. In contrast, the right hemisphere had a thicker cortex in musicians in both the occipital pole and postcentral gyrus. Non-musicians, on the other hand, had no significantly thicker cortex compared to musicians.

Table 2 *P* values cluster size, and MNI coordinates of cluster peak regions of cortical thickness measurements.

Cluster peak region	Voxels	Z_{max}	$P_{uncorr.}$	x_{mm}	y_{mm}	z_{mm}
Left Superior Occipital Gyrus (lateral part)	52	4.08	0.000	-37	-82	11
Left Occipital Pole (superior part)	61	3.66	0.000	-24	-93	2
Left Fusiform Gyrus (posterior part)	30	3.63	0.000	-41	-51	-20
Right Occipital Pole	64	3.63	0.000	27	-98	-1
Left Fusiform Gyrus (anterior part)	12	3.27	0.001	-37	-20	-28
Right Postcentral Gyrus	9	3.27	0.001	9	-40	68

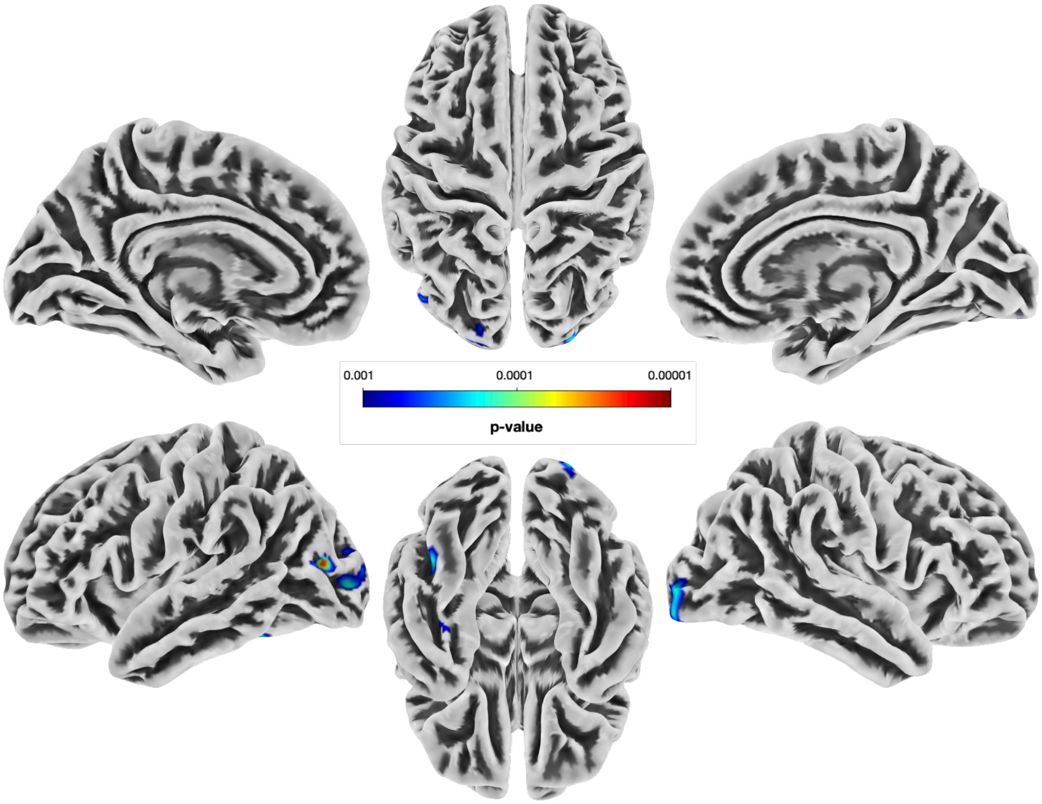

Figure 2 Statistical parametric map (extent threshold P_{uncorr} .= 0.001) showing clusters with statistically significant increased cortical thickness in musicians.

4. DISCUSSION

The comparison of the topographic patterns of sulci and gyri between musicians and non-musicians revealed that musicians had deeper cortex in the superior portion of the left and right postcentral sulci, the left intraparietal sulcus, the left lunate sulcus, the left central sulcus, the left precentral sulcus, and the left inferior temporal sulcus. Multiple brain regions, including the left superior occipital gyrus, the left and right occipital pole, the interior and posterior portions of the left fusiform gyrus, and the postcentral gyrus exhibited thicker cortex in musicians.

Sulcal and gyral topographic alteration in musicians reflects the multi-modal integration of auditory, motor, and cognitive tasks in response to the daily extensive demands of multi-function processes, such as pitch perception, instrument playing, memory, and musical sight-reading. These distinctions suggest a relationship between acquired sensory-motor skills and characteristics of brain topographic patterns, particularly in the primary and pre-motor regions and certain brain regions associated with motor tasks. Animals [46] and humans [47] have demonstrated an association between motor training and changes in the brain's external features [27, 33, 36, 48, 49]. Therefore, it can be expounded that, the differences in sulcal and gyral topography patterns between musicians and non-musicians reflect use-dependent structural adaptation associated with the acquisition of expert musical skill.

Genetics and environment influence brain structure and function significantly [50–55]. Several studies demonstrated the effect of environment and personal experience on the structural characteristics of specific brain regions [56–59].

The most important question is whether structural and functional changes in musicians' brains are associated with musical training or represent a genetic predisposition for music? [50, 52]. The structural and functional correlates of musicianship are highly correlated with the duration of musical proficiency and the intensity of musical practice [60–64], as well as with the age at which the individual began musical training [8, 12, 21, 30, 65, 66]. The findings of this study are consistent with those of the studies cited previously. These differences suggest that cortical tissue has adapted to the lifestyle of professional musicians as a result of their use. Neurorehabilitation strategies for neurologically impaired patients may benefit from the knowledge of training-induced anatomical and functional neuroplasticity [48, 67–74]. Early musical training may contribute to achievement in verbal memory [75–77], verbal intelligence [78], mathematical enhancement [79, 80], and fine motor skills [80, 81].

One of the limitations is that there are insufficient data to accurately account for measurements of certain factors, such as the age at which a person began musical training and the length of time they have possessed musical proficiency. Within the total sample, there are five female musicians and four female non-musicians, with one left-handed individual in each group.

5. CONCLUSION

Collectively, the findings of the present study revealed that musicians have increased cortical volume in various brain regions including postcentral, intraparietal, lunate, central, precentral sulci, inferior temporal sulci, fusiform and postcentral gyri, and occipital pole. These regions are a part of the visual-motor coupling network, suggesting that long-term practice may result in GM adaptation in visual-motor-related regions enhancing spatial attention, and senso-motor transformation. Although musical training may improve the shape and volume of these areas, genetic predisposition may also play a role. The relative contribution of predisposition and practice can only be determined by well-designed studies benefiting from advanced algorithms and techniques that introduced last few years.

CONFLICT OF INTEREST

All authors declare no conflict of interest

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Non

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