Reduced Cerebellar White Matter Volume in Musicians: A Marker of Musical Expertise

Dear Editor,

Musical activity involves simultaneous processing of sensory, motor, cognitive, affective, and social stimulations, which is known to facilitate brain plasticity.[1] Lifelong involvement in musical activities acts as a cognitive reserve, thus protecting the brain against age-related decline in cognition and neurodegenerative disorders.[2] Music therapy has been found to be beneficial in several neurologic and neuropsychiatric conditions like dementia, stroke, Parkinsons's disease, and autism spectrum disorder (ASD).[3] Herholz et al. (2012) reported that the benefits of musical training are highly dependent on the age at which the training began.[4] The cerebellum has often been reported to be involved in music perception, singing, pitch discrimination, and plasticity related to musical training.[5] Lifelong engagement in musical activities maintains cerebellar volumes even in old age, which extends its benefits to cognitive functioning.[6] On the contrary, early training (before 7 years of age) and musical expertise have been associated with decreased cerebellar volumes.[7] These learnings directed us to explore the differences in cerebellar volumes between musicians and non-musicians.

We identified 29 cognitively healthy older adults with considerable experience in Carnatic music (vocals) from the cohort of the Tata Longitudinal Study of Aging (TLSA), which is an ongoing longitudinal aging cohort study from urban Bangalore that is aimed to identify the midlife and above (≥45 years) risks and protective factors associated with dementia and aging.[8] This was followed by a telephonic interview to obtain and clarify further details like years of musical training, genre of music, and whether practicing instrumental or vocal music. We divided the participants into two groups: musicians (singers), who had formal training for more than 5 years (n = 13), and non-musicians, who had no training or less than 5 years of formal training (n = 16).[9] TLSA has been approved by the Institutional Ethics Committee and follows all necessary ethical guidelines. Informed consent was obtained from all the participants. The participants were bilingual English speakers without a history of neuropsychiatric illnesses and

Table 1: Baseline characteristics of the study participants

Baseline characteristics	Musicians (n=13)	Non-musicians (n=16)	*P*
Age (years)	58.97±9	57.83±5.31	0.948
Gender (*n*, %)			
Male	5 (38.46)	8 (50)	0.711
Female	8 (61.54)	8 (50)	
Education (years)	16.08±1.89	16.06±4.20	0.619
Cerebellar volumes (mm^3)			
Left cerebellum WM	13,018.88±1319.92	13,961.78±1225.38	0.062
Right cerebellum WM	12,146.15±1351.10	13,442.96±1544.08	0.040*
Left cerebellum cortex	47,014.25±4714.15	49,999.8±5108.35	0.156
Right cerebellum cortex	47,669.49±4845.89	50,922.57±6057.27	0.092

All continuous variables are represented as mean± SD and categorical variables as frequency (%). SD: standard deviation, WM: white matter. *Indicates statistical significance at $P<0.05$. Mann–Whitney *U* test was used to find the group differences for all the continuous variables which were not normally distributed. Chi-square test revealed no significant association between gender and musician status

Table 2: Results of GLM

Cerebellar volumes	Model (adjusted for TIV) β (95% CI)	*P*
Left cerebellum WM	-756.49 (-1502.95 to -28.02)	0.042*
Right cerebellum WM	-1046.04 (-1849.20 to -242.87)	0.011*
Left cerebellum cortex	-2283.47 (-5219.23 to 652.28)	0.127
Right cerebellum cortex	-2419.20 (-5612.13 to 773.71)	0.138

CI: confidence interval, GLM: Generalized Linear Regression Model, TIV: total intracranial volume, WM: white matter. *Indicates statistical significance at $P<0.05$

Table 3: Partial-correlation between years of training in Carnatic music and cerebellar volumes

Cerebellar volumes	*r*	*P*
Left cerebellum WM	0.197	0.562
Right cerebellum WM	-0.057	0.868
Left cerebellum cortex	-0.257	0.445
Right cerebellum cortex	-0.228	0.501

WM: White matter. *r*: partial correlation coefficient

had a normal cognitive functioning (indicated by Clinical Dementia Rating score of zero). Those with claustrophobia, non-magnetic resonance imaging compatible implants, severe developmental delay, alcohol and other substance abuse or had an inability to actively participate or self-report were excluded. The musician participants in our study were trained Carnatic singers. Brain magnetic resonance imaging (MRI) scans were acquired using a 3.0-T MRI scanner (Magnetom Prisma, Siemens). High-resolution T1-weighted images were acquired using a magnetization-prepared rapid gradient echo sequence, and the cerebellar volumes were extracted using FreeSurfer software. To find the association between brain volumes and musician status, a Generalized Linear Regression Model (GLM) was employed.

The mean age of musicians and non-musicians in our study was 58.97 ± 9 and 57.83 ± 5.31 years, respectively, and the mean years of education was 16.08 ± 1.89 and 16.06 ± 4.20 years, respectively. There was a significant difference in the right cerebellum white matter (WM) volume between musicians and non-musicians ($P = 0.040$). The baseline characteristics of the study participants are summarized in Table 1.

Interestingly, after adjusting for age and total intracranial volumes (TIVs), GLM analysis showed that musicians had significantly reduced WM volumes in both the left (β = −765.49 [95% confidence interval {CI}: −1502.95 to −28.02]; $P = 0.042$) and right (β = −1046.04 [95% CI: −1849.20 to −242.87]; $P = 0.011$) cerebellar hemispheres compared to non-musicians [Table 2]. In addition, we found that the partial correlations between years of training in Carnatic singing and cerebellar volumes controlled for age and TIV were insignificant [Table 3]. Furthermore, the difference in ratio of cerebellum to cerebral volumes between musicians and non-musicians was also not significant ($P = 0.303$).

The results of our study are indicative of reduced cerebellar WM volumes among musicians when compared to non-musicians. These findings suggest that musical training may induce structural changes in the cerebellum and is an important factor to consider while exploring the neural underpinnings of musical expertise. Shenker et al.[10] reported similar findings, where early-trained musicians had reduced cerebellar volumes compared to late-trained musicians. In a study by Baer et al.,[7] it was found that extensive musical training was associated with reduced volume of the cerebellum. Our study interestingly identifies that, musicians had a decreased volume of the cerebellar cortex, although this decrease was statistically insignificant. These findings are suggestive of a reduced activation due to expertise, which has been noticed in the cortical regions of musicians and dancers in previous studies.[11,12] This could be attributed to the concept of metaplasticity that allows more sophisticated processing of musical notes and filters out irrelevant sensory inputs, thereby utilizing lesser brain volumes.[5,7] Metaplasticity refers to the long-term neural changes that occur due to repeated exposure to an activity over a significant amount of time and often acts as a scaffold for further development.[13] Our results also showed an insignificant difference in the ratios of cerebellum to cerebral volume between musicians and non-musicians. This could be

attributed to the low sample size as well as other mechanisms in the cortex that might lead to maintenance of the ratio, thus showing no difference between the two groups. Early training might induce certain metaplastic changes in the cortical regions involved in music, such as the frontal and parietal lobes, left precuneus, and bilateral middle temporal gyrus.[14] Metaplastic changes in the cortex have been scarcely studied, particularly in relation to musical brains, which opens avenues for further exploration. It is important to appreciate the morphologic changes induced by music in specific brain regions like the cerebellum. It is interesting to note that cerebellar size is larger in neuropsychiatric disorders like ASD, where music therapy has found a niche in recent years. Therefore, further research is imperative in understanding the aspects of long-term music therapy and its benefits in modulating cerebellar connectivity.

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Conflicts of interest

There are no conflicts of interest.

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