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Journal of Science and Medicine in Sport 12 (2009) 688–690
Journal of Science and Medicine in Sport
www.elsevier.com/locate/jsams

Original paper

Can exercise shape your brain? Cortical differences associated with judo practice

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Received 31 March 2008; received in revised form 28 September 2008; accepted 11 November 2008

Abstract

Experimental animal studies have shown that physical exercise, associated with planning and execution of complex movements, are related to changes in brain structure. In humans, changes in cortical tissue density in relation to physical activity are yet to be fully determined and quantified. We investigated differences on gray matter volume in judo players by using voxel-based morphometry. Comparison between a group of eight internationally competitive judo players and a group of 18 healthy controls showed a significantly higher gray matter tissue density in brain areas of judo players.

Keywords: Sports; Physical; Magnetic resonance imaging; Voxel-based Morphometry; Brain development; Neuroplasticity

1. Introduction

Experimental studies showed that the regular practice of physical exercises can stimulate cerebral plasticity.[1]

Neuroimaging has been employed to investigate indirect evidence of brain plasticity related to exercise in humans. Using voxel-based morphometry (VBM), Colcombe et al.[2] showed that regular aerobic exercises may cause an increase in regional gray matter volume (GMV) in seniors. Other studies demonstrates cortical changes in Parkinson patients[3] and in practitioners of Tai-Chi.[4]

With the general hypothesis that the long-term practice of a physical exercise involving complex motor tasks might induce GMV differences in healthy young subjects in areas of the central nervous system related with motor skill learning, this study investigated if the practice of judo is associated with significantly higher GM tissue density compared to normal.

2. Methods

Eight men, right-handed, internationally competitive high-level professional judo practitioners with mean age of 25 years (S.D. ± 1.8 years) were evaluated. The judo players had practiced judo for at least 10 years, with an average of 5–6 h/day of training. This group was compared with eighteen men, right-handed sedentary controls obtained from a healthy population with mean age of 25 years (S.D. ± 2.9 years). There was no difference of age between these two groups (Mann–Whitney U test, $p < 0.05$). All men were submitted to the same MRI protocol. Written informed consent was obtained from all men in accordance with the guidelines of the ethics committee from our institution (registration number 428/2005).

High-resolution MRI was performed using a 2T scanner (Elscint Prestige Haifa, Israel). Volumetric (3D) T1 images were acquired in the sagittal plane (flip angle = 35°, repetition time = 22 ms, echo time = 9 ms, matrix = 256 × 220, field of view = 23 cm × 25 cm) and resampled to yield 1-mm isotropic voxels.

MRI images were acquired in DICOM format and converted to ANALYSE format using the software MRIcro.[5]

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doi:10.1016/j.jsams.2008.11.004

Image pre-processing involved spatial normalisation, segmentation into gray matter probabilistic maps and smoothing with an isotropic Gaussian kernel of 10 mm, using SPM2. For normalisation and segmentation routines, an in-house developed template was employed.

Statistical analyses were performed with the Non-parametric Mapping (NPM) software (http://www.sph.sc.edu/comd/rorden/npm/), comparing the group composed of judo players ($n = 8$) with the group of healthy control subjects ($n = 18$). Contrasts were defined in order to estimate the probability of each voxel being gray matter. Statistical results were obtained with the Wilcoxon test (voxel by voxel)[6] and corrected for multiple comparisons using false discovery rate (FDR), with a threshold of $p < 0.05$. Statistical maps of significant differences were overlaid onto the Anatomical Automatic Labeling Atlas (AAL) for the evaluation of the anatomical differences of observed differences.

3. Results

Table 1 shows a significantly higher regional GMV observed in the group of judo players in the frontal, parietal, occipital and temporal lobes.

Higher GMV were also observed in the cerebella. These findings are summarised in Fig. 1. There were not areas of lower GMV in the judo group compared to control.

4. Discussion

The present study observed differences in regional GMV in judo players compared with healthy sedentary controls. The higher GM tissue density was found in frontal lobe related to motor planning and execution[7] and in regions of the prefrontal cortex, related to working memory and cognitive processes. The differences in GMV in middle and inferior temporal gyri found in our study are considered paralimbic areas and are related to motor learning and memory.[7] The region with differences in GMV in regions of the parietal and occipital lobes are related to visual associative processes. We also found differences in GMV bilaterally in the cerebellar cortex, which is not surprising given its importance in motor learning.

The differences in gray matter may reflect plastic modifications induced by motor training in response to a demand imposed by the motor task in specifics brain regions related to the specificity of training.[8] On the other hand,

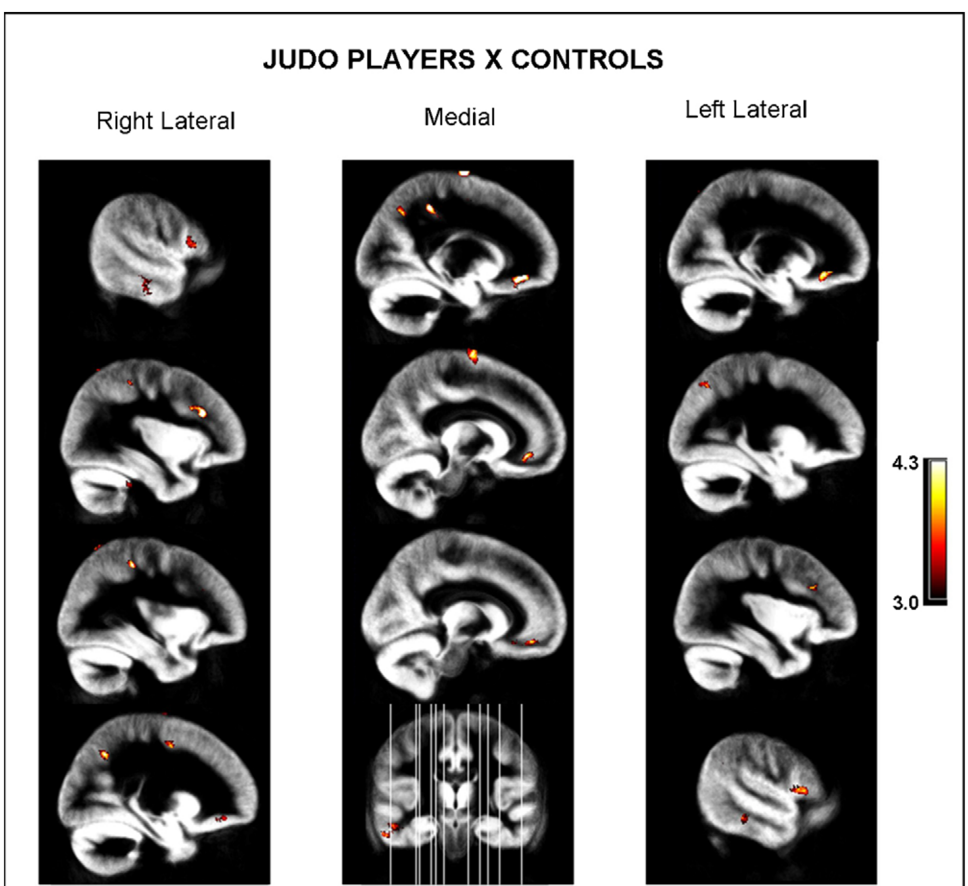

Fig. 1. Sagittal slices of mean gray matter maps with an overlaid statistical map of differences between controls and judo players (Wilcoxon test (voxel by voxel) and corrected for multiple comparisons using FDR and $p < 0.05$). Color scale bar represents Z scores of higher gray matter density in judo players.

Table 1
Areas of higher cortical GMV in judo player.

Anatomical region	Number of voxels	
	Right hemisphere	Left hemisphere
Pre-central gyrus	–	227
Frontal superior gyrus	–	398
Frontal superior orbital gyrus	283	357
Frontal middle gyrus	–	34
Frontal middle orbital gyrus	–	305
Frontal inferior opercular gyrus	472	530
Frontal inferior triangular gyrus	162	418
Rolandic opercular	–	62
Supplementary motor area	51	196
Rectus gyrus	517	69
Paracentral	–	55
Postcentral	–	234
Parietal superior gyrus	114	435
Parietal inferior gyrus	–	46
Precuneus	–	37
Temporal middle gyrus	122	326
Temporal inferior gyrus	398	1040
Occipital superior gyrus	169	–
Occipital middle gyrus	–	133
Cerebellum 1	–	32
Cerebellum 6	29	–
Cerebellum 7b	–	51

Higher cortical gray matter volume (regions and equivalent number of voxels) in judo players compared to sedentary controls (Wilcoxon test (voxel by voxel) and corrected for multiple comparisons using FDR and $p < 0.05$).

these differences may be the consequence of increase in the GMV of cortical brain regions secondary to changes in cerebral blood flow[9] and trophic factor liberation[10] induced by physical exercise.

The results in the present work provide additional evidence for regional cortical differences associated with practice of sports, herein observed in a group of experienced judo practitioners.

5. Conclusion

This study hypothesised that a group of long-term judo practitioners would have significantly higher GM tissue density in brain regions associated with the motor planning and execution, compared to a sedentary control group. These findings demonstrate an association between the practice of a physical exercise involving complex motor planning and control and higher GM tissue density in brain regions responsible for these tasks.

Acknowledgements

W.F.S. Jacini is recipient of a scholarship from CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior). This work is financed by CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) and FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo).

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