Cortical activation during power grip task with pneumatic pressure gauge: an fMRI study

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Abstract. Aging is associated with a decline in cognitive and motor function. But, the relationships with motor performance are less well understood. In this study, functional magnetic resonance imaging (fMRI) was used to assess cortical activation in older adults. This study employed power grip task that utilised block paradigm consisted of alternate 30s rest and active. A visual cue was used to pace the hand grip movement that clenched a cylindrical rubber bulb connected with pressure pneumatic gauge that measure the pressure (Psi). The objective of this study is determined the brain areas activated during motor task and the correlation between percentage signal change of each motor area (BA 4 and 6) and hand grip pressure. Result showed there was a significant difference in mean percentage signal change in BA 4 and BA 6 in both hemispheres and negative correlation obtained in BA 4 and BA 6. These results indicate that a reduced ability in the motor networks contribute to age-related decline in motor performance.

1. Introduction
Decline in cognitive and motor function of older adults is pointed as the reasons for a range of neurodegenerative and neurochemical changes with advancing age [1, 2]. Functional magnetic resonance (fMRI) is one of the approaches that has been used to map age-related changes [4, 5]. Previous studies depicted that the regions of motor area activation on studying the movements of normal right and left fingers via finger tapping stimulation were shown in the primary motor cortex [6, 7, 8]. In a published article of Cortical Activity in Precision-Versus Power-Grip Tasks which utilised auditory cues, power-grip task in right handed 5 young and healthy subjects were associated with stronger activity in the contralateral primary motor cortex (M1), primary sensory cortex (SI) and parietal operculum (PO) than in the precision-grip task [9]. However in this current study, power-grip task was employed which utilised visual cues instead of auditory cues in 14 older adult male and female subjects to identify brain areas activated in older adults while subjects were performing power-grip task.

One of the methods to map functioning human brain is blood oxygenation level dependent (BOLD) which relies on the magnetic properties of blood to measure the changes in local hemodynamic related to neuronal activity [10]. Hence, in finding the activation in motor regions in this fMRI experiment, BOLD contrast was utilised in this study because of its non-invasive nature and it proved to identify...
patterns of activation across the whole brain [11].

Previous research [12] showed BOLD activation increased in relation to force amplitude in the primary motor/somatosensory cortex (M1/S1) in precision grip task in healthy adults. A study of age-dependent changes in the neural correlation with force modulation, involving subjects from age of 25 to 70 showed positive correlation between BOLD signal and grip force in contralateral primary motor cortex (Brodmann area (BA 4), superior cingulated sulcus (BA 6) and primary visual motor (BA 7) [5]. However, diminished correlation was found in primary motor cortex and superior cingulated sulcus in older adults. Due to diminish correlation seen in older adults thus this study focused on a relationship percentage of signal change in motor cortex and pressure (Psi) applied during power grip task. The aim of this study is therefore, by using simple motor task via visual cue, to investigate the differences of brain activation (BA 4 and BA 6) in motor regions in both hemisphere and the correlation between percentage signal change of each motor area (BA 4 and 6) and hand grip pressure. Therefore this study hypothesised that brain activations in left hemisphere is higher compare to right hemisphere in both regions and there will be positive correlation between hand grip pressure and percentage signal change.

2. Method

2.1. Subjects
Fourteen healthy subjects (40-55 years old, mean 44.4 years old, S.D. 4.4 years) comprising of 5 male and 9 female participated in the study and gave their informed consent to a protocol approved by Ethic Committee of The Universiti Kebangsan Malaysia (No: MN052). All subjects were right-handed as judged by Edinburgh Handedness Inventory [13].

2.2. Tasks
The subjects performed a power grip task with the right hand in the presence of visual cues by applying maximum grip to a bulb connected to pneumatic pressure gauge which measured pressure applied by subjects. Prior to scanning, but whilst lying in the scanner, subjects were asked to grip the bulb which connected to pneumatic pressure gauge using maximum force (1-2 Psi). The measurement was recorded for each subject. During the tasks, the subjects rested comfortably in a supine position in the MR scanner. The extended right arm was oriented parallel to the trunk in a relaxed position. Visual cues which employed block-design paradigm consists of 12 alternate active and 12 rest blocks, 30 sec each was used to pace hand movement. Ten measurements were taken for each block with total of 250 measurements noted including 10 baseline measurements. The measurements of the force were monitored during the scanning session.

BOLD fMRI was performed using an optimised gradient-echo EPI protocol using parallel-imaging (GRAPPA) acquisition/reconstruction on a Siemens Trio 3T. Acquisition parameters were: TR/TE=3000/60 ms, 64 × 64 acquisition matrix, 192 mm × 100 mm FOV, 21 slices of 4.5 mm covering the entire brain with a tilted axial orientation.

2.3. Image Preprocessing and Data Analysis
Images were prepared for analysis using statistical parameter mapping (SPM8) (http://www.fil.ion.ucl.ac.uk). For regions of interest analysis (ROI), two regions were selected which were BA4 and BA6. Using Marsbar, a sphere size of 6 mm was utilised to obtained ROI in both BA4 and BA6 in right and left hemisphere.
3. Results

3.1. Brain areas activated

Result from this study which showed number of voxels activated in Broadmann Areas were described in Table 1 (p<0.001) uncorrected [14] in descending order. However in this study, regions of interest were only BA 4 and BA 6.

| Broadmann Area | Anatomical location       | Voxels activated |
|----------------|---------------------------|------------------|
| 6              | Precentral gyrus          | 2379             |
| 40             | Supramarginal gyrus       | 893              |
| 3              | Postcentral gyrus         | 377              |
| 4              | Precentral gyrus          | 369              |
| 2              | Postcentral gyrus         | 237              |
| 7              | Precuneus                 | 168              |
| 8              | Middle frontal gyrus      | 168              |
| 1              | Postcentral gyrus         | 46               |

3.2. Percentage of signal change in BA 4 & BA 6

From the ROIs analysis using Marsbar, four ROIs were obtained which were left BA 4 (-34, -20, 55), right BA 4 (4 -38 72), left BA 6 (-4, 0, 52) and right BA 6 (12, 2, 60) (refer Fig 1). Result showed a significant different (p <0.001) between mean signal change for right and left hemisphere in BA 4 and BA 6. Mean percentage signal change in BA 4 right (0.353), BA 4 left (1.969), BA6 right (0.67) and BA 6 left hemisphere (1.062).

3.3. Grip pressure and percentage signal change

Pearson correlation of both areas in both hemispheres showed weak negative correlation. BA4R correlation coefficient was -0.249 while -0.304 for BA4L with pressure. BA6 correlation coefficient was -0.286 and -0.299 for right and left hemispheres respectively.

![Figure 1](image_url)

Figure 1. (a) & (b) Activation shown in left BA4. (c) & (d) Activation shown in right BA4.(e) & (f) Activation shown in left BA6. (g) & (h) Activation shown in right BA6.
4. Discussion

4.1. Brain areas activated (BA 4 & BA 6)

Previous study reported activation in BA 4 in power grip task [9] but in this study, the results demonstrated a highest activation in BA6 which aligned with findings [15] that described more activation was seen in BA6 rather than BA4 with advancing age due to possibility of older adults forming the task given more like precision grip thus accounting for the trends towards BA 6 since it was reported that there was a age-related decline in accuracy or speed at making fine movements for older adults [16].

4.2. Percentage of signal change in BA 4 & BA 6

In several PET and fMRI experiments a preference for the left hemisphere has been observed in, both in primary motor or sensorimotor regions and in medial and lateral premotor regions. Activations have been reported to be primarily contralateral during right hand movement but notably less strongly lateralised during left-hand movement [17]. Overall, there left hemisphere in both BA 4 and BA 6 showed higher mean percentage signal change in keeping with studies suggesting contralateral (left) primary motor cortex and SMA were strongly in right-handed subjects.

4.3. Grip pressure and percentage signal change

In this study there was a weak negative correlation in BA6L (-0.289) than that in BA6R (-0.299) between grip pressure and percentage signal change. The negative correlation results obtained with older adults may due to the efficiency of the whole brain diminished with increasing age [5, 18] and cortical regions known to contribute to corticospinal tract are less able to increase output-related activity with advancing age. However, in this study only mean value of pressure was measured. Therefore further studies should be done to investigate the relationship between grip pressure and percentage signal change in older adults.

5. Conclusion

Percentage of signal change showed significant difference between both BA4 and BA6 in right and left hemisphere. Weak negative correlation in BA4 and BA6 may due to aging effects. This findings will help understanding the functions in both region and neuroplasticity process to reduce disability in neurological diseases such as stroke.

6. Limitations

The measurement of the grip pressure was collected as a mean value and may vary through out the scanning session.

7. References

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