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Effects of progressive muscle relaxation on cerebral activity: An fMRI investigation

S. Kobayashi*, K. Koitabashi

Department of Nursing, Gunma University Graduate School of Health Sciences, Japan

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ABSTRACT

Objectives: Progressive muscle relaxation (PMR) is one of the self-management relaxation techniques that can be used in the general population and patients with specific issues. However, no study to date has revealed the brain activity associated with PMR. Therefore, we assessed the changes in brain activity induced by PMR using functional magnetic resonance imaging (fMRI).
Design and setting: We conducted an intervention study with PMR and control sessions. The subjects were twelve healthy adult men who had no prior experience of PMR.
Interventions: Subjects performed a control session in which muscles were repeatedly simply tensed and relaxed. Subsequently, a PMR session took place, during which muscle tension was reduced through a systematic procedure of tensing and relaxing of muscle groups combined with structured breathing.
Main outcome measures: We identified and visualised brain activity based on individual and group-level analysis of fMRI data.
Results: Eleven subjects' data were analysed. In the control session, brain activity broadly changed, while the change was limited to specific parts of the cerebral cortex and limbic system in the PMR session. PMR gradually decreased activity in the superior frontal gyrus (SFG), inferior frontal gyrus (IFG), and posterior cingulate cortex (PCC). In a region of interest (ROI) analysis, interactions between sessions were observed in the putamen, anterior cingulate cortex (ACC), postcentral gyrus (PCG), and insula.
Conclusions: That PMR led to few areas showing changed activity suggests that the technique may suppress brain activity. Even novices may be able to induce such a focused mental state.

1. Introduction

Progressive muscle relaxation (PMR) is a self-management relaxation technique developed by Jacobsen in 1938.[1] PMR can enable a deep state of relaxation via repeated tensing and relaxing of muscle groups combined with breathing exercises.[1] PMR has been used to control stress, not only in the general population without mental and physical problems, but also in patient populations. PMR has shown benefits in reducing anxiety and depression, improving sleep quality, alleviating fatigue and reducing pain.[1–3]

Several studies have examined temporal changes in brain activity during PMR. Lee et al.[4] used electroencephalography (EEG) in chemotherapy patients assigned to one of two randomised groups, namely a PMR group and a music therapy group. Their data demonstrated that theta band activity increased in the posterior area, despite decreased beta band activity in the medial frontal area during PMR and music therapy. Further, in the music therapy group, alpha band activity decreased in comparison with the PMR group. However, EEG records electrical activity via multiple electrodes placed on the scalp: therefore, it is difficult to detect the electrical activity in the deeper parts of the brain. Pifarreí et al.[5] assessed brain activity using 18F-fluorodeoxyglucoseon-positron emission tomography (18F-FDG-PET) in patients with cancer, comparing changes in activity among PMR, drug treatment with diazepam, and no intervention groups. Both the PMR and the drug treatment groups showed a significant decrease in glucose consumption in the cortex compared to the no-intervention group. PET detects molecular activity within the body; however, its use should be limited to severely or specifically ill patients because of the associated radiation and the invasiveness of the procedure.

Functional magnetic resonance imaging (fMRI), which is non-invasive and non-radioactive, is able to detect brain activity induced by various stimuli with high temporal and spatial resolution. A number of fMRI studies have reported changes in brain

* Corresponding author at: Department of Nursing, Gunma University, Graduate School of Health Sciences, 3-39-22 Showa-machi Maebashi, Gunma 371-8511, Japan. Fax: +81 27 220 8982.
E-mail address: kobashino831@gmail.com (S. Kobayashi).

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activity induced by complementary therapies such as meditation and yoga.[6,7] However, no study to date has assessed changes in brain activity engendered by PMR. Accordingly, the objective of our study was to assess the brain activations induced by the PMR using fMRI.

2. Materials and methods

2.1. Subjects

Twelve males participated in this study. All gave written, informed consent to take part in this study. The subjects had no history of head injury, learning disability, or psychiatric illness. All subjects had no prior experience of any relaxation techniques. The study was approved by the local Institutional Review Board of Gunma University Graduate School of Medicine.

2.2. Experimental interventions

We compared PMR and control sessions to assess the effects of PMR. All subjects experienced both the PMR session and the control session.

PMR session

PMR is a self-guided stress management technique that reduces muscle tension through a systematic procedure of tensing and relaxing muscle groups combined with breathing exercises.[8] The PMR procedure of this study was adopted from Jacobson's PMR and adjusted to accommodate the fMRI body position (i.e., to stabilise the head position) by omitting the cephalic muscles, facial muscles, and cervical muscles from the exercise. Subjects were instructed to close their eyes, after which they alternately tensed and relaxed groups of muscles in a prescribed sequence. Subjects inhaled slowly through their nose when tensing their muscles, held their breath, and then exhaled a long thin breath through their mouth when relaxing, and were encouraged to gradually feel their bodily changes throughout the tensing/relaxing cycle. Concurrently, PMR instructions were provided via headphones.

Control session

Subjects cyclically tensed and relaxed their muscles. Subjects were instructed to close their eyes and to repeatedly tense and relax the muscle groups in a prescribed sequence. The muscle groups were same as those used in the PMR session. However, the subjects were not instructed to pay attention to their breaths and could relax their muscles during a breath. To avoid focusing their performance and attention in any way, we did not provide specific instructions. Throughout the control session, subjects listened to instructions regarding the control session via headphones.

Before each session commenced, subjects were provided with an explanation of the procedure, and practiced their performance of it in a private room. The order of performance was blocked; the first block was the control session, and the second the PMR session, to avoid knowledge of PMR influencing performance of the control task. There was a one-hour break between sessions.

2.3. MRI acquisition

Image scanning was performed on a 3 T scanning system (MAGNETOM Trio, A Tim System; Siemens, Tokyo, Japan) at the Brain Activity Imaging Center (Kyoto, Japan). A forehead pad was used to stabilise the head position.

A T2-weighted gradient-echo echo-planar imaging sequence was used with the following parameters: repetition time (TR) = 3000 ms, echo time (TE) = 30 ms, flip angle = 80°, matrix size = 64 × 64, 50 slices, voxel size = 3 × 3 × 3 mm. A T1-weighted high-resolution anatomical image was obtained using a magnetization-prepared rapid acquisition with gradient-echo (MPRAGE) sequence (TR = 2250 ms, TE = 3.06 ms, flip angle = 9°, field of view = 256 × 256 mm, matrix = 256 × 256, 208 slices, voxel size = 1 × 1 × 1 mm).

2.4. Image analysis

Image and statistical analyses were performed using the statistical parametric mapping package SPM8 (http://www.fil.ion.ucl.ac.uk/spm) implemented in MATLAB Version 7 (The MathWorks Inc., Natick, MA, USA). Functional images within each run were realigned using the first scan as a reference, to correct for head movements. Then, T1 anatomical images were coregistered to the first scan of the functional images. Following this, the coregistered T1 anatomical image was normalised to a standard space, as defined by the Montreal Neurological Institute (MNI).[9] These spatially normalised functional images were resampled and smoothed with an isotopic Gaussian kernel (8 × 8 × 8 mm).

This block design was subjected to random effects analyses. First, the primary analysis used the general linear model. Both the PMR session and the control session consisted of four blocks of eight trials, with rest periods present before and after each block (pre-rest, post-rest; Fig. 1).

To assess time-wise effects by using parametric contrasts, an autoregressive model was used. Each block was modelled as a boxcar function, convoluted with a canonical haemodynamic response function. We used the parametric contrasts estimated via the linear trends to assess whether brain activity varied over time. Then, the subject-specific contrast images of parameter estimates were used as inputs to the second (random effects) level of analysis, using a one-sample *t*-test based on the summary statistics. Planned T-

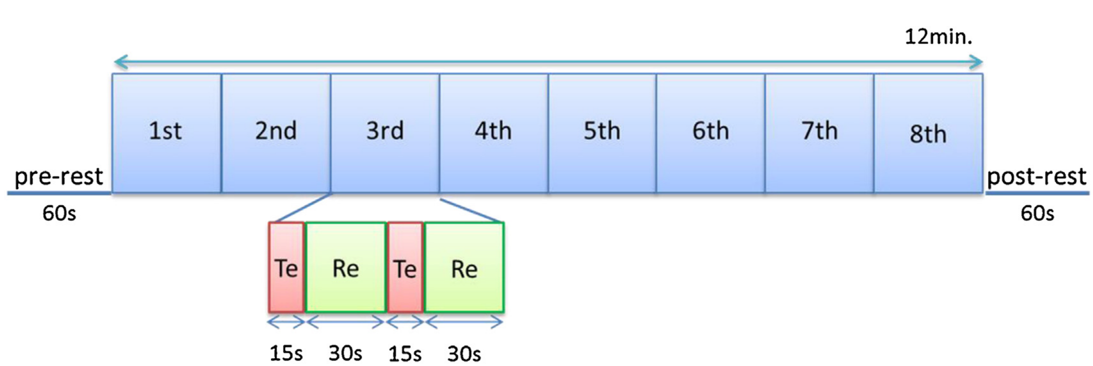

Fig. 1. Experimental design. The PMR session and control session used the same design. After a pre-rest time of 60 s, there were eight parts. Each part was composed of four blocks: a tensing period (Te) of 15 s followed by a relaxation period (Re) of 30 s, repeated twice. There was a subsequent 60 s post-rest time.