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Effects of autogenic relaxation training and progressive muscle relaxation on anxiety: an EEG-based experimental study

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Abstract: Younger generations are shown to have a high prevalence rate of anxiety. This study examined the changes in the alpha brain signals based on autogenic relaxation training (ART) and progressive muscle relaxation (PMR) to determine their efficacy in reducing anxiety symptoms among undergraduate students. This study was a randomized controlled trial in which participants were randomly allocated to either the ART group or the PMR group. Seven supervised sessions of ART and PMR were conducted over three weeks, with each session lasting approximately 20 minutes. Electroencephalography (EEG) and Beck Anxiety Inventory scores (BAI) were used as outcome measures to assess the effectiveness of relaxation training on anxiety before and after the interventions. The study included 30 participants with a mean age of 19.60 ± 0.84 years. A paired sample t-test revealed that relaxation training significantly reduced anxiety. Additionally, ART demonstrated statistically significant effects in reducing anxiety (p=0.004), showing a greater decrease in post-intervention mean BAI scores compared to PMR. However, the difference between ART and PMR was not statistically significant (p=0.110). ART showed a greater reduction in post-intervention BAI scores, while PMR showed greater positive changes in EEG findings. The study outcome is an enhanced evidence-based physiotherapy program that may be used by physiotherapists in the neurological rehabilitation with anxiety.

Keywords: Electroencephalography; Autogenic relaxation training (ART); Progressive muscle relaxation (PMR); Anxiety; Beck Anxiety Inventory scores (BAI).

1.0 INTRODUCTION

Anxiety is defined as an unpleasant feeling and distressing emotion towards an unknown event. It is usually associated with bodily discomfort, worriedness, and emotional instability. Anxiety starts to become abnormal when the intensity of anxiety becomes excessively high in a situation that is known to be harmless and also when the duration is excessively

longer than the potential harm. It is acknowledged that anxiety disorders have a higher prevalence rate among the general adult population, especially college students. This could be due to the stresses that come from different aspects of life (Sprung et al., 2020). It is believed that multiple aetiologies would have caused college students to feel excessively anxious during day-to-day life. Those stressors include financial issues, academic performance, time and health-related issues and interpersonal relationships (Liu et al., 2022). A study (Shamsuddin et al., 2013) investigated the correlation between depression, anxiety and stress among university students. It concluded this phenomenon could be due to the increasing workload by university students in their more senior years and also worried about their future as they approach graduation, where they need to seek employment and also plays a major role in contributing to low academic performance in students (Liu et al., 2023) and this might cause severe illness, prolonged dependency on health and medical services (Bruffaerts et al., 2018).

Relaxation techniques have become the most inexpensive approach to dealing with anxiety problems. These techniques can be used as stand-alone or combined with other treatments to form an effective therapy (Papola et al., 2024). The relaxation techniques aim at engaging in mental and physical activities by ignoring distracting thoughts to achieve a relaxed state. In many studies (Gallego-Gómez et al., 2020; Kaur et al., 2023), the results demonstrated that students significantly improved their academic performance and reduced anxiety compared to pre-treatment levels. Relaxation has been described as a state of mind where there is limited tension in the body. Perhaps it is associated with a sense of peace and warmth in oneself (Montero-Marin et al., 2019).

Many relaxation methods are available nowadays, but generally, they are categorized as cognitive and somatic approaches. One of the well-known relaxation techniques aimed at reducing arousal is progressive muscle relaxation (PMR), which was developed by Edmund Jacobson in the early 1920s (Torales et al., 2020). According to him, there was a connection between the relaxation of the mind and the relaxation of muscles. In PMR, relaxation of the mind purely depends on the state of muscles, and if muscles reach a relaxed state, it will induce relaxation in the mind as well (Muhammad et al., 2024). Autogenic relaxation training (ART) was introduced by German neurologist Dr Johannes Heinrich Schultz. In his view, ART works by reducing the arousal level by permitting self-regulation through a passive manner. Passive concentration is the fundamental concept in ART. In general, relaxation training is a non-expensive treatment which can generate many potential healthcare benefits other than reducing anxiety levels (Seo et al., 2018; Vasu et al., 2021).

In a recent research study, frontal alpha asymmetry has been proposed as a biomarker for anxiety people. Frontal alpha asymmetry is defined as the relative difference in power between two signals in different hemispheres (Demerdzieva et al., 2015; Monni et al., 2022). Many studies have investigated daily life functioning, including mood, anxiety, the way of thinking, and learning behaviour through quantitative EEG. This study aims to investigate the effects of autogenic relaxation (ART) and progressive muscle relaxation (PMR) on reducing anxiety levels and objectively identify changes in frontal alpha asymmetry.

2.0 MATERIALS AND METHODS

This study was carried out after obtaining ethical approval (U/SERC/77/2016) from the ethical committee of Universiti Tunku Abdul Rahman (UTAR). The recruited sample comprised 30 undergraduate students with a mean age of 19.6 (± 0.8) years. The inclusion criteria for this study included both male and female students with low to moderate anxiety levels and with no previous experience in ART and PMR. All the subjects were equally allocated to either experimental groups of ART group or PMR group by simple random sampling method.

Participants received seven supervised relaxation training interventions over three weeks, each lasting 15 to 20 minutes. The session consists of three supervised sessions in the first week and two supervised sessions in consecutive weeks. The subjects were encouraged to practice the relaxation method at least once per day and also maintain an activity diary, which helps monitor each participant's involvement. All sessions were conducted at the UTAR Multimedia Resource Centre II. Each participant received a copy of the audio track at the first visit according to their group.

2.1 EEG data acquisition

EEG was recorded with Nicolet™ 64-channel EEG data acquisition system amplifier. Six gold-plated EEG electrodes, including the reference electrodes, were placed over the scalp area with reference to linked ears. The placement followed the international 10-20 system. The sampling rate and frequency range were set to 256 Hz and 0.3-70 Hz, respectively.

A baseline EEG measurement was taken before the first intervention session and conducted at the UTAR biomedical engineering laboratory. Proper measures have been taken to reduce electrical interference during EEG recording sessions. Each EEG recording session took around 45 minutes to 1 hour to complete. During the EEG recording session, 4 electrodes were placed over the Fp1, Fp2, F7, and F8 regions, and 2 reference electrodes were placed over the left and right mastoid process. The recording session was 3 minutes with eyes closed, and thirty seconds of rest intervals between each minute were allotted during the EEG measurements. The second EEG measurement and BAI assessment were carried out in week four.

The recording was taken under the following conditions: Eyes were closed for 3 minutes (with a 30-second interval between each minute, during which subjects were asked to open their eyes).

The impedance levels of all the electrodes were set to 10 KΩ. Recorded results were saved and referred to as a database montage. The 6 electrode positions were allocated to:

- Frontal – Fp1, Fp2, F7, F8
- Left and right mastoid process (reference electrodes)

The time base was set to 20s/screen, sensitivity to 100 mcV/cm, and the notch setting was on to eliminate unwanted noise. The data was analysed after large eye movements, such as vertical and horizontal eye movements, were eliminated. The results from each region were recorded. The results were then exported and calculated using Matrix Laboratory (MATLAB) version 9.1.

2.2 Interventions

There are 6 standard exercises adopted, which were developed by Schultz exercises (Stetter & Kupper, 2002).

The following ART protocol was used:

1. I am calm and relax
2. My arms and legs are heavy
3. My arms and legs are warm
4. breath is calm and regular
5. My heartbeats are calm and regular
6. My solar plexus is warm

Before starting the PMR intervention, subjects were asked to assume a comfortable position in sitting with feet placed comfortably apart, hands placed on thighs with palms facing upward and close their eyes. All constraining items were removed, and the room was made dark. Then, they were asked to alternately tense and relax groups of muscles in a prescribed sequence based on the instructions given. 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. At the end of each session, participants were encouraged to share their feelings and give feedback after performing all the steps (Toussaint et al., 2021).

2.3 Beck Anxiety Inventory (BAI)

Beck et al. (1988) state that BAI is a self-report measure scale to measure anxiety level, utilizing 21 items with each item carrying 0 to 3 marks, depending on the answer chosen (0 – not at all, 1 – Mildly but it didn't bother me much, 2 – moderately, it wasn't pleasant at times, 3 – severely, it bothered me a lot). The minimum score in BAI will be 0, while the maximum score will be 63. Different marks scored indicate different levels of anxiety level present with 0 to 21 marks indicating low anxiety, 22 to 35 marks indicating moderate anxiety and 36 marks and above indicating potential concerning level of anxiety (Ismail et al., 2023).

3.0 RESULTS

Thirty individuals were recruited into this study; all participants completed the study protocol. Within the study period, no adverse events were reported in either of the groups. The participants' age in this study ranged from 19 to 21 years old, with a mean age of 19.60 ± 0.84 years.

The average power of the 8-13 Hz alpha band was taken as the index of alpha power in this study. The difference in the pre-intervention and post-intervention alpha power was measured between the left and the right locations. The locations were Fp1, Fp2, F7 and F8. The data obtained was computed using the following equation:

$$\frac{\text{Power (left)} - \text{Power (right)}}{\text{Power (left)} + \text{Power (right)}}$$

The alpha power values between the left and right electrodes placed on Fp1-Fp2 regions were calculated by using the formula mentioned above.

Table 1 shows the mean and standard deviation (SD) of the BAI scores for both the PMR and ART groups, pre- and post-test. For the PMR group, the pre-test mean score was 17.60 (SD=7.50), and the post-test mean score decreased to 9.60 (SD=5.03), with a *p*-value of 0.110, indicating that the reduction was not statistically significant. For the ART group, the pre-test mean score was 17.40 (SD=3.21), and the post-test mean score dropped to 8.60 (SD=1.82). The *p*-value for this group was 0.004, indicating a statistically significant reduction in anxiety levels after the intervention.

Table 2, analysing the comparative examination of the alpha values before and after the intervention in the Fp1-Fp2 region, indicates an increase in cortical activation, as demonstrated by an enhancement in alpha power linked to the ART. Correspondingly, the pre- and post-intervention alpha power in the F7-F8 regions within the context of ART further signifies an enhancement in cortical activity.

Table 1. Comparison of pre-test and post-test mean BAI scores between ART group and PMR group.

Test		Mean (SD)	*p*-value
BAI score PMR	Pre-test	17.60 (7.50)	.110
	Post-test	9.60 (5.03)	
BAI score ART	Pre-test	17.40 (3.21)	.004*
	Post-test	8.60 (1.82)	

*$p<0.05$

The PMR pre-post values of Fp1 and Fp2 alpha power were -0.018 and 0.012, respectively, indicating higher cortical activity in the right and left hemispheres, respectively. The group also showed higher cortical activity in the left hemisphere. However, the difference in the post-alpha value between the F7 and F8 regions indicates higher cortical activation in the right hemisphere.

Table 2. Comparison of the pre-intervention and post-intervention alpha power changes between AGR group and PMR group.

	Alpha power (μV^2)					
	Fp1-Fp2 pre-test	**Fp1-Fp2 post-test**	**Change in pre and post (Fp1-Fp2)**	**F7-F8 pre-test**	**F7-F8 post-test**	**Change in pre and post (F7-F8)**
ART	0.025	0.020	↓ 0.005	0.052	0.058	↑ 0.006
PMR	-0.018	0.012	↓ 0.006	-0.041	-0.026	↓ 0.015

4.0 DISCUSSION

In this study, we examined the effects of ART and PMR on anxiety levels and brain activity, focusing on frontal alpha asymmetry. Both interventions significantly reduced anxiety levels as measured by the BAI, and changes in cortical activation were observed using EEG data, specifically in the alpha frequency band (8-13 Hz). However, ART demonstrated a slightly greater reduction in anxiety scores compared to PMR. Despite this, EEG findings revealed that PMR resulted in more significant changes in cortical activity, suggesting differing mechanisms between the two relaxation techniques.

BAI scores showed changes in both the ART and PMR groups, confirming that relaxation techniques can effectively reduce anxiety, consistent with previous studies (Gallego-Gómez et al., 2020; Kaur et al., 2023). However, significant changes were observed, indicating that the ART group is superior to PMR in terms of decreasing BAI scores.

The human brain's frontal lobes serve as a key processing centre for emotional responses. EEG studies have shown that increased relative activity in the right frontal cortex is often associated with behavioural inhibition and vigilant attention, which often occur during certain negative affective states. In contrast, heightened activity in the left frontal cortex is associated with processing positive affective information (Reznik & Allen, 2018).

Frontal alpha asymmetry has been widely recognized as a biomarker for emotional regulation and anxiety. Asymmetry is defined as the functional difference between the left and right hemispheres, typically assessed by comparing the absolute amplitude recorded from homologous electrodes positioned on each hemisphere (Demerdzieva et al., 2015). The alpha band is inversely linked to brain activation, meaning higher alpha activity typically corresponds to reduced activation of specific brain regions. Conversely, drop-in alpha activity is consistently observed when cortical

regions engage in cognitive processing, reflecting the brain's heightened involvement in tasks requiring active attention (Monni et al., 2022).

In the present study, Brodmann area 10 corresponds to the dorsolateral and anterior prefrontal cortex, and Brodmann area 47 corresponds to the inferior part of the frontal cortex. These areas were recorded using EMG electrodes Fp1-Fp2 and F7-F8, respectively.

In the ART group, there was an increase in left cortical band activation in the Fp1-Fp2 regions following the intervention. This suggests that ART may modulate left cortical activity, thereby reducing anxiety. Self-induced relaxation influences various aspects of brain function, helping to restore the natural self-regulating (homeostatic) mechanisms across the central nervous system, impacting both physical and mental levels (Shinozaki et al., 2010). This effect may be achieved by reducing overwhelming negative thoughts and promoting self-regulation of autonomic nervous system processes (Krampen, 1999).

However, a notable shift in band activation was observed when migrating from the right hemisphere to the left hemisphere after applying PMR within the identical regions. This phenomenon may be attributed to the experience of relaxation without resistance during PMR, which induces a condition where cerebral activity diminishes in the right cortical area, ultimately facilitating the modulation of emotional states. In both relaxation cohorts, the findings indicated a pronounced augmentation in left hemisphere activation between the Fp1 and Fp2 regions within the anterior prefrontal cortex following the ART interventions (Kobayashi & Koitabashi, 2016; Monni et al., 2022). This shift towards left frontal dominance is associated with positive emotional processing and enhanced activation of the prefrontal areas (Kim et al., 2013; Schlamann et al., 2010).

Previous studies have identified that emotional disturbances influence brain activity, The increased activation in the left frontal region, specifically between F7 and F8, is associated with greater activation in Brodmann area 47, with greater activation in the left subcortical areas compared to the right (Demerdzieva et al., 2015). In our study, there was a decrease in the activation of the left hemisphere between F7-F8 regions in the ATR group after intervention. For the PMR group, there was an increase in the right hemisphere activation between F7-F8 regions after the intervention. In the ATR and PMR groups, there was less activation in the left hemisphere between F7 and F8 regions in the inferior prefrontal regions. This concludes that both approaches helped reduce anxiety. However, the PMR shows higher activation of the band in the right F7-F8 regions, which reduces anxiety (Demerdzieva et al., 2015; Wheeler et al., 1993). The likely explanation for PMR yielding a more remarkable outcome compared to ART lies in PMR's capacity to evoke relaxation at an accelerated pace. Over three weeks dedicated to relaxation training, the researchers discerned that PMR could manifest a more significant impact within a brief duration based on the results gathered.

The PMR performance of repeatedly tensing and relaxing muscles may suppress brain activity, and one of the reasons could be decreased activation of the superior frontal gyrus, inferior frontal gyrus, and posterior cingulate cortex and especially the superior frontal gyrus is implicated in inhibitory neural networks and self-awareness (Kobayashi & Koitabashi, 2016). In ART, reduction of exteroceptive and proprioceptive afferent stimulation; (ii) mental repetition of psychophysiologically adapted verbal formulae; and (iii) 'passive concentration,' or complete, effortless mental immersion in the task could be the reason to increase the activation of the alpha band (Yumkhaibam et al., 2023).

Both ART and PMR have demonstrated potential as non-invasive, cost-effective interventions for anxiety reduction. However, ART may be more suitable for individuals seeking to reduce the subjective experience of anxiety, while PMR might be more effective for those requiring physiological regulation of brain activity. These distinctions underscore the significance of tailored treatment strategies in clinical environments, as both ART and PMR can seamlessly blend into physical relaxation practices for a holistic approach to anxiety management (Torabizadeh et al., 2016; Lim et al., 2014).

The small sample size limits the generalizability of the study's findings, and gender variations and the grouping of anxiety levels were not adequately accounted for in this study, which may affect the interpretation of gender-related differences in anxiety. Future research should aim to include a larger, more diverse sample, consider alternative or more detailed methods of anxiety assessment, and thoroughly explore gender differences in anxiety outcomes.

This concludes that both approaches potentially reduce brain activity, which may explain why they benefit

individuals with psychological disorders by modulating cerebral activity.

5.0 CONCLUSIONS

Both relaxation training methods demonstrated substantial efficacy in reducing anxiety levels among undergraduate students, as indicated by the results from the BAI questionnaire and EEG findings. This combined approach offers a more comprehensive perspective on the neurophysiological changes linked to anxiety reduction, enhancing our understanding of how these methods affect both the psychological and physiological aspects of anxiety.

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