Attentional Control during Visual Modified Flanker Stimuli using fMRI Data

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ABSTRACT

Background: Selective attention is the ability to concentrate on specific sensory inputs while ignoring other stimuli and sensory inputs, and it is related to job performance, especially in military personnel.

Objective: This study aimed to evaluate selective attention in military personnel rather than normal individuals.

Material and Methods: In this cross-sectional study, 40 individuals were divided into two groups: military personnel and normal individuals. Participants were shown a modified flanker task in a military environment, and functional magnetic resonance imaging (fMRI) was used to assess brain activation and functional connectivity through an attention task.

Results: Military personnel demonstrated quicker response times than civilians in both high- and low-threat environments, particularly in incongruent trials. In high-threat scenarios, the left Medial Frontal Gyrus (MFG) showed increased voxel counts, while the right MFG was more active in low-threat trials. Additionally, military personnel exhibited stronger functional connectivity in attention regions compared to civilians.

Conclusion: Functional connectivity analysis reveals that military personnel show increased connectivity in attention regions during high-threat situations, indicating adaptive neural strategies for managing danger. The study also finds that congruent stimuli demand less neural coordination than incongruent ones, resulting in the understanding improvement of threat perception and attentional processes in military contexts, with significant implications for training and performance.

Keywords

Cognition; Inhibition; Flanker Task; Military; fMRI; Functional connectivity; Neuropsychology; Frontal Lobe

Introduction

The brain is a complex network with specific functions like attention, information processing, and executive function. Selective attention improves the processing of stimuli by directing the mind toward a particular aspect, thereby diminishing the influence of extraneous information and directing human cognition and behavior toward objectives. Early cognitive science theories likened selective attention to a mental filter, sifting through incoming information and prioritizing what matters most [1]. Thus, selective attention as a subset of the cognitive control ability of the brain plays a decisive role in recognizing useful information and ignoring unnecessary information in humans and also allows individuals to focus on aspects of a situation that align with their goals while disregarding irrelevant information [2].

Cognitive control is necessary for the filtration of irrelevant information and the selection of optimal responses. It encompasses mental focus and attention directed towards specific tasks and is widely acknowledged to comprise three fundamental components: inhibition (including behavioral control), Working Memory (WM), and cognitive flexibility (also referred to as mental flexibility) [3,4]. Inhibitory attention control means selectively choosing and focusing on specific information and suppressing attention to another stimulus in space [5]. This mechanism requires coordination between different cognitive abilities, including short-term memory, decision-making, task-keeping, response selection, and suppression. The flanker task, as a cognitive test that examines selective attention and executive control, requires a prompt and correct response to the target stimuli. This task typically includes congruent and incongruent trials. In congruent trials, matching stimulus and target leads to quicker responses. In incongruent trials, different stimuli cause interference, slowing down responses [6]. The difference in Response Time (RTs) between incongruent and congruent conditions measures the ability to overcome cognitive conflicts.

The flanker task assesses attention by measuring focus, accuracy, and selective attention efficiently. Several studies explore brain regions in conflict processing at different levels: detection, assessment, and action consequence evaluation. In particular, the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC) are involved in conflict detection and resolution. In different studies, it is assumed that the ACC recognizes the interference between the input information flow to the brain and increases attention to the relevant stimuli by sending a signal to the frontal cortex while reducing interference. The medial frontal cortex (MFC) is involved in performance monitoring, and response conflict left inferior frontal gyrus suppresses irrelevant information in terms of meaning [7-9].

In recent decades, neuroimaging research has revealed insights into brain functions and structures. Advancements in functional neuroimaging now offer improved methods to assess brain region connections. Functional connectivity is specified as the temporal dependences of neuron activation patterns of structurally separate brain areas. Furthermore, different research has shown the ability to recognize functional connections between brain areas during different tasks. Various task-oriented functional magnetic resonance imaging (fMRI) investigations have significantly enhanced our understanding of the brain areas engaged in performing specific tasks [10]. On the other hand, attention is crucial for job performance, particularly in roles requiring precision and speed, like military personnel. Emotional control, accuracy, focus, and selective attention are critical topics in military, psychological, and neurocognitive studies. One of the main parts of military training is mental preparation exercises. Mental preparation involves utilizing thoughts, emotions, behaviors, and activities to exhibit purposeful behavior in high-pressure situations. The effectiveness of mental training programs for enhancing the psychological readiness of military personnel lacks accurate data, particularly regarding their attention. An important question in human psychology, especially in very stressful jobs, such as soldiers and pilots, is whether brain imaging features can train and increase the soldier's attention in different situations (danger and safe conditions). Therefore, this study evaluated the brain by focusing on areas of related attention in different war environment conditions. Consequently, the current study aimed to explore one or more clearly defined, lightly replicable, and highly dependable brain functional networks, which are believed to coincide with patterns of activation or deactivation while performing attentional tasks like the flanker test.

Scope of the present study

This study examined brain activity related to cognitive control in military personnel compared to normal individuals to identify differences. Military personnel's quick decision-making and emotional regulation were crucial for their job performance. The study hypothesized that military personnel would exhibit higher mental fitness due to their occupational demands. The flanker task was conducted in high- and low-threat zones to mimic military work environments and assess brain responses. fMRI was used to compare brain activity and stimulus responses between military and non-military individuals, with a focus on attention and cognitive processing regions.

Material and Methods

Participants

In this cross-sectional study, 40 healthy men participated in this study. Two groups of volunteers with an equal number of participants were selected for the study: military personnel (mean age 27.3±2.38 years) and normal individuals (mean age 28.4±3.46 years). The individuals who took part in the study were all right-handed, which was a specific criterion for inclusion. Furthermore, they were thoroughly screened to confirm that none of them had any psychiatric or neurological disorders that could potentially interfere with the research outcomes. Additionally, it was ensured that none of the participants suffered from claustrophobia, which could affect their comfort during the study. Additionally, none of the participants possessed any metal fragments in their bodies, such as pacemakers, which could pose risks during the procedures involved. Each participant was also a native speaker of Persian, ensuring that language barriers did not impact the study's effectiveness or the data collection process. Figure 1 shows the flowchart of the current study.

Flanker Task

The flanker cognitive task assesses inhibitory response by measuring the ability to ignore irrelevant stimuli amidst related ones. We created a modified version featuring varying levels of conflict. In the traditional patterns of the Eriksen–Flanker task, congruent trials consist of >>>>>, and incongruent trials consist of >><>>. Congruent trials are those, where the target and distractors are all oriented in the same direction (e.g., all arrows pointing right). Incongruent trials are those where the distractors are oriented in a different direction than the target (e.g., target pointing right, distractors pointing left).

The flanker task was modified for a simulated military environment, requiring participants to focus more than in traditional settings. The proposed design considered individuals' job and operational conditions to better reflect military work scenarios.

Participants completed a modified flanker task in high- and low-threat zones. In low-threat zones, peaceful backgrounds were used, while war and military operation images were shown in high-threat zones. Subjects were instructed to select the correct answer in both incongruent and congruent conditions. We used four blocks of modified flanker tasks; each block included 24 task trials (including 2 congruent and 12 incongruent trials); a total of 96 trials (48 trials in low-threat zones and 48 trials in high-threat zones) randomly were shown to each participant. The interval time (Inter-Trial Interval (ITI)) between each block was 12 seconds. The interval between stimuli was 1.5-3 seconds; each trial was shown for 2 s. These trials are shown to participants in two-dimensional frames at specific times. The subject must press certain buttons at a maximum speed of 2000 ms based on the direction

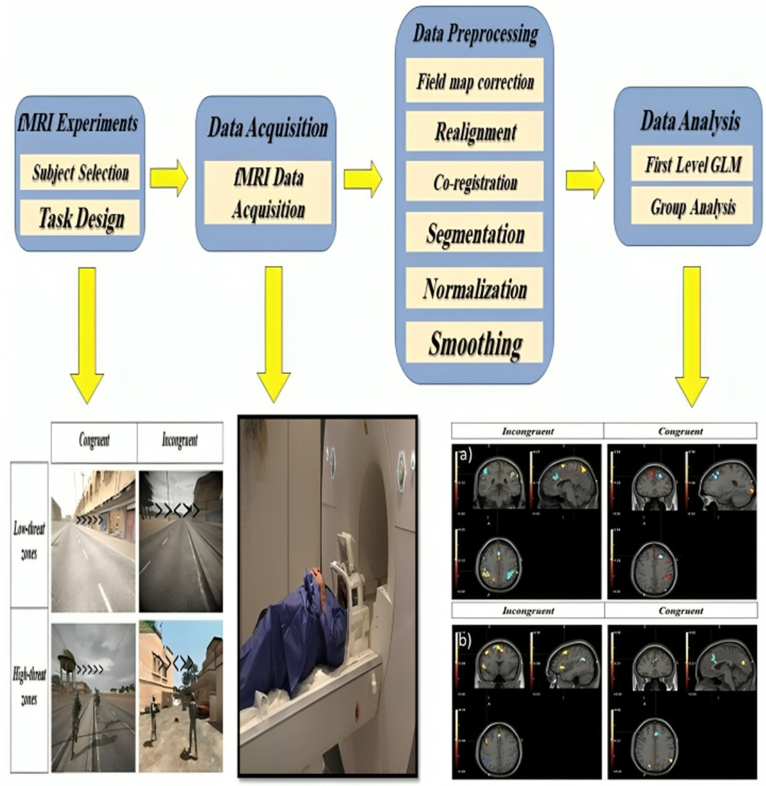

Figure 1: The flowchart illustrates the steps involved in functional magnetic resonance imaging (fMRI) data analysis, from subject selection and task design to group-level statistical analysis.

of the arrow and select the appropriate answer. Results are displayed regarding the number and percentage of correct responses for congruent and incongruent stimuli in each block and the average reaction time in milliseconds for congruent and incongruent stimuli in each block. Figure 2 delineates the various trial types in the flanker task.

Image Acquisition

The fMRI images were acquired using a 3 Tesla Magnetic Resonance Imaging (MRI) System with a standard twenty-channel head coil. A high-resolution T1-weighted brain image was obtained for each participant, comprising 176 continuous slices captured using a magnetization-prepared rapid gradient echo (MPRAGE[P2]) sequence (Repetition Time (TR)=2500 ms, Echo Time (TE)=3.93 ms, TI=900 ms, Field of View (FOV)=256[P3]×256 mm^2, acquisition matrix=256×256, voxel size=1 mm^3). Whole-brain functional volumes were acquired through Echo Planar Imaging (EPI) with a TE of 30 ms and a TR of 2000 ms, utilizing an 80° flip angle. A total of 40 continuous slices (3mm×3mm×4mm) were gathered. Additionally, the PsychoToolbox-3 software was employed to present tasks to participants.

Behavioral Analysis

Response Times (RT) for accurate answers were calculated in congruent and incongruent trials. Reaction times (RTs) were calculated as the time elapsed between trial onset and key press (in milliseconds). Only correct responses were included in the ANOVA analysis, conducted at the 5% significance level.

fMRI Data Analysis

The fMRI data were analyzed using the SPM12 toolbox (http://www.fil.ion.ucl.ac.uk/

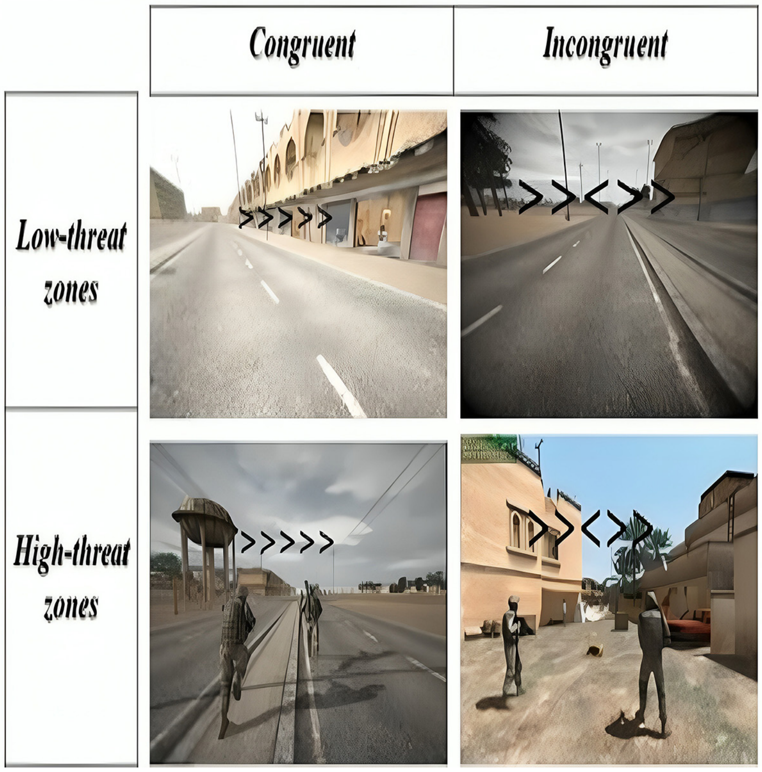

Figure 2: The figure illustrates the different trial types used in the flanker task, showcasing congruent and incongruent stimuli in both low-threat and high-threat zones.

spm/software/spm12), running on MATLAB 2016a. The data pre-processing phases contained the following: field map correction, co-registration of functional and anatomical scans, realignment, segmentation, normalization, and smoothing. Brain activation analysis involved first-level and second-level analyses. First-level maps were created for participants using a linear regression model with two event-related regressors (congruent and incongruent trials). Second-level analysis calculated similarities and differences in data, with activation maps derived from a fixed-effect general linear model [11]. The General Linear Model (GLM) serves as a robust technique for analyzing fMRI data, utilized to assess the variability of activity across various conditions. The GLM can accommodate both qualitative and quantitative independent variables and is represented through an equation that includes: predictors, parameters, and errors. We set *P*-value=0.05 and a minimum of 20 voxels to identify activated brain areas, reducing false positives.

Functional Connectivity

Functional connectivity modeling determines activated brain regions and mostly depends on interregional communication. It can also assess the relationships between regions and particular pathways in the cerebral cortex, as well as the temporal dependence of activation (causality) within brain regions [12]. In the current research, functional connectivity modeling was used to detect the connectivity patterns in the brain attention network while executing the attentional flanker task. Graph theory posits the brain as a sophisticated neuronal network made up of various nodes and edges, facilitating the examination of the topological arrangement of brain correlation networks. Th the overall and specific attributes of brain regions can be assessed based on the graph theory [13,14]. At this stage, fMRI functional analysis was performed to extract the brain attention network using the ROI-to-ROI (region of interest) function in the CONN toolbox. For two-way ROI-to-ROI analysis, False Discovery Rate (FDR) analysis was considered for different brain parts that are involved in attention processing, such as frontal eye field (FEF), Lateral Prefrontal Cortex (LPFC), Insular Cortex (IC), Superior Parietal Lobule (SPL), Anterior Cingulate Cortex (ACC), precuneus, and thalamus regions. General and regional brain characteristics for different ROIs were obtained using graph theory analysis and calculating the correlation coefficients and their FDR-corrected values with a significant *P*-value≤0.05.

Results

a) Behavioral Results

Mean response times were calculated for incongruent and congruent trials in military personnel and normal individuals. In high-threat zones, incongruent RT was 731.2±161.2 ms for the military and 801±99.2 ms for normal individuals; congruent RT was 627.6±146.5 ms for the military and 682.4±102.3 ms for normal individuals. In low-threat zones, incongruent RT was 711.9±253.8 ms for the military and 752±105.9 ms for normal individuals; congruent RT was 590.5±181.1 ms for the military and 644.3±109.1 ms for normal individuals. Figure 3 shows response time in behavioral assessments during the flanker conflict task.

The average errors in the incongruent conditions of the high- and low-threat zones, as well as in the simple mode of the flanker task were 96.32±6.43 and 97.01±5.02 for military personnel and 94.63±7.89 and 95.74±6.12 for normal individuals, respectively. In congruent trials, the average errors in the military group were 97.28±5.36 and 97.86±4.57, and 95.77±6.21 and 96.39±4.68 in normal

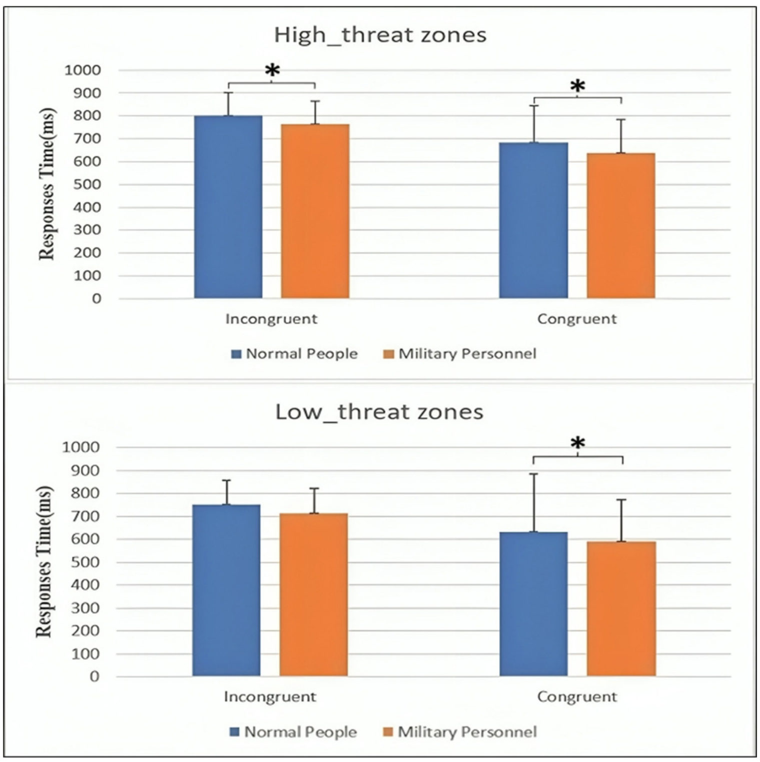

Figure 3: Behavioral response time during the conflict flanker task.

individuals,, respectively. Table 1 illustrates the findings of the flanker task related to behavior.

b) fMRI Data Analysis Result

The group analysis showed that in military personnel, the left Medial prefrontal cortex (N_{Vox}=301) is one of the brain areas with the highest activation during the incongruent trials in high-threat zones. Analysis of brain activation maps revealed that military personnel exhibited peak activity in the right medial frontal gyrus during low-threat zones (N_{Vox}=216). In contrast, normal individuals showed maximum activation in the left medial prefrontal cortex (N_{Vox}=238) and inferior frontal gyrus (N_{Vox}=208) during incongruent trials of the flanker task across varying threat levels. Table 2 shows cortical activations in the brain concerning the attention network under incongruent conditions across various trials of the flanker task, compared between the two participant groups.

Activation maps obtained from congruent trials showed that military personnel exhibited maximum activity in different brain regions under varying threat conditions. In high-threat zones, the left medial prefrontal cortex (N_{Vox}=227) displayed maximum activity, while in low-threat zones, the left superior frontal cortex (N_{Vox}=175) showed the highest activation. Figure 4 demonstrates maps of brain activation for the flanker task involving conflict. In normal individuals, brain activation patterns differed based on the perceived threat level during task performance. During high-threat zone tasks, the left superior frontal gyrus (N_{Vox}=191) showed the highest activation. Conversely, in low-threat zone tasks, the left medial prefrontal cortex (N_{Vox}=146) displayed maximum activity. Table 3 shows cortical activations linked to the attention network in the congruent condition during flanker task trials for both participant groups.

Functional Connectivity Analysis

In the military group, during incongruent mode in the high-threat zone part, the IC l region had a powerful functional connection to the IC r region and the IC l region to the thalamus left and right regions. In the normal group, the IC l region was functionally connected to IC r and the right thalamus. In the low- threat zone, in military personnel, the IC r was connected to the IC l, and in normal individuals, the SPL r had a more powerful functional connection to the SPL l. Figure 5 shows functional connectivity under incongruent conditions.

In military personnel and under incongruent conditions, connections between SPL l to AC and IC r to SPL r are shown to have the lowest connection power in high-threat zones tasks, as well as in normal individuals; they are shown to have the lowest connection power between Thalamus l to Precuneous and SPL r to IC r. In low-threat zones, military personnel and normal individuals have lesser connection power than in other regions, respectively in FEF l to LPFC l and thalamus l to AC. Functional analysis showed that military

Table 1: Behavioral results of flanker task. There were differences between conditions for accuracy ($P<0.05$).

	Task Trials	Military Personnel (mean±sd)	Normal Individuals (mean±sd)	*P*_value
Incongruent Conditions	High_threat zones	96.32±6.43	94.63±7.89	0.048
	Low_threat zones	97.01±5.02	95.74±6.12	0.037
Congruent Conditions	High_threat zones	97.28±5.36	95.77±6.21	0.042
	Low_threat zones	97.86±4.57	96.39±4.68	0.136

personnel during incongruent conditions have more functional brain connections between attention regions than normal individuals. Table 4 presents graph theory analysis of functional connectivity values for military and civilian individuals during incongruent flanker tasks in high and low threat zones).

In the congruent condition, both military personnel showed less number of connections between different brain regions than in the incongruent. In the high-threat zone, military personnel show the highest and lowest power of connections in IC l to IC r and SPL r to FEF l, and normal individuals show IC r to IC l and LPFC l to LPFC r, respectively. Figure 6 shows functional connectivity under congruent conditions. In the low-threat zone, military personnel and normal individuals show the highest connection power in IC r to IC l and lowest in AC to IC l (Table 5) illustrates Graph theory analysis of functional connectivity in military personnel and civilians during congruent flanker tasks in high- and low-threat zones).

Table 2: Brain cortical activations relative to attention network in incongruent condition during different trials of flanker task between the two groups of participants.

	Military Personnel			Normal Individuals		
	Contrast Map and Brain Region	Cluster Size	Analysis (z)	Contrast Map and Brain Region	Cluster Size	Analysis (z)
High_threat zones	L Medial PFC	301	5.2645	L Medial PFC	238	4.3093
	Cingulate Gyrus	83	3.4467	Cingulate Gyrus	64	3.9213
	Thalamus	54	3.4097	Thalamus	61	3.4787
	R Insular cortex	97	4.5653	R Insular cortex	89	4.2548
	L Insular cortex	71	5.1186	L Insular cortex	47	4.2605
	Parietal cortex	128	4.6234	Parietal cortex	119	3.7055
	L Superior frontal gyrus	251	4.1311	L Superior frontal gyrus	202	3.9551
	R Superior frontal gyrus	108	3.8324	R Superior frontal gyrus	126	3.9118
	L Middle Frontal Gyrus	167	4.8581	L Middle Frontal Gyrus	79	2.6816
	R Middle Frontal Gyrus	84	4.2567	R Middle Frontal Gyrus	33	3.8985
	L Superior Temporal Gyrus	45	-3.6236	L Superior Temporal Gyrus	-------	-------
	R Superior Temporal Gyrus	31	4.0256	R Superior Temporal Gyrus	-------	-------
	R Inferior Temporal Gyrus	-------	-------	R Inferior Temporal Gyrus	42	-2.7536
Low_threat zones	R Medial PFC	216	5.0205	R Medial PFC	176	4.949
	Cingulate Gyrus	51	4.6693	Cingulate Gyrus	-------	--------
	Thalamus	40	-2.4592	Thalamus	52	3.9215
	R Insular cortex	73	2.5131	R Insular cortex	60	-3.6361
	Parietal cortex	93	3.5743	Parietal cortex	81	3.875
	L Superior frontal gyrus	206	3.9558	L Superior frontal gyrus	208	3.8128
	R Superior frontal gyrus	121	3.4658	R Superior frontal gyrus	132	3.1342
	R Middle Frontal Gyrus	62	5.7288	R Middle Frontal Gyrus	41	3.4426
	R Middle Temporal Gyrus	33	2.3245	R Middle Temporal Gyrus	29	2.1425
	R Inferior Temporal Gyrus	37	-2.2175	R Inferior Temporal Gyrus	49	2.4865

PFC: Prefrontal Cortex

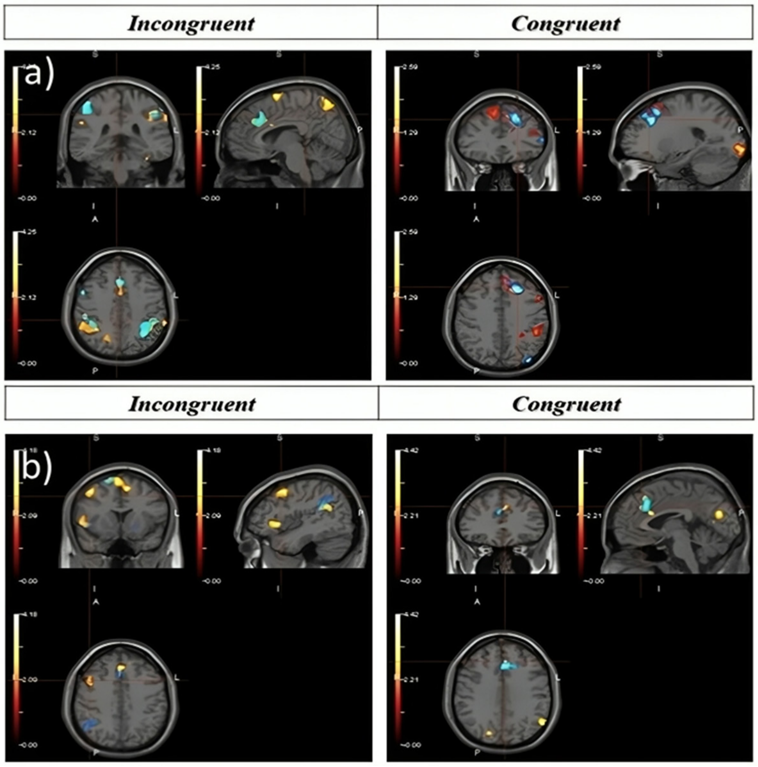

Figure 4: Brain activation maps for conflict flanker task. **a**) High-threat zones, **b**) low-threat zones. Brain activation maps displaying voxels with different blood oxygenation level dependent (BOLD) responses to cue incongruent trials (incongruent vs. congruent trials) in distinct regions of brain (Red indicates the brain activity of military personnel and blue indicates the brain activity of normal individuals).

Discussion

This study utilized a modified flanker fMRI task to identify brain regions linked to stimulus incongruency. A modified flanker task assessed brain activation related to motivation and stress. GLM analysis showed activation changes during the conflict task, while functional connectivity analyses revealed complex networks post-attention. The research aimed to evaluate functional brain process changes between military and civilian individuals during congruent and incongruent effects.

The flanker task serves as an effective tool for evaluating selective attention, as it measures the ability to concentrate, accuracy, and attentional response to stimuli within a short time [15]. Selective attention and attention maintenance in particular situations, particularly in military employees, and those who need a high rate of attention to execute their tasks are essential topics in military and psychological research [16,17]. The results of the present study showed that the response time and error rate in all three conditions (congruent and incongruent task) in the military is less than in normal individuals. A similar study by Robert et al. on fighter pilots and normal individuals found similar results. Accordingly, although there were differences in response speed between the two groups in all conditions except during incongruent tasks in low-threat zone conditions, like the current study, Robert showed that pilots were more accurate and more responsive [18]. In this study, the error rate was lower in military personnel, indicating a higher inhibitory response rate.

This means that it could be used to measure the ability to inhibit attention to related stimuli while ignoring irrelevant stimuli. Significant effects of stress were found on behavioral measures during the modified flanker task.

Also, results showed that the reaction time to incongruent conditions in both groups is higher than the congruent conditions, and this time is less in military personnel than in the control group. The diversity in RTs between incongruent and congruent trials is a measure of the ability to overcome cognitive conflicts. Incongruent and incongruent conditions, the medial prefrontal cortex, superior frontal gyrus, and middle frontal gyrus were mostly activated in military personnel in high- and low-threat zonesconditions. In normal individuals in high- and low-threat zones task, the medial PFC, insular cortex, and cingulate gyrus were the most activated, and our results are very similar to those of previous studies [19,20]. Military personnel exhibit significantly higher levels of selective attention in data analysis compared to civilians due to their precise and disciplined approach to tasks [21]. The findings of this study indicate that order and discipline in the military environment can improve selective attention. The results of the

Table 3: Brain cortical activations relative to attention network in congruent condition during different trials of flanker task between the two groups of participants.

	Military Personnel			**Normal People**		
	Contrast Map and Brain Region	**Cluster Size**	**Analysis (z)**	**Contrast Map and Brain Region**	**Cluster Size**	**Analysis (z)**
High_threat zones	L Medial PFC	227	4.9816	L Medial PFC	173	4.3215
	Cingulate Gyrus	60	3.9213	Cingulate Gyrus	54	2.8493
	Thalamus	41	3.0312	Thalamus	48	-2.5924
	L Insular cortex	58	3.6118	L Insular cortex	39	2.3499
	Parietal cortex	107	3.3055	Parietal cortex	97	3.3364
	L Superior frontal gyrus	198	3.9551	L Superior frontal gyrus	191	4.0221
	R Superior frontal gyrus	116	3.2605	R Superior frontal gyrus	106	3.5653
	L Middle Frontal Gyrus	97	4.8985	L Middle Frontal Gyrus	51	2.6327
	R Middle Frontal Gyrus	65	-2.8931	R Middle Frontal Gyrus	36	-2.3965
	R Middle Temporal Gyrus	24	-2.5912	R Middle Temporal Gyrus	-------	-------
	L Precentral Gyrus	37	2.7634	L Precentral Gyrus	-------	-------
Low_threat zones	L Medial PFC	152	4.1838	L Medial PFC	146	3.9196
	Cingulate Gyrus	43	2.9156	Cingulate Gyrus	48	-2.6909
	Thalamus	38	-2.519	Thalamus	31	2.4618
	L Insular cortex	44	3.0494	L Insular cortex	29	-2.3547
	Parietal cortex	89	3.2707	Parietal cortex	65	3.1157
	L Superior frontal gyrus	175	3.7765	L Superior frontal gyrus	127	3.4236
	R Superior frontal gyrus	91	3.4722	R Superior frontal gyrus	72	3.0494
	L Middle Frontal Gyrus	61	3.1139	L Middle Frontal Gyrus	42	2.8623
	R Middle Temporal Gyrus	72	3.2018	R Middle Temporal Gyrus	80	3.1057
	R Superior Temporal Gyrus	38	2.6257	R Superior Temporal Gyrus	-------	-------

PFC: Prefrontal Cortex

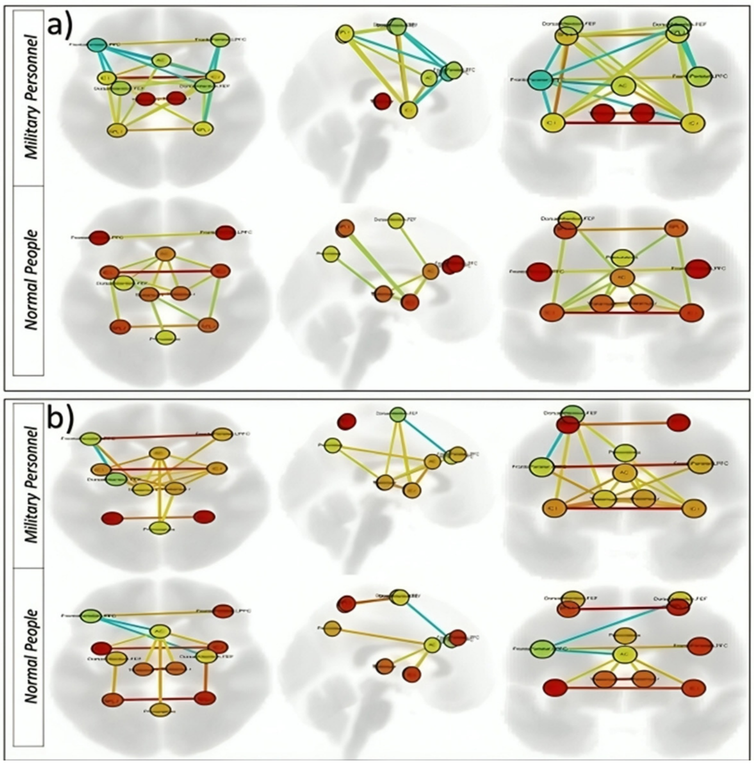

Figure 5: Functional connectivity in incongruent condition. **a**) High-threat zone, **b**) low-threat zone. There were more and powerful connections in military personnel than normal individuals.

present study were in line with and confirmed previous studies. The results of a study on athletes from interceptive and strategic sports indicated the main role of PFC and Inferior Frontal Gyrus (IFG) in selective attention processing [22].

The brain's medial and lateral frontal cortices play a crucial role in generating appropriate responses amidst conflicting options. Functional imaging research of the brain has consistently shown an increase in activity in the frontal areas during the performance of so-called "response conflict tasks" [23], but recent research suggests that different parts of the parietal lobule may be equally important [24].

Findings from earlier research and our investigation consistently indicate that the prefrontal cortex plays a crucial role in cognitive control, and it may also participate in conflict-related processes within the brain [20,25-28]. Investigating the connection changes between activated brain regions based on functional connectivity analysis in the military group during incongruent part has shown the most potent connection between the right IC and the left IC in high-threat and low-threat zones. In these areas, a stronger positive correlation with the default mode component was linked to increased overall activity induced by tasks. On the other hand, normal individuals were shown the strongest connection between the right IC and the left IC in the high-threat zone and between the right SPL and the left SPL in low-threat zones. Notably, the frontal and parietal areas, encompassing regions, such as the SPL, the FEF, and the IC, have shown consistent activation across different tasks that require spatially focused attention [20,24,29]. Various research indicates a

Table 4: Functional connectivity values calculated using graph theory analysis for military personnel and normal people during incongruent condition in high and low threat zones Flanker task.

	Military Personnel			Normal People		
	Functional connectivity	T	p.FDR	Functional connectivity	T	p.FDR
High_threat zones	IC r - IC l	13.90	0.0004	IC l-IC r	18.40	0.0000
	IC l -IC r	13.90	0.0004	IC r-IC l	18.40	0.0000
	IC l- Thalamus l	8.83	0.0017	Thalamus r-Thalamus l	13.77	0.0000
	Thalamus l- IC l	8.83	0.0034	Thalamus l-Thalamus r	13.77	0.0000
	Thalamus l-Thalamus r	7.97	0.0055	SPL r-SPL l	10.38	0.0000
	Thalamus r-Thalamus l	7.97	0.0055	SPL l-SPL r	10.38	0.0000
	IC r- AC	6.41	0.0075	LPFC l-LPFC r	6.37	0.0014
	SPL l-SPL r	7.40	0.0078	LPFC r-LPFC l	6.37	0.0014
	SPL r-SPL l	7.40	0.0078	Thalamus l-AC	5.43	0.0023
	AC- IC r	6.41	0.0079	Thalamus r-IC l	5.02	0.0029
	AC-IC r	-5.88	0.0079	Thalamus r-IC r	4.96	0.0029
	IC l -AC	5.79	0.0079	IC l-Thalamus r	5.02	0.0033
	AC- IC l	5.79	0.0079	IC l-AC	4.85	0.0033
	IC l- SPL r	4.56	0.0123	IC r-Thalamus r	4.96	0.0043
	IC l- SPL l	4.46	0.0123	AC-Thalamus l	5.43	0.0046
	IC l-IC r	-4.45	0.0123	AC-IC l	4.85	0.0050
	IC r-AC	-5.88	0.0134	IC l-SPL l	4.36	0.0050
	IC r-IC l	5.64	0.0134	AC-IC r	4.35	0.0068
	IC r-SPL l	4.78	0.0183	IC r-AC	4.35	0.0068
	IC l-Precuneous	3.63	0.0237	AC-Thalamus r	3.98	0.0088
	IC r-IC l	-4.45	0.0239	Thalamus r-AC	3.98	0.0088
	IC r-Precuneous	-3.82	0.0239	SPL l-IC l	4.36	0.0100
	IC l-Thalamus l	-3.79	0.0239	AC-FEF l	3.44	0.0162
	SPL l-IC r	4.78	0.0243	IC l-Thalamus l	3.37	0.0182
	SPL l-IC l	4.46	0.0243	IC r-SPL r	3.31	0.0248
	SPL l-Precuneous	3.96	0.0266	IC l-SPL r	3.01	0.0270
	SPL l-Thalamus l	3.84	0.0266	Thalamus l-IC l	3.37	0.0303
	Precuneous-SPL l	3.96	0.0332	Thalamus l-Precuneous	2.91	0.0477
	Precuneous-IC r	-3.82	0.0332	SPL r-IC r	3.31	0.0496
	Precuneous-IC l	3.63	0.0332	....	....	....
	SPL r-IC l	4.56	0.0333	....	....	....
	IC r-Thalamus l	3.25	0.0416	....	....	....
	SPL r-Precuneous	3.65	0.0430	....	....	....
	SPL l-AC	3.20	0.0439	....	....	....
	IC r-SPL r	3.01	0.0466	....	....	....

	Military Personnel			Normal People		
	Functional connectivity	T	p.FDR	Functional connectivity	T	p.FDR
Low_threat zones	IC r-IC l	9.34	0.0001	SPL r-SPL l	9.67	0.0001
	IC l-IC r	9.34	0.0001	SPL l-SPL r	9.67	0.0001
	LPFC l-LPFC r	8.30	0.0002	Thalamus r-Thalamus l	8.97	0.0001
	LPFC r-LPFC l	8.30	0.0002	Thalamus l-Thalamus r	8.97	0.0001
	SPL r-SPL l	6.30	0.0015	IC l-IC r	8.31	0.0002
	SPL l-SPL r	6.30	0.0015	IC r-IC l	8.31	0.0002
	IC l-Thalamus r	5.70	0.0016	SPL r-FEF r	6.75	0.0005
	IC l-Thalamus l	5.26	0.0019	FEF r-SPL r	6.75	0.0009
	Thalamus r-IC l	5.70	0.0019	SPL l-FEF l	4.44	0.0090
	Thalamus r-Thalamus l	5.56	0.0019	AC-Precuneous	4.58	0.0134
	Thalamus l-Thalamus r	5.56	0.0029	IC r-AC	4.17	0.0134
	Thalamus l-IC l	5.26	0.0029	AC-IC r	4.17	0.0134
	IC l-AC	4.74	0.0029	Precuneous-AC	4.58	0.0145
	Thalamus l-LPFC l	4.76	0.0038	LPFC l-LPFC r	4.57	0.0149
	Thalamus l-IC r	4.26	0.0050	LPFC r-LPFC l	4.57	0.0149
	Thalamus l-LPFC r	4.21	0.0050	FEF l-SPL l	4.44	0.0180
	LPFC l-Thalamus l	4.76	0.0057	AC-Thalamus r	3.50	0.0190
	Thalamus r-AC	4.35	0.0068	AC-LPFC l	-3.48	0.0190
	Thalamus r-IC r	4.06	0.0078	AC-Thalamus l	3.33	0.0193
	AC-IC l	4.74	0.0101	AC-IC l	3.21	0.0196
	AC-Thalamus r	4.35	0.0101	Thalamus r-AC	3.50	0.0369
	IC r-Thalamus l	4.26	0.0104	LPFC l-AC	-3.48	0.0379
	IC r-Thalamus r	4.06	0.0104	LPFC l-FEF r	-3.09	0.0478
	LPFC r-Thalamus l	4.21	0.0125	Thalamus l-AC	3.33	0.0482
	AC-Precuneous	3.84	0.0145	……….	…….	…….
	AC-IC r	3.65	0.0147	……….	…….	…….
	IC r-AC	3.65	0.0147	……….	…….	…….
	IC l-FEF l	3.30	0.0203	……….	…….	…….
	Thalamus r-Precuneous	3.22	0.0230	……….	…….	…….
	Thalamus l-FEF l	2.97	0.0269	……….	…….	…….
	Thalamus l-AC	2.92	0.0269	……….	…….	…….
	IC r-FEF l	3.05	0.0302	……….	…….	…….
	AC-Thalamus l	2.92	0.0377	……….	…….	…….
	FEF l-IC l	3.30	0.0430	……….	…….	…….
	FEF l-LPFC l	-3.13	0.0430	……….	…….	…….

FDR: False Discovery Rate, IC: Insular Cortex, AC: Anterior Cingulate, SPL: Superior Parietal Lobule, LPFC: Lateral Prefrontal Cortex, FEF: Frontal Eye Field

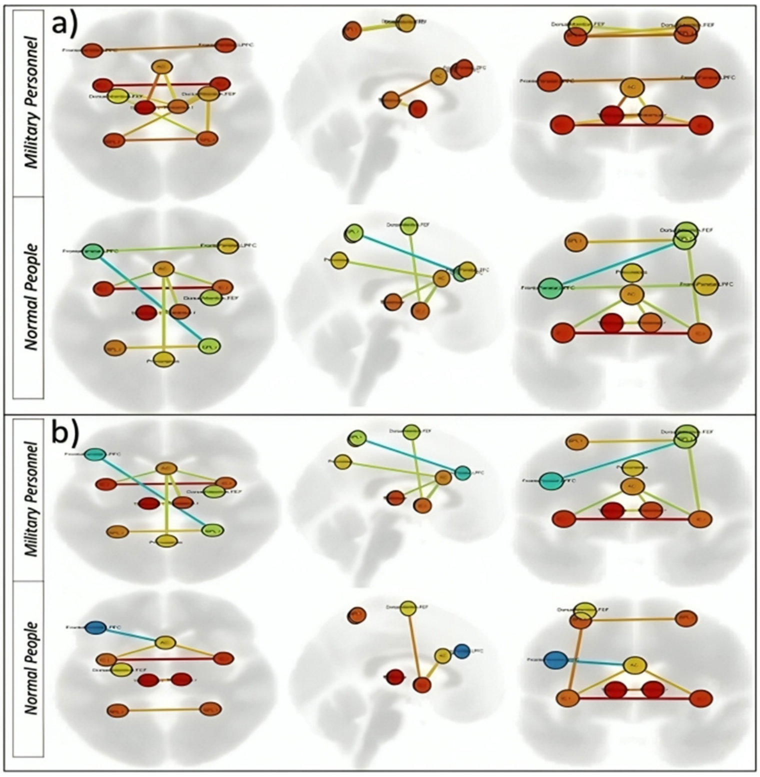

Figure 6: Functional connectivity analysis in congruent condition. **a**) High-threat zone, **b**) low-threat zone. There were more and powerful connections in military personnel than normal individuals.

frontoparietal network engaged in the processing of attention. Regions in the frontal and parietal lobes play a role in attentional regulation and processing during activities, implying that the mechanisms involved activate comparable neural systems.

The functional connectivity analysis revealed that military personnel exhibited more connections between brain regions involved in attention processing during most conditions of the modified flanker task compared to normal individuals. These connections suggest that military personnel engage more brain regions in attention processing, possibly due to stress effects, which may reflect the body's defense mechanisms. In high-threat zone trials, the number of connections was more significant than in low-threat zones, and in high-threat zones, the power of those connections was more significant than in low-threat zones in most conditions. They believed those brain networks are involved in achieving and maintaining the alert state [30]. Neuroimaging reveals overlapping neural networks for attention in adults, involving frontal and parietal areas [14].

In this study, we could distinguish between selective attention in military personnel and normal individuals using the flanker task model. The results showed that the response to the stimulus in military personnel was shorter than in normal individuals. On the other hand, brain areas were activated with a greater number and extent in military personnel than in normal individuals, showing that military personnel have higher mental readiness in response to attention stimuli than ordinary individuals.

Despite the endeavors, the current study had some limitations, as follows: 1) while the study provides valuable insights into attentional

Table 5: Functional connectivity values calculated using graph theory analysis for military personnel and normal people during congruent condition in high and low threat zones Flanker task.

	Military Personnel			Normal People		
	Functional connectivity	T	p.FDR	Functional connectivity	T	p.FDR
High_threat zones	IC l-IC r	10.08	0.0000	IC r-IC l	10.89	0.0001
	IC r-IC l	10.08	0.0000	IC l-IC r	10.89	0.0001
	Thalamus l-Thalamus r	7.41	0.0002	SPL r-SPL l	8.87	0.0033
	Thalamus l-AC	7.41	0.0002	SPL l-SPL r	8.87	0.0033
	SPL l-SPL r	7.77	0.0003	SPL r-LPFC l	-6.44	0.0074
	SPL r-SPL l	7.77	0.0003	LPFC l-SPL r	-6.44	0.0148
	Thalamus r-Thalamus l	7.41	0.0004	Thalamus r-Thalamus l	6.06	0.0195
	AC-Thalamus l	7.41	0.0004	Thalamus l-Thalamus r	6.06	0.0195
	LPFC l-LPFC r	7.07	0.0006	IC r-AC	4.04	0.0373
	LPFC r-LPFC l	7.07	0.0006	IC r-FEF r	4.01	0.0373
	SPL l-FEF r	4.98	0.0042	AC-Precuneous	4.44	0.0408
	FEF r-SPL l	4.98	0.0071	AC-IC r	4.04	0.0408
	FEF r-SPL r	4.60	0.0071	AC-Thalamus r	3.92	0.0408
	SPL r-FEF r	4.60	0.0071	AC-IC l	3.61	0.0408
	Thalamus r-IC r	4.36	0.0100	Thalamus r-AC	3.92	0.0412
	IC r-Thalamus r	4.36	0.0100	LPFC l-LPFC r	3.88	0.0412
	Thalamus r-IC l	3.81	0.0153	……….	…….	…….
	Thalamus r-AC	3.61	0.0154	……….	…….	…….
	IC l-Thalamus r	3.81	0.0229	……….	…….	…….
	AC-Thalamus r	3.61	0.0309	……….	…….	…….
	SPL r-FEF l	3.25	0.0369	……….	…….	…….
Low_threat zones	IC r-IC l	11.90	0.0001	IC r-IC l	9.78	0.0004
	IC l-IC r	11.90	0.0001	IC l-IC r	9.78	0.0004
	SPL r-SPL l	8.87	0.0033	IC l-FEF l	8.83	0.0017
	SPL l-SPL r	8.87	0.0033	FEF l-IC l	8.83	0.0034
	SPL r-IC r	-6.44	0.0074	Thalamus l-Thalamus r	7.97	0.0055
	IC r-SPL r	-6.44	0.0148	Thalamus r-Thalamus l	7.97	0.0055
	Thalamus r-Thalamus l	6.06	0.0195	IC r-AC	6.41	0.0075
	Thalamus l-Thalamus r	6.06	0.0195	SPL l-SPL r	7.40	0.0078
	IC r-AC	4.04	0.0373	SPL r -SPL l	7.40	0.0078
	IC-Precuneous	4.01	0.0373	AC-IC r	6.41	0.0079
	AC-Precuneous	4.44	0.0408	AC-LPFC l	-5.88	0.0079
	AC-IC r	4.04	0.0408	IC l-AC	5.79	0.0079
	AC-Thalamus r	3.92	0.0408	AC-IC l	5.79	0.0079
	AC-IC l	3.61	0.0422	……….	…….	…….

FDR: False Discovery Rate, IC: Insular Cortex, AC: Anterior Cingulate, SPL: Superior Parietal Lobule, LPFC: Lateral Prefrontal Cortex, FEF: Frontal Eye Field control during modified visual flanker stimuli, the relatively small sample size of 40 healthy men limits the generalizability of the findings to the broader population and 2) the exclusive use of military personnel may introduce biases due to their unique characteristics and experiences. Future studies with larger and more diverse samples could help to address these limitations and enhance the robustness of the conclusions. It is recommended that a broader age range and a larger sample size be employed to improve future studies. The study's findings may apply to other high-stress professions, such as firefighters and nurses. Future research could compare these groups to better understand the effects of stress across different occupations. Also, a longitudinal study in the future could offer additional insights into the long-term implications of this training.

Conclusion

Military environments affect personnel's physical and cognitive performance, increasing human error due to stress. Research utilizing GLM and functional connectivity analyzed brain networks during the flanker task, revealing distinct neural connectivity patterns in attention processing. Increased activity in the frontal cortex and parietal lobule was observed, with different brain activation maps for congruent and incongruent trials. This study demonstrates the potential of fMRI as a tool to assess military readiness and recommends further research on cognitive tasks, especially those involving female participants, to deepen our understanding of selective attention in military personnel.

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Authors' Contribution

M. Jalalvandi conceived the idea. Introduction of the paper was written by H. Sharini, E. Rajeyan, and M. Jalalvandi. Sh. Faraji and E. Rajeyan gathered the images and the related literature. The method implementation was carried out by H. Sharini, A. Faramarzi, M. Ahmadi, and M. Jalalvandi. Results and Analysis was carried out by Sh. Faraji and M. Jalalvandi. The manuscript was revised by M. Jalalvandi, H. Sharini, and M. Ahmadi. All the authors read, modified, and approved the final version of the manuscript.

Ethical Approval

The protocol of the human study was approved by the Local Ethics Committee of AJA University of Medical Sciences (approval number: IR.AJAUMS.REC.1398.258).

Informed Consent

All experimental methods were performed in accordance with the Declaration of Helsinki; participants provided written informed consent.

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Conflict of Interest

None

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

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