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Modulation of stress and neuroplasticity biomarkers via rhythmic vocalization: a controlled study on NDNF, cortisol, and monoamines

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Abstract

Background The aim of this study is to investigate the effect of reciting the Quran (from Mushaf) on serotonin, dopamine, NDNF, and cortisol levels in relation to mental well-being.

Methods This study was conducted on a sample of university students who know how to read the Quran in Türkiye, selected by a non-probability method, with a pre-test-post-test control group and a longitudinal design; the assignment to the groups was also done randomly. The research was carried out with 72 university students (36 female, 36 male), aged 19–30, who know how to read the Quran and do not have any health problems. Two groups were formed: a 36-person experimental group and a 36-person passive resting control group. The Mental Well-Being Scale and a personal information form were used to evaluate the participants' well-being status. Salivary serotonin, dopamine, NDNF, and cortisol levels were examined using the ELISA technique in samples taken before and after the experimental group recited verses 195–200 of Surah Al-i Imran aloud. Number, percentage, mean, Pearson correlation, and ANOVA tests were used to evaluate the data. Statistical significance was accepted as $p < .05$ for all analyses.

Results A significant group-time interaction was found ($p < .05$). Compared to the passive resting control group, the experimental group showed statistically significant increases in salivary serotonin, dopamine, and NDNF levels, and a significant decrease in cortisol levels. However, a critical dissociation was observed: despite this neuroprotective biomarker profile, the control group reported statistically significantly higher post-intervention mental well-being scores than the experimental group ($p < .05$). This suggests that the acute cognitive load and performance anxiety associated with the recitation task may temporarily mask physiological benefits in self-reports.

Conclusions A brief (5-minute) 'Tartil' recitation of the Quran demonstrates immediate, positive neurobiological effects by reducing stress hormones (cortisol) and increasing reward- and neuroplasticity-related biomarkers (dopamine, serotonin, NDNF). However, this did not immediately translate to higher self-reported well-being, suggesting the relationship between the neurobiology of recitation and its perceived psychological effects is complex and potentially confounded by factors such as performance anxiety or cognitive load in an experimental setting.

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Clinical trial number Not applicable.

Highlights

- A 5-minute 'Tartil' (rhythmic) recitation of the Quran significantly increased salivary NDNF, serotonin, and dopamine levels compared to a 5-minute passive resting control.
- Recitation significantly decreased salivary cortisol (stress hormone) levels, while the control group's levels remained stable.
- While neurochemical changes correlated with well-being as expected, the recitation group unexpectedly reported lower mental well-being scores post-intervention than the control group.
- Findings suggest recitation has immediate, positive neurobiological effects, but its short-term psychological impact on well-being is complex, possibly due to performance anxiety or cognitive load.

Keywords Neuron-Derived Neurotrophic Factor (NDNF), Serotonin, Dopamine, Cortisol hormone, Reading, Quran, Mental well-being

Introduction

Islam is a body of beliefs and practices that guides the lives of millions of people worldwide. The fundamental practices of Islam can enrich individuals' spiritual lives and may also have positive effects on their mental and physical health [1]. Among these practices, reciting the Quran holds an important place, and it is considered both a religious duty and a source of spiritual healing for Muslims [2]. The unique rhythm, sound, and depth of meaning of the Quran create a calming, peaceful, and spiritual atmosphere for readers and listeners [3]. This leads to positive emotional states such as reducing stress, providing inner peace and increasing mental well-being [4]. Modern psychology and neuroscience research has begun to examine the effects of spiritual practices and religious rituals on brain chemistry [5–8].

Building on this neurotheological foundation, the present study posits that the act of reciting the Quran (specifically, "aloud, slowly, and audibly from the Mushaf" as performed in this intervention) is more than a passive spiritual observation; it is a complex 'mind-body' intervention that activates specific neurobiological pathways. We hypothesize that this intervention comprises three core components: (1) Rhythmic Respiration and Vocalization (inherent in 'Tajwid' recitation); (2) Focused Cognitive Attention (concentration on a complex, sacred text); and (3) Affective-Spiritual Connection (the rewarding relationship with the content). These components are expected to directly influence the neurochemicals detailed below.

Serotonin (5-HT or 5-hydroxytryptamine) is a neurotransmitter that gives people a sense of happiness, vitality and vitality. Known as the happiness hormone, serotonin has an effect on mood, sleep, appetite and mental well-being. It also plays a role in functions such as mood, sleep, appetite, learning and memory by providing communication between neurons in the brain [9]. Low serotonin levels are thought to be associated with depression, anxiety, and other mental health problems

[10]. Critically, serotonin levels do not operate in isolation; they are closely interconnected with both the stress (cortisol) and reward (dopamine) systems. The serotonergic system extensively modulates the [11], and conversely, high cortisol levels can impact serotonin function. Similarly, there is a dense and complex interaction between the serotonin and dopamine pathways, where 5-HT signaling directly regulates dopamine release [12]. We therefore expect that the combined effect of reduced stress (lower cortisol, supporting H1) and increased spiritual reward (higher dopamine, supporting H2) will positively modulate the serotonergic system, promoting an increase in serotonin levels.

Dopamine is a neurotransmitter that plays a role in many body functions such as memory, mood, motivation, attention and reward, movement control, learning, memory, attention and arousal [13–16]. Since dopamine has different functions in different areas of the brain, its deficiency or dysfunction leads to various neurological and psychiatric diseases. The basis of these diseases is the insufficiency or imbalance of dopamine, especially in certain brain areas (nigrostriatal pathway, mesolimbic pathway, etc.) [16]. Beyond relaxation, recitation is also an 'affectively rewarding' and 'meaningful' spiritual act (Component 3). The fulfillment of a sacred duty, the achievement of a spiritual goal, or the feeling of 'connection' to the text has the potential to activate the brain's mesolimbic reward pathway. Indeed, neurotheological studies using fMRI have demonstrated that intense religious and spiritual experiences, such as prayer or scripture reading, are reproducibly associated with activation in core reward-processing regions of the brain, including the Nucleus Accumbens and Caudate Nucleus [17]–[18]. As dopamine is the principal neurotransmitter of this pathway, playing a key role in motivation, reward, and mood, we predict that the spiritual satisfaction derived from recitation will lead to an increase in dopamine levels.

Stress is an emotional, mental and physical reaction caused by anxiety that occurs as a result of an event or thought that occurs momentarily, makes the person feel in danger or requires struggle. It can cause fluctuations in emotional state [19]. Stress is a factor that can negatively affect cognitive development and memory functions and Neurotrophic factor levels [20]. Cortisol is a steroid hormone produced in the cortex region of the adrenal glands and is also known as the “stress hormone” [21]. However, as well as its relationship with stress, it also has important roles in many vital functions such as the body’s energy metabolism, blood sugar regulation, immune system, inflammatory processes and blood pressure control [22]. It also plays an important role in cognitive functions such as memory formation and recall [23]. Abnormalities in cortisol levels can disrupt the body’s delicate balance and lead to various health problems [22, 24–26]. The effect of Quranic recitation on the ‘stress response’ is a primary focus of this study. The rhythmic respiration and vocalization required by recitation (Component 1) are known to trigger the ‘relaxation response’. We hypothesize that this action shifts the autonomic nervous system (ANS) from a sympathetic (stress) state toward a parasympathetic (PSS; ‘rest and digest’) state. PSS activation, in turn, is expected to directly inhibit the release of cortisol, the primary output of the HPA (stress) axis.

NDNF (Neuron-Derived Neurotrophic Factor); is a protein that has a development, differentiation, synaptic plasticity and neuroprotective effect of neurons [27–29]. Finally, the act of reciting the Quran aloud from the Mushaf is a highly ‘cognitively demanding’ task (Component 2). It requires sustained attention, complex visual-linguistic processing (decoding Arabic script), and memory retrieval (recalling ‘Tajwid’ rules). Such intensive cognitive efforts, similar to those engaged during sustained mindfulness meditation, are known to stimulate neuroplasticity and induce structural changes in the brain [5, 8]. We hypothesize that this sustained cognitive engagement will promote the release of neurotrophic factors, such as NDNF, which support neuronal health and synaptic plasticity. The existing gap in the literature is not only the lack of study on these specific variables but the absence of a theoretical framework explaining why Quran recitation should affect them.

To strictly isolate the specific neurobiological effects of the recitation intervention (which involves vocalization, cognitive effort, and breath control), a ‘passive resting’ condition was selected as the control. This selection aims to establish a physiological baseline free from the confounds of alternative cognitive tasks or physical exertion, allowing for a clear comparison between the ‘active’ intervention and the body’s homeostatic state.

This study aims to fill this gap by testing the neurotheological model detailed above. The proposed

neurotheological framework illustrating the interaction between the intervention components, biological markers, and psychological outcomes is presented in Fig. 1. Based on this theoretical framework, we established the following specific hypotheses: H1: The Quran recitation intervention (experimental group) will activate the ‘relaxation response’, leading to a statistically significant decrease in salivary cortisol levels compared to the passive resting control group. H2: The spiritually ‘rewarding’ nature of the recitation (Component 3) will stimulate the mesolimbic pathway, resulting in a significant increase in salivary dopamine levels. H3: The intensive ‘cognitive engagement’ (Component 2) required for recitation will promote neural activity, leading to a significant increase in NDNF levels. H4: As a combined effect of reduced stress (H1) and increased reward (H2), we predict a significant increase in mood-associated serotonin levels. H5: We further hypothesize that these neurochemical changes (lower cortisol, higher dopamine/serotonin/NDNF) will be positively correlated with the participants’ self-reported scores on The Mental Well-Being Scale.

Methods

Participants and procedures

Participants and Procedures The current study was conducted on 72 students aged 19–30, studying at Bayburt University, who volunteered to participate in the study and knew how to read the Quran. Two groups were formed, 1 experimental group and 1 control group, each consisting of 36 individuals. The sample size ($n=72$) was determined using G*Power 3.1.9.7 based on a 95% confidence interval, 5% margin of error, and 80% power. Saliva samples were collected from the participants to determine Serotonin, Dopamine, NDNF, and Cortisol Hormone levels. To assess subjective psychological outcomes, The Warwick-Edinburgh Mental Well-being Scale (WEMWBS) was administered to all participants immediately after the intervention (post-test).

In the study, which included a total of 72 participants (36 women, 36 men) who knew how to read the Quran, the participants were randomly assigned to the groups. Both interventions were conducted in an isolated, quiet room to minimize distractions and were matched for duration (5 minutes). The Experimental Group ($n=36$) was instructed to recite verses 195–200 of Surah Al-i Imran from a Mushaf (a physical, bound copy of the Quran) aloud, clearly, and in the manner of ‘Tartil’ (slow, measured, and rhythmic recitation) for this fixed 5-minute duration. The Passive Resting Control Group ($n=36$) served as the baseline condition. Participants in this group were instructed to sit comfortably in a silence, isolated room and rest with their eyes closed for the fixed 5-minute duration, avoiding any sleep, vocalization, or specific cognitive tasks. Ethical committee approval

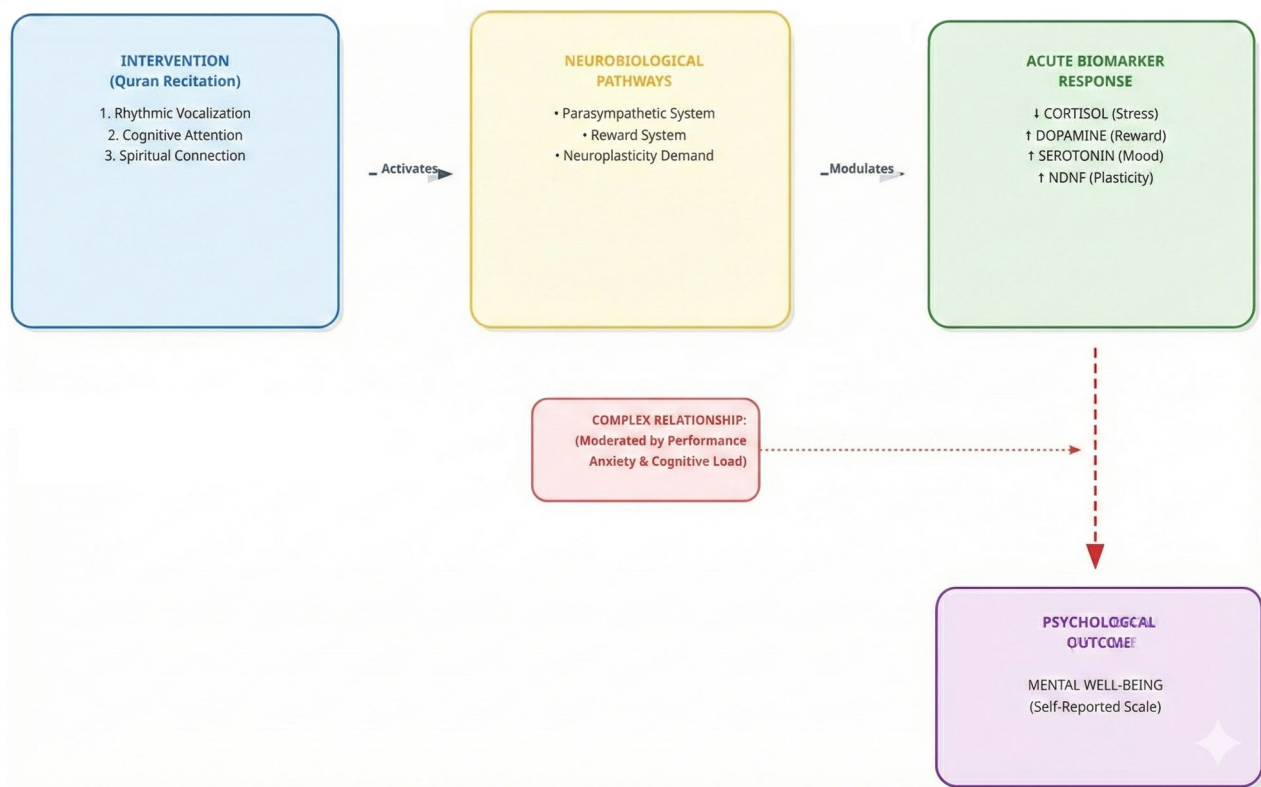


Fig. 1 The proposed Neurotheological Model of Quran Recitation. The model illustrates how the three core components of recitation (Rhythmic Vocalization, Cognitive Attention, Spiritual Connection) activate specific neurobiological pathways, leading to the observed acute changes in biomarkers. The dashed arrows indicate a complex relationship with self-reported well-being, likely moderated by performance anxiety and cognitive load

(07.01.2025/Decision no: 25) and institutional permission were obtained before the study. All participants were informed in writing and gave their consent in accordance with the Declaration of Helsinki.

Measures

Personal information form and mental well-being scale were collected through face-to-face interviews. To investigate serotonin, dopamine, NDNF, and cortisol hormone levels, saliva samples were taken between 08:00 and 09:00 in the morning using the passive saliva method into salivette tubes, before and after reading from the experimental group, and before and after resting from the control group, using the pre-test - post-test method. Participants were instructed not to consume any liquids or food for one hour before the samples were taken, not to brush their teeth, and not to consume foods rich in tryptophan (e.g., red meat, eggs, fish, nuts, seeds, and yogurt). After the samples were collected, they were centrifuged at 2000 g for 20 min in a refrigerated centrifuge (NF 1200R, Turkey) and then stored at -80 °C until analysis.

Measurement of Serotonin, Dopamine, NDNF and Cortisol Hormone levels in salivary: All hormone and neurotransmitter levels were measured using human-specific Sandwich ELISA kits from SinoGeneclon (CHINA). The

specific kits, catalog numbers, and their manufacturer-reported assay sensitivities were:

Human Serotonin (ST) Elisa Kit (Cat.No SG-11400; Sensitivity: 0.6 ng/ml)
Human Dopamine (DA) Elisa Kit (Cat.No SG-11575; Sensitivity: 0.8 pg/ml)
Human Neuron-Derived Neurotrophic Factor (NDNF) Elisa Kit (Cat.No SG-16752; Sensitivity: 25 pg/ml)
Human Cortisol Elisa Kit (Cat.No SG-00111; Sensitivity: 0.02 ug/L)

The study was carried out in accordance with the procedure specified in the manufacturer's catalog, meeting the quality control standards of an intra-assay coefficient of <8.0% and an inter-assay coefficient of <10.0%. The results were evaluated by reading the absorbance values at 450 nm in accordance with the kit procedures."

Mental well-being scale The Warwick-Edinburgh Mental Well-Being Scale, developed by Tennant et al., was adapted into Turkish by Ayşe Sibel Demirtaş and Kemal Baytemir [30]. The scale, consisting of 7 items, has a 5-point Likert-type rating and is unidimensional. It offers

Table 1 Salivary NDNF levels of the study groups and statistical comparisons

Vari-ables	n	NDNF (%) (Before)	NDNF (After)	Group-Time
Experimental Group	36	1106 ± 504 ↓	1359 ± 585 ↓	$p < .000^*$ F (1,70) = 117.051 $p < .000^*$
Control Group	36	1099 ± 466 ↓	1106 ± 484 ↓	$p > .505$
		F (1,70) = 0.004 $p < .948$	F (1,70) = 3.962 $p < .050^*$	

Note: Data presented as Mean ± Standard Deviation in pg/ml. Experimental Group: Quran recitation group (n=36). Control Group: Passive resting control group (n=36). Interaction Effect (Time × Group): F(1, 70) = 117.051, $p < .000^*$ Group Main Effect (Post-test): F(1, 70) = 3.962, $p < .050^*$

* $p < .05$, Repeated measures two-factor analysis of variance

answers for each item as “(1) never”, “(2) rarely”, “(3) sometimes”, “(4) often” and “(5) always”. The Cronbach's alpha reliability coefficients were calculated as 0.840 and 0.860 by the researchers. In this study sample, the KMO and Bartlett's Test value was found to be 0.728, and the Cronbach's alpha reliability coefficient was found to be 0.727. In addition, the skewness value was found to be 0.142 and the kurtosis value was found to be - 0.849, and it was decided that the data had a normal distribution.

Data analysis

Statistical analyses were performed using the SPSS software package. Numerical data were presented as mean ± and standard deviation (SD). Repeated measures two-way analysis of variance was used to compare the two groups. Pearson correlation test was used in the correlation analysis between the parameters. All analyses

were performed at a 95% confidence interval, and a p -value < 0.05 was considered statistically significant.

Results

Table 1 shows the mean salivary NDNF levels of the groups. A statistically significant difference ($F(1,70) = 3.962$, $p < .050$) was found between the study groups in the mean salivary NDNF levels after the reading and resting intervention. Before reciting verses 195–200 of Surah Al-i Imran, the mean salivary NDNF level was 1106 pg/ml in the experimental group and 1099 pg/ml in the control group. After reciting verses 195–200 of Surah Al-i Imran, the mean salivary NDNF level was 1359 pg/ml in the experimental group, and 1106 pg/ml in the control group after the resting intervention. In addition, the group-time interaction was also found to be significant $F(1,70) = 117.051$ $p < .000$ (Table 1). Table 2 shows the mean salivary NDNF levels of the groups by gender. While the mean NDNF level before reading was 1094 pg/ml in women in the experimental group, the mean NDNF level after reading was found to be 1333 pg/ml. While the mean NDNF level before reading was 1119 pg/ml in men in the experimental group, the mean NDNF level after reading was found to be 1384 pg/ml. While the pre-resting NDNF level was 1136 pg/ml in women in the control group, the mean NDNF level after resting was 1157 pg/ml; while the pre-resting NDNF level was 1062 pg/ml in men, the mean NDNF level after resting was found to be 1056 pg/ml. According to the results of the three-way mixed ANOVA; The main effect of both groups' general NDNF average and groups on NDNF levels was significant $p < .05$, but the effect of gender on NDNF and the gender-group interaction of NDNF measurements were not significant $p > .05$ (Table 2).

Table 2 Salivary NDNF levels and statistical comparisons of study groups according to gender, group and time factors

	n (%)	Time	Time Group	Time Sex	Time-Sex Group
Experimental Group	Female	Before	1094 ± 517		
		After	1333 ± 613		
	Male	Before	1119 ± 506		
		After	1384 ± 537		
			$p < .000^*$	$p < .000^*$	$p > .983$
Control Group	Female	Before	1136 ± 476		
		After	1157 ± 506		
	Male	Before	1062 ± 465		
		After	1056 ± 470		

Note: Data presented as Mean ± Standard Deviation in pg/ml. Experimental Group: Quran recitation group (n=36). Control Group: Passive resting control group (n=36). Main Effect (Time): $p < .000^*$ Interaction Effect (Time × Group): $p < .000^*$ Interaction Effect (Time × Sex): $p > .983$ Interaction Effect (Time × Sex × Group): $p > .262$

* $p < .05$, Three-way mixed model ANOVA

Table 3 Salivary serotonin levels of the study groups and statistical comparisons

Variables	n	Serotonin (%)	Serotonin (Before)	Serotonin (After)	Group-Time
Experimental Group	36	4.829 ± 0.664 ↓	5.509 ± 0.526	$p < .000^*$	F (1,70) = 6.521 $p < .013^*$
Control Group	36	4.599 ± 0.518 ↓	4.772 ± 0.749	$p > .301$	
		F (1,70) = 2.632 $p < .109$	F (1,70) = 23.284 $p < .000^*$		

Note: Data presented as Mean ± Standard Deviation in ng/ml. Experimental Group: Quran recitation group (n=36). Control Group: Passive resting control group (n=36). Interaction Effect (Time × Group): F(1, 70) = 6.521, $p = .013^*$ Group Main Effect (Post-test): F(1, 70) = 23.284, $p < .000^*$

* $p < .05$, Repeated measures two-factor analysis of variance

Table 3 shows the mean serotonin levels of the groups. A statistically significant difference (F(1,70) = 23.284, $p < .000$) was found between the study groups in mean serotonin levels after the reading and resting intervention. Before reciting verses 195–200 of Surah Al-i Imran, the mean serotonin level was 4.82 ng/ml in the experimental group and 4.59 ng/ml in the control group. After

reciting verses 195–200 of Surah Al-i Imran, the mean serotonin level was 5.50 ng/ml in the experimental group, and 4.77 ng/ml in the control group after the resting intervention. In addition, the group-time interaction was also found to be significant F (1,70) = 6.521 $p < .013$ (Table 3). Table 4 shows the mean serotonin levels of the groups by gender. While the mean serotonin level before reading was 5.10 ng/ml in women in the experimental group, it was found to be 5.49 ng/ml after reading. While the mean serotonin level before reading was 4.55 ng/ml in men in the experimental group, it was found to be 5.52 ng/ml after reading. While the pre-resting serotonin level was 4.69 ng/ml in women in the control group, it was 5.03 ng/ml after resting, and the pre-resting serotonin level was 4.50 ng/ml in men, it was found to be 4.51 ng/ml after resting. According to the results of the three-way mixed ANOVA; The main effect of both groups' general serotonin average, the groups on serotonin levels, and the time-gender-group interaction for serotonin were significant $p < .05$, but the gender-time interaction was not significant $p > .05$ (Table 4).

Table 5 shows the mean dopamine levels of the groups. A statistically significant difference (F(1,70) = 104.391,

Table 4 Salivary serotonin levels and statistical comparisons of study groups according to gender, group and time factors

	n (%)	Time	Time Group	Time Sex	Time-Sex Group
Experimental Group	Female	Before	5.101 ± 0.607		
		After	5.497 ± 0.548		
	Male	Before	4.552 ± 0.615		
		After	5.521 ± 0.520		
			$p < .000^*$	$p < .011^*$	$p > .517$
Control Group	Female	Before	4.696 ± 0.456		
		After	5.030 ± 0.636		
	Male	Before	4.501 ± 0.569		
		After	4.515 ± 0.781		

Note: Data presented as Mean ± Standard Deviation in ng/ml. Experimental Group: Quran recitation group (n=36). Control Group: Passive resting control group (n=36). Main Effect (Time): $p < .000^*$ Interaction Effect (Time × Group): $p = .011^*$ Interaction Effect (Time × Sex): $p > .517$ Interaction Effect (Time × Sex × Group): $p = .024^*$

* $p < .05$, Three-way mixed model ANOVA

Table 5 Salivary dopamine levels of the study groups and statistical comparisons

Variables	n (%)	Dopamine (Before)	Dopamine (After)	Group-Time
Experimental Group	36	7559 ± 983 ↓	8583 ± 903 ↓	$p < .000^*$
Control Group	36	6405 ± 839 ↓	6720 ± 616 ↓	$p > .031^*$
		F (1,70) = 28.673 $p < .000^*$	F (1,70) = 104.391 $p < .000^*$	

Note: Data presented as Mean ± Standard Deviation in pg/ml. Experimental Group: Quran recitation group (n=36). Control Group: Passive resting control group (n=36). Interaction Effect (Time × Group): F(1, 70) = 12.074, $p < .001^*$ Group Main Effect (Post-test): F(1, 70) = 104.391, $p < .000^*$

* $p < .05$, Repeated measures two-factor analysis of variance

Table 6 Salivary dopamine levels and statistical comparisons of study groups according to gender, group and time factors

		<i>n</i> (%)		Time	Time Group	Time Sex	Time-Sex Group
Experimental Group	Female	18	Before	7769 ± 854			
			After	8.643 ± 0.991			
	Male	18	Before	7348 ± 1080			
			After	8522 ± 830			
Control Group	Female	18	Before	6750 ± 622	<i>p</i> < .000*	<i>p</i> < .001*	<i>p</i> > .082
			After	6857 ± 694			<i>p</i> > .778
	Male	18	Before	6060 ± 900			
			After	6582 ± 511			

Note: Data presented as Mean ± Standard Deviation in pg/ml. Experimental Group: Quran recitation group (*n* = 36). Control Group: Passive resting control group (*n* = 36). Main Effect (Time): *p* < .000* Interaction Effect (Time × Group): *p* < .001* Interaction Effect (Time × Sex): *p* > .082 Interaction Effect (Time × Sex × Group): *p* > .778

* *p* < .05, Three-way mixed model ANOVA

Table 7 Salivary cortisol levels of the study groups and statistical comparisons

Vari-ables	<i>n</i>	Cortisol (%)	Cortisol (Before)	Cortisol (After)	Group-Time
Experi-mental Group	36	2.015 ± 0.147	↓	1.851 ± 0.161	<i>p</i> < .000* F (1,70) = 70.000
Control Group	36	2.012 ± 0.141	↓	2.155 ± 0.182	<i>p</i> > .031*
		F	F		
		(1,70) = 0.007	(1,70) = 55.940		
		<i>p</i> < .932	<i>p</i> < .000*		

Note: Data presented as Mean ± Standard Deviation in ng/ml. Experimental Group: Quran recitation group (*n* = 36). Control Group: Passive resting control group (*n* = 36). Interaction Effect (Time × Group): F(1, 70) = 70.000, *p* < .000* Group Main Effect (Post-test): F(1, 70) = 55.940, *p* < .000*

* *p* < .05, Repeated measures two-factor analysis of variance

p < .000) was found between the study groups in mean dopamine levels after the reading and resting intervention. Before reciting verses 195–200 of Surah Al-i Imran, the mean dopamine level was 7559 pg/ml in the experimental group and 6405 pg/ml in the control group. After reciting verses 195–200 of Surah Al-i Imran, the mean dopamine level was 8583 pg/ml in the experimental group, and 6720 pg/ml in the control group after the resting intervention. In addition, the group-time interaction was also found to be significant F (1,70) = 12.074 *p* < .001 (Table 5). Table 6 shows the mean dopamine levels of the groups by gender. While the mean dopamine level before reading was 7769 pg/ml in women in the experimental group, it was found to be 8643 pg/ml after reading. While the mean dopamine level before reading was 7348 pg/ml in men in the experimental group, it was found to be 8522 pg/ml after reading. While the pre-resting dopamine level was 6750 pg/ml in women in the control

group, it was 6857 pg/ml after resting, while the pre-resting dopamine level was 6060 pg/ml in men, it was found to be 6582 pg/ml after resting. According to the results of the three-way mixed ANOVA; The main effect of both groups' general dopamine average and groups on dopamine levels was significant *p* < .050, but the interaction of time-dependent dopamine measurements with gender and gender-group interaction were not significant *p* > .05 (Table 6).

Table 7 shows the mean cortisol levels of the groups. A statistically significant difference (F (1,70) = 55.940, *p* < .000) was found between the study groups in mean cortisol levels after the reading and resting intervention. Before reciting verses 195–200 of Surah Al-i Imran, the mean cortisol level was 2.01 ng/ml in the experimental group and 2.01 ng/ml in the control group. After reciting verses 195–200 of Surah Al-i Imran, the mean cortisol level was 1.85 ng/ml in the experimental group, and 2.15 ng/ml in the control group after the resting intervention. In addition, the group-time interaction was also found to be significant F (1,70) = 70.000 *p* < .000 (Table 7). Table 8 shows the mean cortisol levels of the groups by gender. While the mean cortisol level before reading was 2.07 ng/ml in women in the experimental group, it was found to be 1.87 ng/ml after reading. While the mean cortisol level before reading was 1.95 ng/ml in men in the experimental group, it was found to be 1.82 ng/ml after reading. While the pre-resting cortisol level was 2.04 ng/ml in women in the control group, it was 2.15 ng/ml after resting, and the pre-resting cortisol level was 1.97 ng/ml in men, it was found to be 2.15 ng/ml after resting. According to the results of the three-way mixed ANOVA; the Time-Group (*p* < .000) and Time-Sex (*p* < .015) interactions were found to be statistically significant. However, the main effect

Table 8 Salivary cortisol levels and statistical comparisons of study groups according to gender, group and time factors

		<i>n</i> (%)	Time		Time Group	Time Sex	Time-Sex Group
Experimental Group	Female	18	Before	2.073 ± 0.153	<i>p</i> < .390	<i>p</i> < .000*	<i>p</i> > .015*
			After	1.877 ± 0.144			
	Male	18	Before	1.958 ± 0.118			
			After	1.824 ± 0.178			
Control Group	Female	18	Before	2.048 ± 0.151	<i>p</i> > .940	<i>p</i> > .015*	<i>p</i> > .940
			After	2.157 ± 0.198			
	Male	18	Before	1.977 ± 0.125			
			After	2.152 ± 0.170			

Note: Data presented as Mean ± Standard Deviation in ng/ml. Experimental Group: Quran recitation group (*n* = 36). Control Group: Passive resting control group (*n* = 36). Main Effect (Time): *p* = .390 Interaction Effect (Time × Group): *p* < .000* Interaction Effect (Time × Sex): *p* = .015* Interaction Effect (Time × Sex × Group): *p* > .940

* *p* < .05, Three-way mixed model ANOVA.A

Table 9 Mental well-being scale scores of the study groups

	<i>n</i> (%)	<i>m</i>	<i>sd</i>
Experimental Group	36	24.222	± 4.229
Control Group	36	26.472	± 4.178

Note: Data presented as Mean ± Standard Deviation. Experimental Group: Quran recitation group (*n* = 36). Control Group: Passive resting control group (*n* = 36)

* *p* < .05, Independent-Samples T Test

of Time (*p* > .390) and the Time-Sex-Group interaction (*p* > .940) were not statistically significant (Table 8).

Table 9 shows the overall mental well-being scores for both groups, while Table 10 presents the analysis of these scores by gender. The data indicate that the passive resting control group's mental well-being scale scores (*M* = 26.47, *sd* = 4.17) were higher than the experimental group's scores (*M* = 24.22, *sd* = 4.22). According to the two-way ANOVA results (Table 10), there is a statistically significant effect of the group variable on The Mental

Well-Being Scale scores ($F(1, 68) = 5.277, p < .025$). However, there is no statistically significant effect of the gender variable on The Mental Well-Being Scale scores ($F(1, 68) = 0.039, p < .843$), and the gender-group interaction is also not statistically significant (*p* > .05).

Table 11 shows the relationships between NDNF, serotonin, dopamine, and cortisol levels and mental well-being scores; there is a positive but insignificant relationship between NDNF and mental well-being ($r = .185, p > .120$). There is a weak positive significant relationship between mental well-being and serotonin and dopamine ($r = .323^{**}, p < .006$ - $r = .280^{*}, p < .017$). There is a weak negative significant relationship between cortisol hormone and mental well-being ($r = -.236^{*}, p < .046$). There is a positive, weak, significant relationship between NDNF and serotonin ($r = .395^{**}, p < .001$), a positive, weak, significant relationship with dopamine ($r = .322^{**}, p < .006$), and a negative, strong, significant relationship with cortisol ($r = -.734^{**}, p < .000$). A negative, moderate, significant relationship was found between cortisol and serotonin

Table 10 Mental well-being scale scores and statistical comparisons of study groups according to gender and group factors

		<i>n</i> (%)	<i>m</i> ± <i>sd</i>	Sex	Group	Sex-Group
Experimental Group	Female	18	23.388 ± 3.836	$F(1,68) = 0.39$ <i>p</i> > .843	$F(1,68) = 5.277$ <i>p</i> < .025*	$F(1,68) = 3.611$ <i>p</i> < .062
	Male	18	25.055 ± 4.543			
Control Group	Female	18	27.500 ± 3.761			
	Male	18	25.444 ± 4.422			

Note: Data presented as Mean ± Standard Deviation. Main Effect (Sex): $F(1, 68) = 0.39, p = .843$ Main Effect (Group): $F(1, 68) = 5.277, p < .025^{*}$ Interaction Effect (Sex × Group): $F(1, 68) = 3.611, p = .062$

* *p* < .05, Two-way ANOVA

Table 11 Relationship between NDNF, Serotonin, Dopamine, cortisol hormone and mental Well-Being

		NDNF	Serotonin	Dopamine	Cortisol H.	M. Well-Being
NDNF	r	1				
	p					
Serotonin	r	0.395**	1			
	p	0.001				
Dopamine	r	0.322**	0.498**	1		
	P	0.006	0.000			
Cortisol	r	-0.734**	-0.481**	-0.590**	1	
	p	0.000	0.000	0.000		
M. Well-Being	r	0.185	0.323**	0.280*	-0.236*	1
	p	0.120	0.006	0.017	0.046	

and dopamine ($r = -.481^{**}$, $p < .000$ - $r = -.590^{**}$, $p < .000$). In addition, a positive, moderate, significant relationship was found between serotonin and dopamine ($r = .498^{**}$, $p < .000$).

Discussion

This study is one of the first to examine the effects of reciting the Quran on salivary serotonin, dopamine, NDNF, and cortisol levels, as well as their relationship to mental well-being. Our findings demonstrate that reciting the Quran, particularly verses 195–200 of Surah Al-i Imran, leads to significant changes in these neurotransmitter and hormone levels in the experimental group, consistent with the neurotheological pathways illustrated in Fig. 1.

One of the most striking findings of our study is the significant increase in salivary NDNF levels in the experimental group after Quran recitation (Table 1). Considering the role of NDNF in fundamental neuronal functions such as neuronal survival, development, and synaptic plasticity [28], this increase may have potential neuroprotective effects. Although no study in the literature directly examines the relationship between Quran recitation and NDNF, studies showing the positive effects of spiritual practices and meditation on brain structure and function support this finding [5, 8]. The unique rhythm and melody of Quran recitation may trigger the release of neurotrophic factors in the brain, thereby supporting neuronal health. Crucially, our correlation analysis revealed a strong negative relationship between NDNF and cortisol ($r = -.734$, $p < .01$). This finding is particularly significant as it provides objective evidence of the brain's shift to a more 'reparative state'; specifically, suggesting that as physiological stress (cortisol) is down-regulated via recitation, the neural environment becomes

more conducive to neurotrophic upregulation and synaptic maintenance.

Significant increases in serotonin and dopamine levels were also detected in the experimental group after Quran recitation (Tables 3 and 5). The central role of serotonin and dopamine in functions such as mood, motivation, reward, and pleasure [9, 14–16] increases the importance of these findings. The spiritual pleasure and calming effect of Quran recitation may increase the release of these neurotransmitters, contributing to enhanced emotional regulation and subjective well-being.

Changes in cortisol levels are also noteworthy. A significant decrease in cortisol levels was observed in the experimental group after Quran recitation (Table 7), while an increase was detected in the control group. Given the role of cortisol in the stress response [20] and the association of high cortisol levels with various health problems [22–24], it can be said that Quran recitation has a stress-reducing effect. This finding is also consistent with previous studies supporting the positive effects of Quran recitation on both mental and physical health [4].

When looking at the gender variable, no significant difference was found between genders in NDNF and dopamine levels (Tables 2 and 6), while significant interactions were found in serotonin and cortisol levels (Tables 4 and 8). This suggests that men and women may respond differently to the Quran recitation experience at the hormonal level.

One of the most significant and unexpected findings of this study was the result from The Mental Well-Being Scale. Our H5 hypothesis was not supported; instead, the passive resting control group reported statistically significantly higher mental well-being scores than the experimental group (Table 9). This finding, which contradicts the positive neurochemical changes (lower cortisol, higher dopamine/serotonin), demands careful

interpretation. Several factors could explain this. First, the intervention involved recitation in an observed, experimental setting. This may have induced ‘performance anxiety’ in the recitation group (e.g., anxiety about reciting ‘Tartil’ correctly as instructed), which could counteract the immediate spiritual benefits. The passive resting control group, merely resting, had no such performance pressure. Second, as established in our H3 hypothesis, recitation is a ‘cognitively demanding’ task. The 5-minute intervention may represent a short-term cognitive load that is momentarily fatiguing, whereas simple rest is purely restorative. Third, our correlation analyses (Table 11) did reveal the expected positive relationship between mental well-being and serotonin/dopamine levels, and a negative relationship with cortisol levels. This suggests that while the neurochemical basis for enhanced well-being was activated, the perceived psychological outcome was confounded by the short-term, high-pressure nature of the experimental task. The positive neurochemical changes might precede the perceived psychological benefit, which may only emerge after a longer duration or repeated practice.

Fourth, the discrepancy between the neurobiological and psychological findings may be attributed to the nature of the measurement tool itself. The Mental Well-Being Scale tends to capture more stable, trait-like aspects of well-being or broader affective states, rather than micro-level, immediate shifts in neurobiological status. While salivary biomarkers can fluctuate within minutes, a participant’s self-perception of ‘well-being’ may be more resistant to such rapid changes, reflecting a general state rather than the immediate physiological reality. Our study has some limitations. The relatively small sample size and the fact that the participants consisted only of university students limit the generalizability of the results. Furthermore, the study specifically recruited participants who were proficient in Quranic reading and likely possessed a baseline of religious belief. We did not control for varying degrees of ‘religiosity’ or ‘belief strength,’ nor did we include a non-believer comparison group.

Since the ‘reward’ mechanism (dopamine release) hypothesized in our neurotheological model relies heavily on the subjective spiritual value and meaning attributed to the text, the observed neurobiological responses may not be replicable in non-believers or individuals unfamiliar with the cultural and religious context of the Quran. Additionally, the use of a general mental well-being scale might not have been sensitive enough to detect the acute, immediate effects of the 5-minute intervention, as opposed to state-specific anxiety or mood inventories.

Studies with larger and more diverse samples will help us to understand more comprehensively the effects of

Quran recitation on neurotransmitter and hormone levels and mental well-being. Moreover, future research should move beyond acute protocols to longitudinal designs with repeated sessions. Such studies are necessary to determine if the transient neurochemical spikes observed here translate into sustained ‘trait-level’ well-being and long-term neuroplastic adaptations, potentially diminishing the performance anxiety seen in single-session experiments. Finally, to rigorously disentangle the specific neurobiological contributions of rhythmic vocalization versus cognitive processing, future research should employ multi-arm designs that include ‘listening-only,’ ‘silent reading,’ and ‘secular text’ control conditions.

Conclusions

In conclusion, this study provides important preliminary evidence that a brief, 5-minute Quran recitation significantly impacts salivary neurochemical levels, promoting a relaxation response (decreased cortisol) and activating reward and neuroplasticity pathways (increased dopamine, serotonin, and BDNF). However, a critical paradox emerged: despite this favorable neurochemical shift, the control group reported statistically higher mental well-being than the experimental group. This indicates that while the physiological ‘relaxation response’ was activated, the subjective psychological state was likely dampened by the acute cognitive effort required for correct recitation. Research at the intersection of theology and neuroscience can help integrate this knowledge into educational and spiritual settings.

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Author contributions

S.O. and B.B. designed the study. S.O. and B.B. collected data. S.O. analyzed the data. B.B. prepared the draft plan. All authors contributed to writing the manuscript. All authors read and approved the final manuscript.

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Data availability

The corresponding author upon reasonable request will provide data supporting the findings of this study.

Declarations

Ethical approval

The study received ethical approval from the Bayburt University Research Ethics Committee (07.01.2025/Decision no: 25). Before data and sample collection, participants were informed about the study and their written/verbal consent was obtained in accordance with the Declaration of Helsinki. All methods were carried out in accordance with the relevant guidelines and regulations.

Consent to participate

Informed consent was obtained from all individual participants included in the study. Written informed consent was obtained from the participants in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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