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Psychophysiological effects of music therapy in adolescents with borderline personality features

Ahmed Kazımov, Dilara Aliyeva, Fidan Babakhanova*

Department of Normal Physiology, Azerbaijan Medical University, Ministry of Health of the Republic of Azerbaijan, 165 Samad Vurghun Str., AZ1022, Baku, Azerbaijan

****For correspondence:** *f.aliyeva84@mail.ru*

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The present study was devoted to the investigation of age-related characteristics in the dynamics of psychophysiological parameters during the application of Medical Resonance Therapeutic Music (MRTM) procedures in practically healthy male adolescents aged 15–18 years and in adolescents of the same age group diagnosed with neurotic disorders. The research was aimed at evaluating the influence of specially selected musical compositions on the functional state of the nervous system, emotional stability, stress resistance, and adaptive capacities of the organism. Particular attention was paid to the analysis of individual responses to musical stimulation and to the identification of factors determining the effectiveness of MRTM. The MRTM procedures were developed with consideration of the individual musical preferences of the participants. Musical fragments were selected according to subjective emotional significance, aesthetic attractiveness, and personal choice, allowing the therapeutic intervention to be adapted to the psychological characteristics of each recipient. Psychophysiological indicators were assessed before, during, and after exposure to MRTM, enabling the evaluation of dynamic changes associated with the therapeutic process. The results demonstrated that MRTM possesses pronounced antistress and psycho-corrective effects. Exposure to individually preferred musical fragments was associated with improvements in emotional state, reduction of anxiety manifestations, normalization of autonomic nervous system activity, and enhancement of adaptive psychophysiological responses. In healthy adolescents, MRTM contributed to the stabilization of functional parameters and optimization of regulatory mechanisms. In participants with neurotic disorders, more significant positive shifts were observed, including decreased emotional tension, improved self-regulation, and restoration of psychophysiological balance. The findings indicate that the effectiveness of MRTM is largely determined by the degree of correspondence between therapeutic musical material and the individual preferences of recipients. At the same time, the therapeutic outcomes depend on age-related developmental characteristics, individual psychological traits, and typological properties of the nervous system.

***Keywords**: Psychophysiological correlates, medical resonance therapeutic music, neurotic disorders*

INTRODUCTION

The introduction of the impact of music and other sound information on the human body is of extreme importance. It is known that specially selected music can influence mood, trigger or suppress aggression, and optimize various vegetative functions and hormonal status (Blinova, 1998; Greenberg, 2002; Epifanov et al., 2002).

Numerous studies have shown that the activation of acoustic sensory inputs to the brain (in the form of music therapy procedures) is an effective non-pharmacological rehabilitation technology and can be used in the comprehensive treatment of patients with depression, stress-related

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emotional disorders, and to enhance mental performance (Klassina et al., 2001; Malyarenko, 2001; Shutova, 2001). Special musical compositions have been proposed, such as the Medical Resonance Therapeutic Music (MRTM) by P. Hubner (Hubner, 1996). The effectiveness of which has been demonstrated in a number of clinical studies for neurotic disorders in adolescents (Mikhaylova, 1992; Reznikov et al., 1996; Alekperova, 1999; Veyin, 2000; Humeniuk et al., 2002). The effectiveness of music therapy procedures depends on the content of the musical composition, its genre, tempo-rhythm, variability of the acoustic flow energy, as well as, on the other hand, on the age, personality, and individual-typological characteristics of the person (Sudakov, 1998; Shutova, 2001; El Sayed et al., 2025). At the same time, despite the widespread use of music therapy, the physiological mechanisms of its perception (at both the conscious and subconscious levels) and the specific neuro- and psychophysiological mechanisms through which music influences a person's functional state remain largely unclear (Schäfer et al., 2020; Haslam, 2022). These questions have only received fragmented coverage. Among the available literature, we did not encounter scientific studies concerning the impact of organized or recreational music use on the psycho-emotional sphere of healthy adolescents and young individuals with borderline disorders (Hereld, 2019), yet it is precisely at this age that music occupies one of the most important places in a person's emotional life. Based on the above, the goal of our work is to investigate the age-related features of the dynamics of psychophysiological correlates of medical resonance therapeutic music (MRTM) procedures in practically healthy young men aged 15-18 and young men of the same age group with borderline disorders (Stoffers et al., 2012; Strehlow et al., 2016).

MATERIALS AND METHODS

Based on clinical symptoms, the identified borderline disorders in young men were classified according to ICD codes 41.1 – "generalized anxiety disorder" and 43.2 – adjustment disorders. Dynamic studies were conducted on 48 practically healthy young men and 48 young men with neurotic disorders, who were divided into 4 age groups: 15, 16, 17, and 18 years old, with 24 subjects in each age group. The subjects undergo studies of subjective, electrophysiological, psychophysiological, and autonomic indicators during single presentations of emotionally pleasant fragments of "medical resonance therapeutic music (MRTM)" (Shutova, 2001), specifically the piece *Sonnen Simphonie* ("Hymns of the Sun, No. 1 - 'Relaxation-B'"). Initially, the young men were seated in a chair in a dimly lit room, where they were asked to rate 5 musical fragments, each lasting 1.5-2 minutes, on a 7-point scale. Based on the ratings, the most emotionally pleasant (high-rated) and least emotionally pleasant (low-rated) music fragments were determined. The MRTM procedure lasted 20 minutes, and the stereophonic sound of the music was provided from licensed compact discs through computer speakers. Before and after the musical interventions, the young men undergo electroencephalogram (EEG) recordings, completed computer-based versions of the "well-being-activity-mood" (WAM) tests, and the Ch. Spielberger test to determine levels of trait (LT) and state anxiety (SA) (Reznikov et al., 1996). Additionally, systolic (SBP) and diastolic (DBP) blood pressure, heart rate (HR), and the calculation of the Kerd's vegetative index (VI) were measured. The EEG was recorded using an 8-channel electroencephalograph from the company "Neurosoft" (Ivanovo) in a relaxed state ("eyes closed") with monopolar placement at 6 points on the head: F3, F4, C3, C4, O3, O4, according to the international 10-20 electrode placement system. The time constant for EEG recording was 0.3 seconds with a 30 Hz filter, and the calibration signal was 50 μV. Indifferent electrodes were placed on the earlobes. The recording duration was 180 seconds. EEG data were processed using the "Neyrospektr" automated processing package. Spectral power (μV^2), both total and within specific frequency bands, was calculated based on the Fourier transformation. The analysis epoch was 8 seconds. Additionally, for each EEG registration area, the proportion (in %) of spectral power in the α-range (7-13 Hz) and the total α-rhythm power (across all analysis epochs) was calculated, and the statistical significance of their dynamics

was assessed individually. Statistical data processing was performed using the "Statistics for Windows" 6.0 software. Considering the small size of the comparison groups, the non-parametric Mann-Whitney U-test was used to assess the significance of differences for paired and unpaired samples.

RESULTS AND DISCUSSION

It was found that in all the identified age groups, the young men in the clinical subgroups with neurotic disorders showed significant differences in psychophysiological and psychological indicators compared to their practically healthy peers (Table 1). Thus, in these individuals (with the exception of the subgroup of 15-year-olds), a relative depression of the alpha rhythm was observed, predominantly in the anterior leads, along with lower self-assessment scores for general well-being and mood, and higher scores for situational anxiety (in the 18-year-old subgroups) (Aftanas et al., 2001). At the same time, no significant differences were found between the vegetative parameters of the groups of healthy young men and those with anxiety disorders (Alekperova, 1999). The presentation of an individually selected music fragment led to a complex of psychophysiological changes that were fundamentally similar across all age groups, both in the practically healthy young men and in the subgroups of young men with neurotic disorders. These changes included an increase in the spectral power of the alpha rhythm across all recorded leads, predominantly in the frontal and central regions (except in the subgroups of 17- and 18-year-old young men), a decrease in the level of situational anxiety (SA), an increase in self-assessment scores, activity levels, a slight decrease in baseline blood pressure (BP), and a statistically significant decrease in diastolic blood pressure (DBP), along with the optimization of the values of vegetative index coefficients (VIC) within the range of normotonia. Such changes overall indicate the effectiveness of music therapy (MT) for correcting the psychological and emotional state of young men aged 15-18 (Kenner et al., 2020; Wang et al., 2018). By comparing the complex of EEG changes, vegetative characteristics, and mental status indicators, it can be assumed that music therapy (MT), by influencing integrative brain processes and the emotional state of the subjects, helps to alleviate the dysfunction of nonspecific regulatory systems identified in neurotic disorders in adolescents. The obtained results are supported by the study (Sudakov, 1998), which shows a reduction in sympathetic influences, predominant in adolescents with neurotic disorders before the exposure to functional music, and a trend towards balance between the sympathetic and parasympathetic systems at the periphery. These findings reflect the interaction between the ergotropic and trophotropic systems in the suprasegmental regions of the autonomic nervous system (Greenberg, 2002). At the same time, in different age groups, the nature of the shifts in psychophysiological indicators during the dynamics of music therapy procedures differed and was likely dependent both on the characteristics of the music fragment preferred for reproduction and on the individual traits of the subjects (Table 2).

Thus, in the dynamics of musical exposure in the group of 15-year-old healthy young men, a significant increase in the spectral power of the alpha rhythm was observed, from 314.8±55.9 to 406.7±73.1 ($p<0.05$), along with a decrease in situational anxiety from 41.5±3.4 to 37.5±2.3 ($p<0.05$), with minimal shifts in psychological indicators. In the subgroup of young men with neurotic disorders, the increase in the spectral power of the alpha rhythm was significant, from 254.9±31.5 to 310.3±44.5 ($p<0.05$), while a decrease in diastolic blood pressure (DBP) was observed, from 84.2±2.2 to 79.0±2.2 ($p<0.05$). Situational anxiety scores decreased from 39.8±2.1 to 36.7±2.1 ($p<0.05$), and heart rate (HR) decreased from 71.0±1.6 to 69.2±1.7 ($p<0.01$), accompanied by a significant reduction in heart rate (HR) and blood pressure (BP).

In 16-year-old practically healthy young men, the music therapy procedure only led to a trend towards an increase in the spectral power of the alpha rhythm (45.6%) (Sarnthein et al., 1997) while the vegetative parameters changed in opposite directions and were not statistically significant. In young men with neurotic disorders, after functional music exposure, a decrease in diastolic blood pressure (DBP) was observed, from

85.0±2.8 to 80.0±3.2 ($p<0.05$), a decrease in activity from 5.5±0.2 to 4.8±0.2 ($p<0.05$), and a change in the vegetative index coefficient (VIC) from 22.3±3.2 to -11.6±3.3 ($p<0.05$). Additionally, changes in the alpha rhythm were noted in the frontal and central leads, as well as normalization of the values.

Table 1. Vegetative indicators of healthy young men and young men with neurotic disorders aged 15-18 years and during FM exposure.

		Spectral power		HR		SBP		DBP		PBP	
		before	after	before	after	before	after	before	after	before	after
age 15	H	314.8±55.9	406.7±73.1	68.7±2.2	69.0±3.1	120.4±3.3	117.9±3.4	82.9±1.9	78.6±2.6	37.9±1.9	39.2±1.2
	P		**<0.05**								
	N	254.9±31.5	310.3±44.5	71.0±1.6	69.2±1.7	121.6±3.7	119.2±3.2	84.2±2.2	79.0±2.2	39.8±2.6	41.3±1.5
	P1		**<0.05**		**<0.01**				**<0.05**		
age 16	H	325.8±61.2	359.6±63.7	67.1±1.3	67.9±1.3	116.7±4.0	114.6±3.6	80.4±3.5	78.3±2.9	35.4±1.7	37.0±1.4
	P										
	N	286.3±73.4	321.4±52.9	67.3±1.3	72.0±2.2	117.9±3.8	117.1±3.6	85.0±2.8	80.0±3.2	39.3±4.4	37.0±1.6
	P1								**<0.05**		
age 17	H	372.2±69.3	362.3±52.4	70.3±2.1	68.3 ±1.6	116.7±4.3	112.9±3.5	78.8±1.9	74.5 ±2.0	37.3±2.7	38.3±1.8
	P								**<0.05**		
	N	267.2±46.1	311.8±45.9	71.5±2.5	70.8±1.9	120.8±4.4	113.4±2.8	80.0±2.3	73.7±2.2	40.4±2.3	38.4±1.3
	P1						**<0.05**		**<0.01**		
age 18	H	309.0±46.2	320.0±49.5	69.4±1.8	67.3±2.1	113.0±3.7	110.4±4.1	79.6±2.4	78.3±3.3	33.3±2.9	38.8±2.7
	P				**<0.05**						
	N	248.6±69.1	275.1±58.4	68.1±1.5	66.8±1.8	114.6±3.2	111.4±3.7	80.8±2.5	75.0±3.0	35.0±2.6	35.4±1.8
	P1								**<0.05**		

Note: Spectral power (μV²), HR - heart rate, SBP - systolic blood pressure, DBP - diastolic blood pressure, PBP – pulse blood pressure, 1 - values before MRTM, 2 - after the procedure, p - significance of differences in the healthy group before and after MRTM, p1 - in subgroups with neurotic disorders.

Table 2. Values of psychophysiological indicators in healthy young men and young men with neurotic disorders during the dynamics of MRTM procedures (M±m).

		Well-being		Activity		Mood		VIC		SA		PA	
		before	after	before	after	before	after	before	after	before	after	before	after
age 15	H	4.8±0.2	4.6±0.2	4.7±0.3	3.6±0.8	4.4±0.4	4.7±0.4	16.5±8.1	16.6±7.9	41.5±3.4	37.5±2.3	41.2±2.5	38.7±2.5
	P										**<0.05**		
	N	4.8±0.2	4.9±0.3	4.9±0.3	5.0±0.3	5.3±0.2	5.3±0.3	-13.7±2.3	-9.7±3.5	39.8±2.1	36.7±2.1	36.7±2.1	36.4±2.4
	P1										**<0.05**		
age 16	H	5.1±0.1	4.7±0.2	4.8±0.1	4.6±0.2	4.9±0.2	5.1±0.2	-14.2±3.7	-5.8±5.3	39.9±1.8	34.4±1.8	39.5±2.0	38.8±2.0
	P												
	N	5.3±0.2	4.9±0.2	5.5±0.2	4.8±0.2	4.0±0.4	4.2±0.4	-22.3±3.2	-11.6±3.3	45.5±3.1	44.3±2.8	39.9±1.6	4.8±1.9
	P1				**<0.05**				**<0.05**				
age 17	H	5.2±0.2	4.9±0.2	4.9±0.2	4.6±0.2	4.8±0.3	5.0±0.3	-11.4±3.7	9.1±4.2	41.3±3.2	39.1±2.9	38.7±2.1	38.1±1.6
	P		**<0.05**						**<0.001**		**<0.01**		
	N	5.3±0.2	4.7±0.1	4.8±0.2	4.6±0.2	5.2±0.3	5.1±0.3	-11.9±1.4	-9.6±3.0	42.1±2.0	43.0±3.5	40.8±2.0	42.6±1.8
	P1		**<0.05**										
age 18	H	4.9±0.1	4.9±0.2	4.8±0.2	4.6±0.2	4.9±0.3	5.1±0.2	-15.4±4.1	-14.7±6.7	38.9±2.3	33.9±2.3	36.8±2.3	36.0±2.4
	P										**<0.01**		
	N	5.0±0.1	5.1±0.2	5.1±0.3	4.7±0.2	4.8±0.2	4.8±0.2	-19.2±3.6	-14.0±2.8	44.2±3.7	40.3±3.8	38.2±2.7	37.9±1.8
	P1												

Note: Well-being, activity, mood, VIC (vegetative index coefficient), PA - personal anxiety, SA - situational anxiety, H - healthy, N - neurotics, statistically significant difference p - with indicators before and after in practically healthy individuals, and p1 - in neurotic individuals of this age group.

In the subgroup of 17-year-old healthy young men, no significant changes were observed in the EEG characteristics after functional music exposure. However, a decrease in diastolic blood pressure (DBP) was noted, from 78.8±1.9 to 74.5±2.0 ($p<0.05$), normalization of vegetative index coefficient (VIC) from -11.4±3.7 to 9.1±4.2 ($p<0.001$), as well as a deterioration in subjectively assessed well-being, from 5.2±0.2 to 4.9±0.2 ($p<0.05$), and a decrease in situational anxiety (SA) from 41.3±3.2 to 39.1±2.9 ($p<0.01$). In individuals with neurotic disorders of this age, no significant changes were observed in EEG values or vegetative parameters after music therapy, although there was a slight decrease in systolic blood pressure (SBP) from 120.8±4.4 to 113.4±2.8 ($p<0.05$), diastolic blood pressure (DBP) from 80.0±2.3 to 73.7±2.2, and in self-assessed well-being from 5.3±0.2 to 4.7±0.1 ($p<0.05$). When presenting the most emotionally pleasant music to 18-year-old, practically healthy young men, the values of spectral power in the alpha range did not change significantly. However, a significant decrease in heart rate (HR) was observed, from 69.4±1.8 to 67.3±2.1 ($p<0.05$), as well as a statistically significant decrease in situational anxiety (SA), from 38.9±2.3 to 33.9±2.3 ($p<0.01$). When 18-year-old young men with neurotic disorders underwent the music therapy procedure, an increase in the spectral power of the alpha rhythm was observed across all recorded leads. At the same time, a decrease in diastolic blood pressure (DBP) was noted, from 80.8±2.5 to 75.0±3.0 ($p<0.05$), but significant changes were also observed in the average scores for self-assessed mood and well-being.

To analyze the reasons for the different psychophysiological reactions of the subjects to the music therapy procedures, a retrospective analysis of the types of preferred music fragments was conducted. It was found that young men in the younger age groups (15-16 years old) predominantly preferred to listen to melodic, yet rhythmic musical compositions (75% of healthy individuals and 88.1% of young men with neurotic deviations). This had a synchronizing effect on the limbic-reticular structures of the brain, manifested by an increase in alpha rhythm power, a decrease in the amplitude of fast oscillations, and a mild sedative effect in healthy individuals–such as a reduction in situational anxiety, the experience of positive emotions, and normalization of the vegetative sphere. However, in young men with neurotic disorders, when there was initial emotional-vegetative arousal, listening to such compositions led to only a minimal increase in alpha activity and some normalization of vegetative parameters, while subjective emotional tension and anxiety remained, and even increased. Young men in the older age groups (17-18 years old) preferred melodies that were more energetic, with a clear tempo-rhythm and moderate volume, which, evidently, were accompanied by tonic effects. This was reflected in an ambiguous dynamic of alpha rhythm, with an increase in the amplitudes and indices of fast EEG oscillations. However, positive shifts were observed in the vegetative sphere, including a decrease in hemodynamic indicators, as well as a reduction in levels of situational anxiety (normalization of the emotional background). Some of the 17-18-year-old young men with neurotic disorders chose rhythmic music fragments combined with melodic, lyrical melodies. It is possible that this particular type of music most closely matched their initial negative emotional background, characterized by a high level of anxiety. This led, after music therapy procedures, to opposing shifts in EEG values, some optimization of vegetative status, while the level of situational anxiety was maintained or even increased. This reflects the persistence and circulation of excitations in the cortico-thalamic and cortico-limbic neural circuits (possibly influenced by the emotions associated with the content of the musical fragments themselves).

CONCLUSION

Thus, the conducted study, dedicated to examining the age-related features of the dynamics of psychophysiological and vegetative correlates of medical resonance therapeutic music (MRTM) procedures in practically healthy young men aged 15-18 and in young men of the same age group with neurotic disorders, made it possible to establish the following: MRTM procedures, tailored to individual preferences in musical fragments, have pronounced anti-stress

effects, manifesting both in the optimization of emotional state and in the normalization of vegetative regulation of cardiovascular functions. (Ramos-Loyo et al., 2024; Rivera-Tello et al., 2023; Yang et al., 2025; Lin et al., 2010; Kuzyaev et al., 2023). It can be assumed that the complex influence of the frequency characteristics of the musical sequence and the emotional perception of music have a synchronizing effect on the limbic-reticular structures, leading to the activation of the alpha rhythm spectrum primarily in the frontal areas of the brain, reducing the activity of suprasegmental ergotropic sympathetic influences in the regulation of visceral functions, and normalizing the emotional background of the examined young men aged 15-18. At the same time, the pronounced polymorphism of subjective, vegetative, and EEG reactions of the subjects to identical music exposures indicates the ambiguity of the emotional response of young men from different age groups to their presentation **(**Kulinski et al., 2022). This depends on the initial, previously formed dynamic stereotypes in the subjects and is particularly evident in the subgroups of young men with borderline neurotic disorders. On the other hand, the effects of MRTM are largely determined by the individual preferences of the subjects in choosing musical fragments. In the groups of 17-18-year-old young men, the preference was for more energetic melodies with a clear tempo-rhythm, which was evidently accompanied by tonic effects, manifested in an increase in the amplitudes and indices of fast EEG oscillations, normalization of hemodynamic indicators, and the elimination of situational anxiety (Gebhardt et al.,2018).

Meanwhile, 15-16-year-old young men preferred to listen to melodic, yet rhythmic musical compositions, which led to sedative effects, the experience of positive emotions, and the normalization of vegetative disorders (more pronounced in healthy individuals, but with the persistence of high levels of situational anxiety in young men with neurotic disorders). It can also be assumed that the influence of different MRTM fragments depends not only on their frequency and rhythmic characteristics but also on the individual traits of the subjects (such as the type of nervous system, personality accentuations, health status, age, etc.), which opens up prospects for further research.

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CONFLICT OF INTEREST

The authors confirm the absence of a conflict.

AUTHOR CONTRIBUTIONS

Ahmed Kazımov contributed to the study design, participant recruitment, psychophysiological data collection, and interpretation of the findings. Dilara Aliyeva participated in the implementation of the Medical Resonance Therapeutic Music (MRTM) procedures, statistical analysis, and manuscript preparation. Fidan Babakhanova conceived and supervised the study, coordinated the research process, critically revised the manuscript, and approved the final version for publication. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

AI STATEMENT

The authors declare that no artificial intelligence (AI) tools were used to generate, analyze, interpret, or validate the research data and scientific conclusions presented in this study. Any AI-assisted technologies, if used, were limited to language editing, grammar correction, or formatting support. The authors take full responsibility for the originality, accuracy, and integrity of the manuscript.

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ORCIDs:
Ahmed Kazimov: https://orcid.org/0009-0004-4268-0582
Dilara Aliyeva: https://orcid.org/0009-0007-0135-1434
Fidan Babakhanova: https://orcid.org/0009-0006-8089-2900