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The Effect of Exercise with Mental Stress on the Electrical Waves of the Heart of Young Men

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Abstract

Introduction: In different studies, the effects of exercise and mental stress on electrical waves of the heart have been investigated separately. Nonetheless, the aim of this study was to investigate the simultaneous effect of exercise with mental stress on changes in electrical waves of the heart of young men.

Methods: 24 healthy inactive men were selected and randomly divided into two groups of exercise and exercise with mental stress. The subjects in the exercise group biked for 37 minutes (60 % of the maximum aerobic capacity), and the subjects in the exercise with mental stress, biked for 37 minutes while they received 20 minutes of mental stress during biking, from minute 10 to 32. Heart electrocardiogram was recorded at 6 stages of resting, before exercise, 10, 20, 32 and 37 minutes since exercising. Statistical analysis was performed using ANOVA with repeated measures at a significant level of 0.05.

Results: No significant difference in heart rate changes (p = 0.71), QRS voltage changes (P = 0.41), QT changes (P = 0.57), QTc changes (P = 0.54) ST segment changes (P = 0.053) and R-R interval changes (P = 0.58) were observed in the interactive effect of group and time.

Conclusion: The pattern of changes in the electrical waves of the heart applied in this study was similar in two groups of moderate intensity exercise with mental stress and without mental stress.

Keywords: Exercise, Heart, Mental Stress

Introduction

Today, increasing stress in modern life is considered as a negative experience. In behavioral sciences, to understand the stress in people, usually questionnaires are used to help to measure behavioral changes as well as facial expressions such as faces and speeches, but there are still some limitations in this regard (1- 3). Stress is associated with physiological changes and the activation of stress marker systems, including sympathetic adrenal system, hormones, adrenal hypothalamic pituitary axis (3). Progress in recording these physiological changes together with the help of advanced physiological sensors has made stress recognition more feasible. Physiological changes, especially in situations with multiple stresses, may create complex conditions on the physiological system. Many occupations, such as firefighters, police officers, and even people who do recreational exercises, are exposed to multiple stresses, with a possible death rate in such conditions (4). The cardiovascular system is directly or indirectly affected by stress. Electrocardiogram is an important parameter in cardiovascular studies (5). Physiological factors such as exercise, body mass index, age, race, and pathologic factors such as blockage of cardiac branches, electrolyte imbalance, coronary artery disease, and psychological factors can affect electrocardiogram changes (6). Several studies have shown that excitement and stress may affect cardiac arrhythmias, electrocardiogram and ventricular re-polarization (7- 9). Although the mechanism of how the stress exertion destabilizes heart electrophysiology and causes ventricular arrhythmias is not fully understood; evidence suggests that central nervous system processing may play an important role in this regard (10, 11). Recent evidence suggests that there is an interactive system in the upper centers of the brain, including the cerebral cortex, the brain stem and the autonomic nervous system that can affect the electrical activity of the heart (12). This brain-heart interaction helps to know the mechanism of electrical cardiac changes associated with exercise and stress. In recent years, researchers have shown a greater interest in the effect of physiological stress due to exercise and stress in the performance of athletes and normal people induced by mental challenge. Although the effect of mental stress on heart rate is well clarified, its effect on electrical waves of the heart is not well known. In this vein, the purpose of this study is to investigate the effect of a session of sports exercise with mental stress on young men's electrical waves.

Methods

In this semi-experimental study, 24 inactive male students of Science and Research Branch at Islamic Azad University who volunteered to participate in the study, were considered. Drawing on SAI questionnaire, 24 subjects were homogenized based on stress level and the maximum aerobic power. Then, the sample was divided into two groups (exercise and exercise with mental stress) through simple random sampling. The criteria for inclusion in the study demanded that subjects should have no regular exercise programs in the last 6 months, they were completely healthy based on a medical questionnaire, they should not have hearing and visual impairment problems such as blindness and history of mental disorders, drug abuse and smoking, and at least in the past six months, they had not experienced a terrible incident in everyday life (death of close relatives and affiliates, divorces, etc.). All subjects were advised not to perform any physical activity, in particular heavy and high intensity physical activity, 48 hours before participating in the exercise program. The subjects completed three stages of the test. In the first stage, they completed the health questionnaire and familiarized themselves with the method of testing. The second stage was to assess the maximum aerobic power of the subjects using a Metamax gas analyzer device manufactured by the German cortex. The assessment was conducted at constant temperature and humidity at Shahid Beheshti Faculty of Physical Education in accordance with the following steps. All subjects first warmed up for 3 minutes on a Monarch bike with 25 watts, then they started the test at 100 watts, and every 90 seconds 50 watts was added to allow the subjects to have maximum heart rate, respiratory rate ratio greater than 1.1 and perceived pressure above 15, and in these conditions the test was completed and the maximal oxygen uptake (Vo_{2max}) was determined (13). The third stage included a physical exercise protocol with and without mental stress. There was a one-week gap between the second and third stages of testing. 37 minutes of biking on Monaco's fixed bike was 60 % of the maximal oxygen uptake (Vo_{2max}) by each person, which is presented with mental stress in the following (13). Mental stress included a modified version of the Stroop test and mental calculation challenge. It was performed from 12th to the 32nd minutes of the exercise, in five times of four minutes, each involving two minutes of Stroop color word test stress and two minutes of mental calculation challenge. In the Stroop test, the color of the word was shown to the subjects for half a second with conflicting fonts by presenting the color name as audible and visual, and the subject had a half-second chance to answer the screen. Subjects were continuously given feedbacks on the screen about their accuracy. When the answers were false, they were alerted by the computer. In the mental calculation test, the subjects encountered three-digit numbers with math, and when they responded incorrectly, they were alerted by the computer. By giving feedback during the test (e.g., you are slow; the others are doing better), a more mental challenge came in (13). Electrocardiogram recording was simultaneously performed with the recording of subjects' respiratory gases during the test by a 12-lead electrocardiogram (manufactured by German cortex company) synchronized with the Metamix 3 gas analyzer device (of the same company), when subjects were exercising on a Monarch bike, 30 minutes before the beginning of the exercise (resting mode), before the exercise, 10, 20, 32, and 37 minutes since exercising. To analyze the data, Kolmogorov-Smirnov test was used to check the normal distribution of the test. After verifying the normality of the data, ANOVA with repeated measures was used to compare the groups and the variables within the groups. To determine the sphericity hypothesis, Mauchly's test was used and in case of failure to establish sphericity hypothesis, the results of the Greenhouse-geisser test were reported. Bonferroni's test was used to compare the effects exercise with and without mental stress in different minutes on the changes in the electrical waves of the heart. All stages of this research were approved by the ethics Committee of Islamic Azad University, Science and Research Branch, with the identity Code IR.IAU.SRB.REC.1396.70. Data analysis was performed using SPSS software version 24, and level of significance was considered at $P < 0.05$.

Results

The demographic information of the subjects is presented in Table 1. Also, data on the variables of the research is also listed in Table 2. As presented in Table 3, there was no significant difference in heart rate changes in the interactive effect of group and time ($P = 0.312$, $F = 0.714$). As shown in Table 4, there was a significant difference in the increase in heart rate in the exercise group at resting mode and at 10, 20, 32, and 32 minutes of exercise; there was a significant difference in the increase in heart rate in the exercise group with mental stress at resting mode and at 10, 20, 32, and 32 minutes of exercise (Table 4). As presented in Table 3, there was no significant difference in QRS changes (voltage) in the interactive effect of group and time ($P = 0.41$, $F = 0.93$). As presented in Table 3, there was no significant difference in QT in the interactive effect of group and time ($P = 0.57$, $F = 0.66$). In the exercise group, there was a significant difference between the resting time and the beginning of the exercise and minute 37. In the exercise group with mental stress, there was a significant difference between the resting time and the time intervals of 20, 32, and 37 minutes, and the difference between zero time and 20 minutes was significant ($P = 0.008$), as shown in Table 5. As presented in Table 3, there was no significant difference in QTc changes in the interactive effect of group and time ($P = 0.54$, $F = 0.80$). QTc changes in the exercise group and in the exercise group with mental stress are not significant at different times. As presented in Table 3, there was no significant difference in ST segment changes in the interactive effect of group and time ($P = 0.53$, $F = 0.72$). Changes in ST segment in the exercise group with mental stress were significant before the beginning of the exercise and minute 32 ($P = 0.04$) and 37 ($P = 0.04$). As presented in Table 3, there was no significant difference in R-R interval in the interactive effect of group and time ($P = 0.58$, $F = 0.47$). R-R interval changes in the exercise group were significant before the beginning of the exercise and at minutes 10, 20, 32, and 37. RR interval changes in the exercise group with mental stress were significant before the beginning of the exercise and at minutes 10, 20, 32, and 37, as presented in Table 6.

Table 1. The demographic characteristics of the subjects

Variable	Exercise group	Exercise with mental stress group
Age (yrs)	27.75±2.65	25.22±1.56
Weight (kg)	72.87±3.15	74.50±3.07
Height (cm)	177.25±2.49	178.77±2.94
Vo2max(ml/km/min)	39.11±3.01	35.88±3.07
BMI(kg/m^2)	22.75±2.97	22.66±1.58

Table2. The electrical waves of the heart at rest, before exercise, within 10 minutes, within 20 minutes, within 32 minutes and within 37 minutes

Variable	Group	HR(bpm)	QRS	QTC	QT	R-R	ST
Rest	Exercise	75.5±13.55	1.65±0.42	387.75±26.08	355.16±29.04	726.12±324.77	92.87±30.06
	Exercise with mental stress	77.44±13.39	1.52±0.35	395.33±26.811	353.5±30.37	689±246.20	98± 39.94
Before exercise	Exercise	86.12±15.07	1.60±0.49	408.37±35.18	337.16±15.14	602.50±236.29	88.5±14.93
	Exercise with mental stress	89.77±16.4	1.36±0.26	399.11±60.86	333.62±5.20	690.33±123.44	91.55±35.88
Within 10 minutes	Exercise	143.75±20.62	1.63±0.49	398.75±24.40	279.83±56.04	372.75±111.88	77±36.24
	Exercise with mental stress	137.44±48.06	1.39±0.28	427.33±37.64	274.87±45.22	390.66±36.13	94.66±58.01
Within 20 minutes	Exercise	157.25±9.96	1.37±0.71	403.87±28.77	262.43±43.06	350.25±87.57	79±35.89
	Exercise with mental stress	164.22±13.9	1.33±0.24	407.33±32.51	244.62±21.92	364.11±26.97	74.22±40.22
Within 32 minutes	Exercise	160.47±12.51	1.41±0.5	396.62±36.11	257.16±52.57	335.25±81.42	73.12±40.64
	Exercise with mental stress	162.44±17.09	1.27±0.33	413.22±49.67	228.5±62.17	365.22±35.97	55.88±16.03
Within 37 minutes	Exercise	162.37±13.75	1.38±0.5	394.5±20.25	232.66±14.06	332.87±81.44	63.37±13.02
	Exercise with mental stress	167.13±13.31	1.31±0.35	418.88±21.77	254.25±12.68	361.88±31.01	53.22±17.46

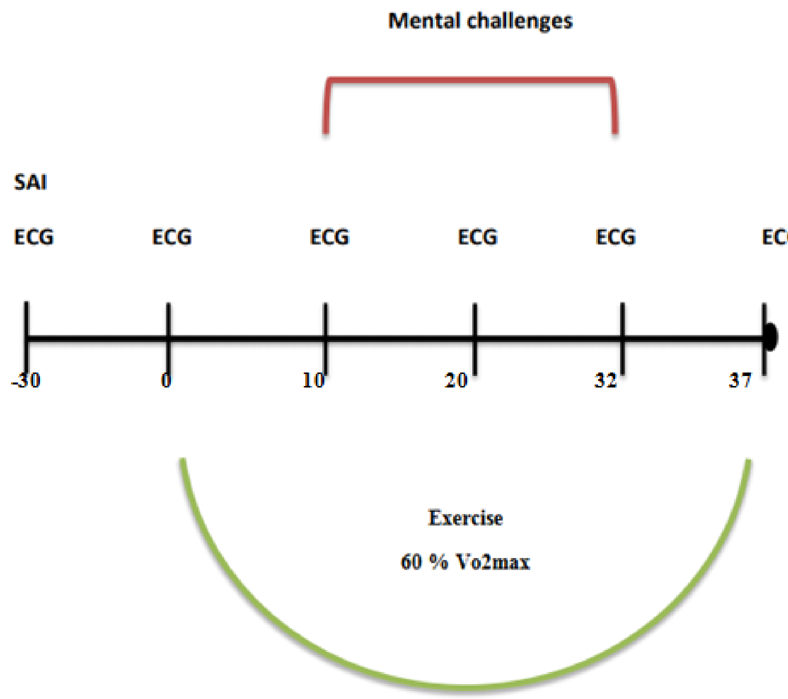

Figure 1. Schedule of exercise protocol and mental stress applied during exercise

Table 3. Results of repeated measures for review of the changes of electrical waves of heart

Variable	Factor	Sum of square	F	Sig	Effect size
Heart rate changes	time	132805.19	85.94	0.001	0.851
	group	130.240	0.161	0.694	0.011
	group×time	482.614	0.312	0.714	0.02
QRS changes	time	0.938	5.752	0.005	0.277
	group	0.535	0.599	0.451	0.038
	group×time	0.153	0.936	0.451	0.059
QT changes	time	163355.199	21.84	0.001	0.645
	group	685.080	0.322	0.581	0.026
	group×time	4901.485	0.656	0.574	0.052
QTc changes	time	4189.80	0.804	0.55	0.051
	group	3593.242	1.513	0.238	0.092
	group×time	4210.0623	0.808	0.548	0.051
ST changes	time	18313.453	4.087	0.014	0.214
	group	28.190	0.012	0.913	0.001
	group×time	3235.963	0.722	0.537	0.46
R-R changes	time	2326291.632	32.674	0.001	0.685
	group	14127.804	0.226	0.641	0.015
	group×time	33926.847	0.477	0.580	0.031

Table 4. Results of Bonferroni's test to compare the effects of exercise with and without mental stress in different minutes on heart rate changes

Factor	Rest	Before exercise	Within 10 minutes	Within 20 minutes	Within 32 minutes	Within 37 minutes
Exercise group		P=1 M=-10.625	P=0.001 M=-68.25	P=0.001 M=-80.75	P=0.001 M=-85.25	P=0.001 M=-86.87
Exercise group with mental stress		P=1 M=-10.625	P=0.13 M=-60.0	P=0.001 M=-86.75	P=0.001 M=-85.0	P=0.001 M=-89.55

Blank spaces in the table represent the comparison of this time with other times.

Table 5. Results of Bonferroni's test to compare the effects of exercise with and without mental stress in different minutes on QT changes

Factor	Rest	Before exercise	Within 10 minutes	Within 20 minutes	Within 32 minutes	Within 37 minutes
QT changes in exercise group	P=0.002 M=-122.5	P=0.001 M=-104.25	P=0. 1 M=-47.16	P=0. 1 M=-29.75	P=0. 1 M=-24. 5	
QT changes in Exercise group with mental stress		P=1 M=19.87	P=0.13 M=78.620	P=0.001 M=108.75	P=0.001 M=125.0	P=0.001 M=99.25

Table 6. Results of Bonferroni's test to compare the effects of exercise with and without mental stress in different minutes on R-R interval changes

Factor	Rest	Before exercise	Within 10 minutes	Within 20 minutes	Within 32 minutes	Within 37 minutes
Decrease in the R-R interval in the exercise group	P=1 M=-122.5		P=0. 032 M=229.75	P=0. 046 M=225.25	P=0. 031 M=267. 25	P=0. 039 M=269. 62
Decrease in the R-R interval in the exercise group with mental stress	P=1 M=1.33		P=0.001 M=299.66	P=0.001 M=326.22	P=0.002 M=325.11	P=0.001 M=328.44

Discussion

The aim of this study was to examine the effect of 37 minutes of exercise with 60 % maximum aerobic power with mental stress, which was performed from minutes 12 to 32 in 5 turns of 4 minutes each including two minutes of color test and two minutes of mental calculation challenge, by measuring electrocardiogram at rest, immediately before exercise, 10, 20, 32 and 37 minutes since exercising. The results of this study showed that responses of heart rate, R-R interval and QT were significant in exercise and exercise groups with mental stress at different times.

The ST segment response was significant only in the exercise group with mental stress, but there was no significant difference in QRS, ST, R-R, QTc heart rate changes as a result of intervention in the groups at different times. Early findings on the electrocardiogram recorded showed that heart rate increased during stress. In car racing, the heart rate of the subjects increased to 130 beats per minute, or in parachuting up to 180 beats per minute (14). These observations are consistent with the general belief that stress is associated with an increase in heart rate. However, some people who have been treated for dentistry or exposed to seeing horror films, despite a great deal of stress, have had a decrease in their heart rate and the levels of catecholamine turnover (14). These observations show the complex interaction between the sympathetic and parasympathetic activity of autonomic nervous systems in response to different types of stress (15). The anterior part of the right hemisphere is related to sympathetic activity and the anterior part of the left hemisphere with parasympathetic activity (16). An increase in heart rate can be due to increased sympathetic activity induced by exercise and stress, that is accompanied by a decrease in the QT, R-R interval, which is consistent with the results of the present study, because heart rate is the main determinant of QT. Stress monitoring systems include sympathetic adrenal system, adrenal hormones, adrenal medullary hormones, HPA axis of the sympathetic nervous system, renin angiotensin-aldosterone and vasopressin. Prolonged QT is an index of the imbalance in the distribution of sympathetic activity on the heart (17). At resting mode, QT in the ECG denotes ventricular re-polarization. QT is affected by internal factors (genetic, physiological and pathological) and external factors (food, medicine, temperature). QT is strongly correlated with heartbeat (18, 19); and there is a positive relationship between QT and age. Previous studies have presented contradictory results on the effect of mental stress on QT time. In some studies, QT was reported to be prolonged when a person was awakened with bad news (20). In contrast, laboratory results showed that QT was reduced during stressful situations such as interviews, color and math tests (20). The results of this study showed that QT time in the exercise group with mental stress is reduced, which is consistent with the results of previous studies (21, 22), but these findings were not consistent with the results of the Andrassy *et al.*'s study, which reported that QT was prolonged under stress conditions (23). In ST wave, mental stress accompanied by exercise made significant changes in the ventricular depolarization. The pattern of increasing heart rate, reducing the R-R interval and ST is similar in both groups. In the rest of the cases, the patterns of change are not different in both groups. Several studies in humans have shown that excitement and stress may affect electrocardiographic changes and ventricular repolarization (24), although the mechanism for how excitement and stress can destabilize cardiac electrophysiology and cause arrhythmias in the ventricles is not fully understood. Robinson in a study reported that hemodynamic changes during mental stress are equivalent to hemodynamic changes in the light to moderate exercise (24). Changes in hemodynamics caused by mental stress include increased cardiac output, heart rate, blood pressure, myocardial contractility, and reduced peripheral resistance (12), which probably occur through adrenergic mechanism and increased release of plasma catecholamine levels during mental stress. Falkner reported an increase in heart rate within 10 minutes of mental stress (25). Based on studies, 3 minutes was a reasonable time to increase the effects of mental stress on the cardiovascular system. In a research study, the effect of psychological stress on changes in the ST index was investigated. In this study, the effect psychologic stress from urban traffic on the ST segment time and electrocardiogram of 16 people under stressful and stress-free conditions were compared. The results showed that the mean ST time was shorter in stressful condition than stress-free condition, but this difference was not statistically significant (26). Stress affects the cardiovascular response differently, resulting in the activation of the nervous system and arrhythmia through the nerves of the heart (27). Epidemiological findings suggest a relationship between stress and the type of mortality of individuals. The two parts of the autonomic nervous system are usually interacting on the target organs in accordance with the concept of opposite processing, which is called the principle of the autonomic control of the fundamental function (27). The connection between the brain and the heart and its role on the electrocardiogram is a topic of interest. Evidence suggests that there is an interactive system in the upper centers of the brain, including the cerebral cortex, the stem, and the autonomic nervous system that can affect the electrical activity of the heart. This brain-heart interaction helps the heart's response to stress (12). Evidence suggests that the right hemisphere of the brain is often associated with negative emotions and stress and sympathetic activity, while the left hemisphere is often involved in positive emotions and excitement and parasympathetic activity. Based on a wide range of asymmetrical behaviors of brain hemispheres, Lane *et al.* suggested the lateral brain-heart hypothesis. This hypothesis states that emotions and stresses in the brain are transmitted bilaterally through the brain stem to autonomic nerves that are distributed asymmetrically in the heart's myocardium (28). Recent evidence suggests that the lateral activity of the brain during stress can irritate the heart asymmetrically, leading to heterogeneity in repolarization and electrical instability as well as arrhythmias in the heart (29). Some studies have shown that the right and left sympathetic nerves are distributed asymmetrically in the ventricle, and bilateral stimulation may create heterogeneous repolarization (12). The general belief is that increased excitement and stress is associated with the release of catecholamines (adrenaline) and increased activity of the sympathetic system. But some excitements and stresses seem to be associated with parasympathetic activity. In the meantime, whether different kinds of excitement and stress are associated with different patterns of autonomic nervous and cortical activity is questionable. The dual challenge in this study does not have much effect on electrocardiogram changes in the heart. Sympathetic adrenal axis and HPA may not be particularly sensitive to color and mental stress tests and such things as anger are more effective in stimulating this axis, which is consistent with previous research findings in this area (29).

Conclusion

The pattern of changes in the electrical waves of the heart applied in this study was similar in two groups of moderate intensity exercise with mental stress and without mental stress.

Ethical issues

The study was approved by the Research Ethics Committee of Science and Research Branch, Islamic Azad University, Tehran, Iran with the code IR.IAU.SRB.1396.70 and all participants signed a written informed consent regarding participation in the research project.

Authors’ contributions

All authors equally contributed to the writing and revision of this paper.

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