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Original Research

The Influence of Aqua Aerobic Exercise on Cardiac Autonomic Function and Blood Pressure in College Male Students

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ABSTRACT

Cardiac autonomic function may have beneficial adaptive changes from performing regular aqua aerobic exercise. We examined the effects of regular aqua aerobic exercise on heart rate variability and blood pressure in college male students. One hundred forty-eight subjects were randomly assigned to the aqua aerobic exercise ($n = 74$) and control ($n = 74$) groups. The aqua aerobic exercise group received training (65 to 75% of heart rate reserve) for three weeks. Blood pressure and heart rate variability were measured before and after intervention protocol in study groups. Dependent and independent t-test was used to analyze within and between group differences. The correlation between blood pressure and heart rate variability was calculated via Pearson's correlation. Within and between groups analysis showed significant effects on blood pressure and heart rate variability ($p < 0.001$) and sympathetic and parasympathetic ratio ($p < 0.05$) after performing regular aqua aerobic exercise. Also, after performing aqua aerobic exercise, the result showed a significant negative correlation between root mean square of the differences in successive R-R intervals (after $r=-0.348$, $p\leq0.003$; before $r=0.139$, $p\leq0.23$) and systolic blood pressure, positive correlation between very low frequency(after $r=0.300$, $p\leq0.010$; before $r=0.00$, $p\leq0.99$) and diastolic blood pressure, positive correlation between very low frequency (after $r=0.269$, $p\leq0.021$; before $r=-0.050$, $p\leq0.67$) and mean blood pressure and negative correlation between root mean square of the differences in successive R-R intervals (after $r=-0.232$, $p\leq0.048$; before $r=0.037$, $p\leq0.75$) and mean blood pressure. Performing the aqua aerobic exercise improved cardiac autonomic function and blood pressure levels in college male students. Also, blood pressure levels control due to aqua aerobic exercise associated with some of the heart rate variability parameters.

Key Words: Blood Pressure, Cardiac Autonomic Function, Aqua Aerobic Exercise

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Introduction

Today, cardiac autonomic dysfunction was introduced as one of the main results of inappropriate lifestyle (1-6). Previous studies have demonstrated that lifestyle change and performing regular aerobic exercise has beneficial adaptive changes in cardiac autonomic function related to the subject's age, sex, and health or disease states (7-15). But performing regular aerobic exercise in different environmental conditions such as aqua condition proposed as the kinds of aerobic exercise that it has rarely been studied.

Transmitting impulses role of the autonomic nervous system as an efferent system from the central nervous system to peripheral organs, Affect the heart rate oscillations (16). The fastest rhythms of heart rate are due to the heart contraction from sympathetic nerve activity, but the slower variations of heart rate may be related to a variety of factors, including hormunal and neural mechanisms (17). The arterial baroreflex as blood pressure regulator associated with heart rate oscillations. The arterial baroreflex by modulating a reference set point of heart rate, play an important role in maintaining blood pressure homeostasis (18). Heart rate variability (HRV) as the noninvasive method applied to evaluate the cardiac autonomic nervous system (ANS) (19). Heart rate variability refers to the beat to beat oscillations of the heart autonomic nervous system (19). The major methods of heart rate oscillations analysis can be divided into time-domain and frequency-domain methods. In time-domain as statistical methods; include the standard deviation of the average R-R intervals (SDANN), the standard deviation of NN intervals (SDNN), the percentage of normal R-R intervals that differ by 50 ms (pNN50) and the root mean square of the differences in successive R-R intervals (RMSSD). Frequency-domain methods describe the spectral components of heart rate; include the high frequency (HF) components (between 0.14 and 0.40 Hz) reflect the activity of the peripheral nervous system (PNS), low frequency (LF) components (between 0.04 and 0.15 Hz) are accepted to reflect the activity of the sympathetic nervous system. The low frequency / high frequency (LF/HF) ratio reported as the relationship between sympathetic and parasympathetic (vagal tone) activity. The two methods of HRV were important for assessed cardiac autonomic function but frequency domain methods (VLF, LF, HF, and LF/HF ratio) better describe relationships between blood pressure and heart-rate variability (20).

It seems that reduced baroreceptor sensitivity (BRS), associated with the greater sympathetic drive (7) and increased arterial stiffness (8). In the early stages of initial hypertension, neurohormonal dysregulation (9, 10) from greater sympathetic drive suggested as its etiology (7). To buffer blood pressure, sympathetic and parasympathetic nervous systems result in adaptive changes in heart rate (3, 11). The most important of these adaptive changes are heart rate reduction and a decrease in total peripheral vascular resistance (14). Many investigations have shown that the arterial resistance (12-14) and heart rate reduction (15, 21) of young men associated with the regulation of blood pressure. In similar physiological mechanisms, neurovascular contact of the left rostral ventrolateral medulla (RVLM) regulates both blood pressure (22, 23) and heart rate circadian rhythms (19). RVLM received a feedback message from the baroreflex system (24). Baroreflex system is one of the most important mechanisms that mediate both heart rate and blood pressure changes (25). With sympathetic inhibition action of RVLM, vascular total peripheral resistance reduced (vasodilatation) and with parasympathetic activation of RVLM, chronotropic regulation of the heart rate occurs (22). Thus sympathovagal balance is the main mechanism in the regulation of blood pressure. Christofaro and et al (2016) demonstrated that adolescents with higher resting heart rate (RHR) values have higher systolic blood pressure (SBP) and diastolic blood pressure (DBP) values (26). However, studies on the relationship between BP and HRV in young subjects are scarce. Thus, Variations in heart rate and blood pressure appear to be related together and exogenous factors such as aerobic exercise maybe influence on the adaptation of these two health factors. It seems that lower body negative pressure during performing aqua aerobic exercise leads to reduction in cardiac preload. So our first hypothesis is that reductions in preload from performing aqua aerobic exercise without any changes on stroke volume or blood pressure from exercise environment (only changes from exercise activity) can improve the heart rate variability in college male students and second hypothesis in this study is the relationship between blood pressure and heart rate variability before and after performing aqua aerobic exercise in college male students.

Methods and Subjects

Study design and subjects

This study was a semi experimental double-blind clinical trial with a randomized parallel group design. The statistical population of this study included all academic male students with daily recreational sports activities (more than six months) in Ardabil city. One hundred sixty male students without any cardiovascular disease aged from 20-30 years were recruited from the different academic educational centers (Mohaghegh Ardabiliuniversity, Islamic Azad University and Payamenoor University) in Ardabil city (Mean age= 26.23, SD= 3.49) and were randomly assigned to the aerobic exercise (N = 93) and control groups (N = 93). The inclusion criteria were: (26) Not having any cardiovascular, respiratory disease and disorder, (2) having a normal electrocardiogram record in the baseline, (3) not participating in sever sports and activity during the past 6 months, (4) having good sleep and awakening habits over the past 1 year, (5) no addiction to drug and cigarettes, (6) being 20 to 30 years old. The study as clinical trial study was approved by the local Institutional Research Board and Ethics Committee at the Ardabil University of Medical Sciences with code of IR.ARUMS.REC.1396.217 and performed according to the Declaration of Helsinki ethical standards and registered in international clinical trials registry platform with code of IRCT20180724040579N1. Participants gave their written informed consent before participation in this study, and at all stage of study, participants were free to withdraw from this study. Three subjects refused to participate; seven subjects did not meet inclusion criteria and one subject excluded from study for other reasons. The exclusion criteria of this research included: observing any cardiac failure in the diagnosis of a physician present in the research team during the test, irregular participation in training and any injuries during training. So, one hundred forty-nine subjects completed informed consent to participate in this study and were randomly (to equal allocation one subject removed) assigned to the aqua aerobic exercise (N = 74) and control groups (N = 74). Two subjects from the experimental group and three subjects from the control group could not complete the whole study stages, and thus our final analysis was conducted on 72 subjects experimental and 71 subjects in control groups. Descriptive information of the subjects is shown in Table 1.

Table 1. Physical characteristics and physiological responses of the subjects (Mean ± SD).

		Experimental	Control	p-value*
Sample size (n)		73	72	
Age – Mean (SD)		26.54 (3.14)	25.86 (2.74)	0.748
Sex – Male (female)		73 (0)	72 (0)	
Bodyfat – Mean (SD)		25.36 (3.27)	24.93 (3.62)	0.853
Height(cm) – mean (SD)		174.46(2.85)	175.37 (2.46)	0.924
Weight(kg) – mean (SD)		78.51 (4.55)	79.14 (5.68)	0.769
Vo2max (ml/kg/min)– mean (SD)		46.31 (3.57)	45.21 (4.84)	0.657
Heart Rate– mean (SD)	Rest	73.67 (4.09)	74.86 (2.46)	0.752
	Maximal	194.42 (5.10)	195.15 (4.26)	0.658
	Reserve	128.93 (4.27)	126.14 (3.87)	0.549
65%	Reserve	158.89 (3.13)	157.21 (2.45)	0.892
75%	Reserve	168.53 (4.26)	169.03 (3.61)	0.741

Table note: Vo2max = maximum rate of oxygen consumption; M = Mean; SD = Standard Deviation; n = number of subjects; ml = milliliter; kg = kilogram; min = minute; * = between group differences in descriptive variables were explored using kolmogrov-smirnov test

Measurements and protocol

Anthropometric measurements

Within 3 hours before the appointment, subjects were asked not to eat or drink any things and have an empty bladder before the anthropometric measurements were started. Anthropometric measurements were performed according to kinanthropometry advancement of International Society protocols (ISAK, 2001). Under laboratory conditions, all anthropometric measurements were measured by professionally trained staff. The digital scale used to weights measurement to the nearest 10 g. Measurements of body height was held by using a standard meter with 0.01 cm sensitivity. According to the protocol recommended by ISAK, eight skinfolds thickness (triceps, biceps, subscapular, supraspinal, iliac crest, abdominal, front thigh, medial calf) was measured on the right side of the subjects' body and Holtain (Holtain Ltd, Crymych, UK) skinfold caliper used for skinfold thickness measurements. The sum of seven parts of eight skinfolds thickness measurements was calculated. Durnin and Womersley equations for ages between 20-29 for males; $D = 1.1631 – (0.0632 * L)$ were used to determine the body density. D = predicted body density (g/ml), and L = log of the total of the 4 skinfold thicknesses (subscapular, triceps, biceps and iliac crest) (in mm). Using the Siri Equation: $\%BF = (495 / \text{Body Density}) – 450$, the measured density values were converted to %BF. Bruce treadmill protocol performed to VO2max measurements and effects forty-eight hours prior to the measurements of VO2max the subjects were asked not to participate in any vigorous activity or exercise to avoid any possible side.

Heart rate variability measurement

The standards developed Task Force of the North American Society of Pacing and the European Society of Cardiology and Electrophysiology used for HRV analysis (27). Time and frequency domain methods of HRV were assessed from three 5-min consecutive RR intervals at baseline, and after study intervention. For analysis of normal R-R intervals, NN, all ectopic beats were removed from electrocardiographic waveforms and interpolated beats derived from the nearest valid data replaced instead of missing data. The time domain variables analyses include: the standard deviation of NN intervals (SDNN), the standard deviation of the average R-R intervals (SDANN), the root mean square of the differences in successive R-R intervals (RMSSD), and the percentage of normal R-R intervals that differ by 50 ms (pNN50). The standard Fast Fourier spectral analyses of frequency domain measures include: very low frequency power (0.01–0.04 Hz), low-frequency power (0.04–0.15 Hz), and high-frequency power (0.15-0.4Hz). The My Patch & Vx3 + System made in American DMS-Service/Scole Engineering Company were used to measure heart rate variability. Participants were advised to attend carefully to researcher guideline: sheave and clean the area of the subject's body that electrodes were connected, for 12 h don't drink caffeine-containing substances (including tea, coffee, and cola drinks), for 24 h prior to the assessment don't use alcoholic beverages or smoking, for 48 h prior to the assessment don't do any kind of additional physical activity, during recording instructed subjects to close their eyes and avoid conversation or any movement. After 5 min of rest at temperatures of 24°C, HRV was recorded for 20 min in the supine position.

Blood pressure measurement

The study subjects were requested to maintain routine lifestyle habits with regard to diet intake and sleep time throughout the study. Before the intervention period, the average values of 2 separate visits of blood pressure measurements with an interval of 1 week were used as the baseline blood pressure value. Blood pressure measurements were conducted in the morning hours. After rested in the sitting position for at least 5 minutes, the standard mercury sphygmomanometer with appropriate cuff size was used to arterial blood pressure measurements. Thirty minutes prior to the blood pressure measurement, subjects prohibited from consuming any caffeinated products, smoking, and exercising. Blood pressure records 2 times from cuff on the left arm and when the results of second records had a difference of more than 5 mmHg from the first record, an average of the 2 measurements considered as a final reading record. SBP and DBP were read to the nearest 2 mmHg at Korotkoffs sounds phase I and V. By the formula to diastolic pressure plus one third of pulse pressure + 1/3 pulse pressure, mean arterial pressure (MAP) was calculated.

Aqua aerobic exercise protocol

The exercise protocol was conducted in 3 weeks for 21 consecutive days (28) on college male students. In the present study, all stages of aqua aerobic exercise were performed in the pool and in the shallow area. After warm-up for 15 minutes, all subjects in experimental group walked in shallow water up to the chest. The average temperature of the pool water was 26 to 28 degrees Celsius. The humidity (50-60%) and ambient temperature of the pool (26-28 ° C) were also monitored by the researcher. The aerobic training time was 70 minutes, which was approximately 30-32 meters per minute walking in water for each subject at this time. In sum, on average, in total of the 70 minutes of exercise, each subject traveled approximately a distance of 2160 meters. In addition to controlling the distance of exercise, during the aqua aerobic exercise program the subjects used pulse monitors (Polar Electro Oy Professoriate 5, Polar, US6584344, FI-90440 KEMPELE, Finland) to ensure that they were exercising at the appropriate intensity(65 to 75% of heart rate reserve). After completing the exercise, the cooling and recycling exercises were performed for 10 minutes, including stretching and lying in the water. During the intervention period, the control group was remained in the relaxation state in water environment without performing any activity.

Statistical analysis

Data analyses were conducted with the statistical software SPSS for Windows, version 24.0. The normality of variance of collected data was confirmed by Shapiro-Wilk test. Dependent and independent t-test were used to analyze within and between group differences. The correlation between blood pressure and heart rate variability was calculated via Pearson’s correlation. A significance level of $p < 0.05$ was used for all statistical analysis.

Results

Blood pressure and aqua aerobics exercise

Within group analysis showed significant differences between pre-intervention and post-intervention measurements for experimental group in SBP ($p < 0.001$), DBP ($p < 0.001$) and MAP ($p < 0.001$) measurements. Between-group comparisons outcome measures showed no significant difference between control and experimental groups in the pre-intervention of SBP ($p < 0.19$), DBP ($p < 0.81$) and MAP ($p < 0.13$),but significant between-group differences in the post-intervention in SBP ($p < 0.001$; % -0.40 vs % – 4.10 changes from pre-test, respectively), DBP ($p < 0.001$; % -0.16 vs % – 1.99

changes from pre-test, respectively) and MAP (p < 0.001; % -0.30 vs % – 2.92 changes from pre-test, respectively).

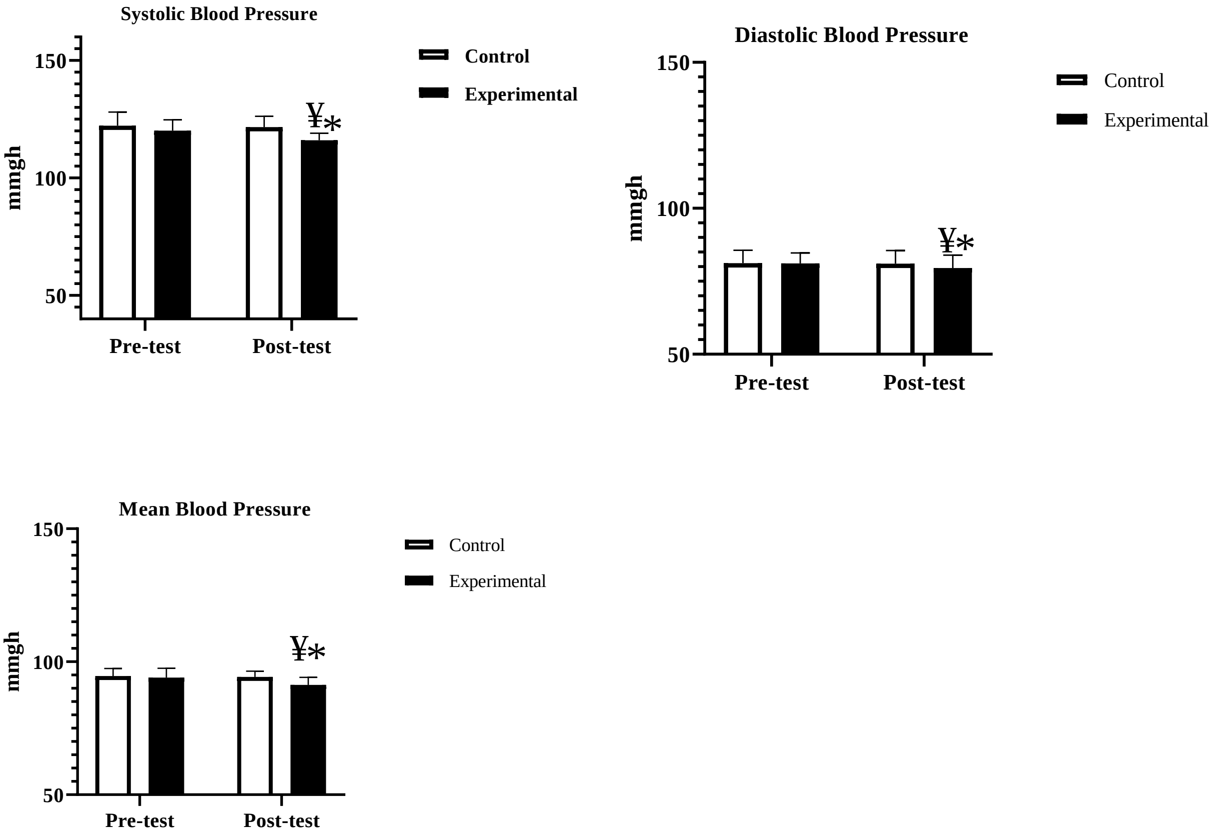

Figure 1. Systolic, diastolic and mean blood pressures measured at baseline and after participated in regular aqua aerobic exercise in college male students. Values are shown as mean ±SEM. p＜0.05. (*; Within group differences, ¥; Between-group differences).

Heart rate variability and aqua aerobics exercise

Within group analysis showed significant differences between pre-intervention and post-intervention measurements for experimental group in SDNN (p < 0.001), SDANN (p < 0.001), pNN50 (p < 0.001) and rMSSD (p < 0.001) measurements. Between-group comparisons outcome measures showed no significant difference between control and experimental groups in the pre-intervention of SDNN (p < 0.19), SDANN (p < 0.27), pNN50 (p < 0.35) and rMSSD (p < 0.36), but significant between-group differences in the post-intervention in SDNN (p < 0.001; % 0.26 vs % 4.82 changes from pre-test, respectively), SDANN (p < 0.001; % 2.47 vs % – 18.84 changes from pre-test, respectively), pNN50 (p < 0.001; % 1.99 vs % – 30.46 changes from pre-test, respectively) and rMSSD (p < 0.001; % 1.74 vs % – 25.10 changes from pre-test, respectively).

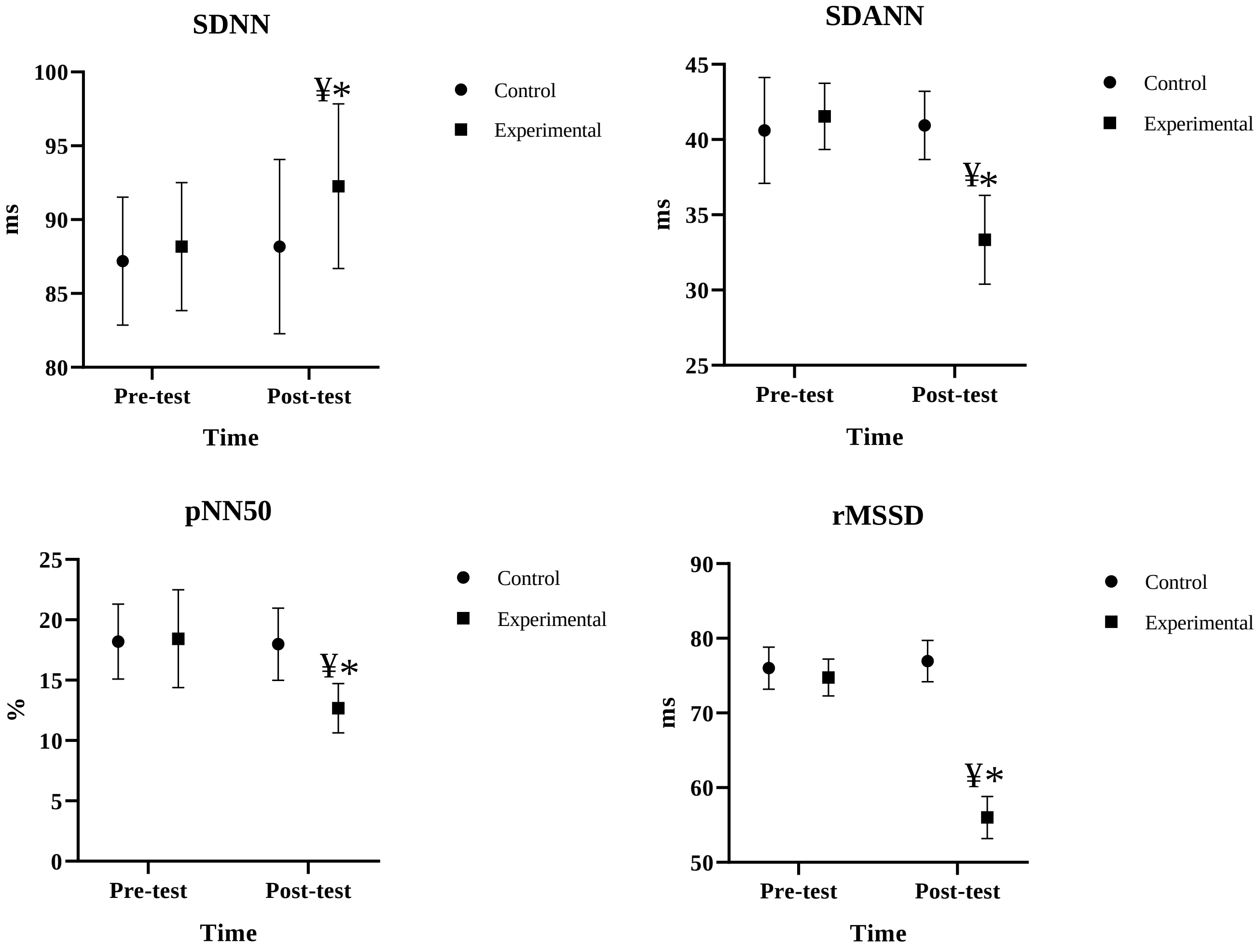

Figure 2. Mean and SD change in SDNN= standard deviation of all NN intervals; SDANN= standard deviation of the averages of NN intervals in all 5-minute segments of the entire recording; pNN50= number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording divided by the total number of all NN intervals and rMSSD= the square root of the mean of the sum of the squares of differences between adjacent NN intervals at baseline and after participated in regular aqua aerobic exercise in college male students. Values are shown as mean ±SEM. $p < 0.05$.(*; Within group differences, ¥; Between-group differences).

Pre and post-intervention measurements for experimental group in VLF ($p < 0.001$), LF ($p < 0.0001$), HF ($t = 15.30$, $p < 0.001$) measurements showed significant differences, but non-significant differences in LF/HF ($p < 0.578$) measurement. Between-group comparisons outcome measures showed no significant difference between control and experimental groups in the pre-intervention of VLF ($p < 0.57$), LF ($p < 0.84$), HF ($p < 0.10$) and LF/HF ($p < 0.45$), but significant between-group differences in the post-intervention in VLF ($p < 0.001$; % 1.32 vs % - 7.77 changes from pre-test, respectively), LF ($p < 0.001$; % 0.92 vs % – 19.45 changes from pre-test, respectively), HF ($p < 0.001$; % 4.70 vs % – 18.97 changes from pre-test, respectively) and LF/HF ($p < 0.041$; % -2.95 vs % – 0.93 changes from pre-test, respectively).

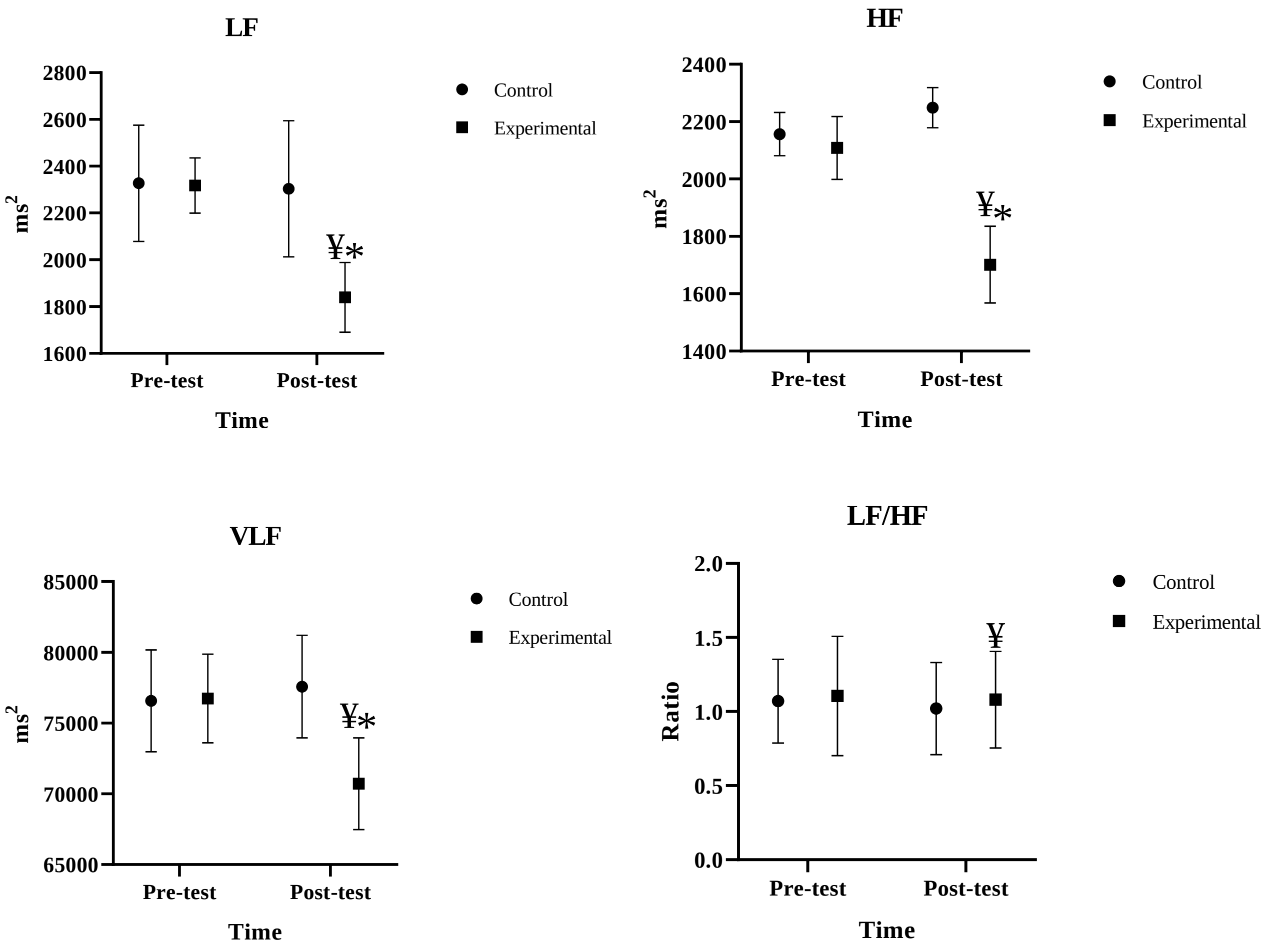

Figure 3.Mean and SD change in VLF= Very Low Frequency; LF= Low Frequency; HF= High Frequency; LF/HF= Low Frequency to High Frequency ratio at baseline and after participated in regular aqua aerobic exercise in college male students. Values are shown as mean ±SEM. p＜0.05. (*; Within group differences, ¥; Between-group differences).

Correlation between Blood pressure and Heart rate variability

The Pearson correlation between HRV and BP variables in young men at baseline and after participation in regular aqua aerobic exercise is presented in Table 2. In control group SBP, DBP and MAP showed a non-significant correlation with all the HRV measures at baseline and post period measurements. In experimental group SBP, DBP and MAP showed a non-significant correlation with all the HRV measures at baseline and post period measurements, with the exception of significant negative correlation between rMSSD($r=-0.348$, $p\leq0.003$) and SBP, positive correlation between VLF($r=0.300$, $p\leq0.010$) and DBP, Positive correlation between VLF($r=0.269$, $p\leq0.021$) and MAP and negative correlation between rMSSD($r=-0.232$, $p\leq0.048$) and MAP in post period measurements.

Table 2. Pearson correlation between HRV and SBP variables in college male students at baseline and after participated in regular aqua aerobic exercise

	Frequency-domain				Time-domain			
	VLF	LF	HF	LF/HF	rMSSD	SDNN	SDANN	pNN50
Control Group								
SBPpre	-0.051	0.230	0.147	0.144	-0.050	-0.075	-0.052	0.060
p-Value	0.669	0.052	0.217	0.228		0.676	0.529	0.664
0.616								
SBPpost	-0.022	0.110	-0.010	0.109	0.073	-0.144	0.092	-0.152
p-Value	0.857	0.356	0.931	0.363		0.540	0.228	0.440
0.201								
DBPpre	-0.170	0.098	0.019	0.078	-0.126	-0.079	-0.208	0.105
p-Value	0.154	0.412	0.871	0.517		0.292	0.507	0.080
0.379								
DBPpost	0.090	-0.198	0.012	-0.223	-0.203	0.075	0.064	-0.218
p-Value	0.450	0.056	0.923	0.059		0.062	0.529	0.595
0.066								
MAPpre	-0.173	0.205	0.094	0.142	-0.135	-0.108	-0.207	0.122
p-Value	0.145	0.083	0.433	0.233		0.258	0.366	0.081
0.305								
MAPpost	0.057	-0.121	0.002	-0.102	-0.164	-0.039	-0.114	-0.277
p-Value	0.636	0.313	0.986	0.392		0.169	0.747	0.342
0.019								
Experimental Group								
SBPpre	-0.068	-0.043	0.150	-0.143	0.139	-0.02	-0.011	-0.067
p-Value	0.570	0.716	0.205	0.227		0.239	0.824	0.924
0.57								
SBPpost	-0.003	0.004	-0.121	0.073	-0.348	0.093	0.037	0.068
p-Value	0.978	0.971	0.307	0.540		0.003	0.435	0.755
0.524								
DBPpre	0.000	-0.173	-0.043	-0.095	-0.093	-0.209	0.030	0.161
p-Value	0.999	0.143	0.721	0.423		0.433	0.075	0.800
0.175								
DBPpost	0.300	-0.047	-0.067	0.008	0.019	-0.106	0.156	-0.103
p-Value	0.010	0.691	0.575	0.946		0.871	-0.373	0.187
0.386								
MAPpre	-0.050	-0.155	0.081	-0.174	0.037	-0.168	0.030	0.064
p-Value	0.673	0.190	0.494	0.141		0.754	0.155	0.802
0.590								
MAPpost	0.269	-0.040	-0.147	-0.060	-0.232	-0.029	0.168	-0.045
p-Value	0.021	0.739	0.214	0.616		0.048	0.807	0.156
0.707								

Table note: Data in bold for the R value indicate significant difference as mean ±SEM. p＜0.05 and p＜0.01.

Abbreviations: SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MAP= Mean Atrial Pressure; LF= Low Frequency; HF= High Frequency; VLF= Very Low Frequency; LF/HF= Low Frequency to High Frequency ratio; rMSSD= the square root of the mean of the sum of the squares of differences between adjacent NN intervals; SDNN= standard deviation of all NN intervals; SDANN=

standard deviation of the averages of NN intervals in all 5-minute segments of the entire recording; pNN50= number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording divided by the total number of all NN intervals.

Discussion

We found that performing regular aqua aerobic exercise significantly improved heart rate variability and blood pressure levels, but these effects were not associated with the strongest effects on correlations between heart rate variability and blood pressure. Our findings support the main concept that cardiac autonomic functions improved from participating in regular aqua aerobic exercise, but other related factors associated with heart rate variability and blood pressure correlations. It seems that participation in the regular aqua aerobic exercise with similar physiological mechanisms improved blood pressure levels and cardiac autonomic functions. Several studies supported our results in improved effectiveness of performing regular aqua aerobic exercise on heart rate variability (28, 29) and blood pressure (30). On the other hand, some studies (31) reported that performing non-consecutive day's aerobic exercise in young men was non-significant effects on MAP and HRV. This means that performing regular aerobic exercise in consecutive days increases the effects of aerobic exercise on heart rate variability and blood pressure. Accordingly, in the animal study, Konarska and et al (1989) showed that daily stressful stimulation of sympathetic-adrenal medullary for 26 consecutive days modulate basal plasma levels of norepinephrine and epinephrine in rats (32).This means that regular stimulations of sympathetic-adrenal medullary from baroreflex sensitivity modulate sympathetic outflow and controlled blood pressure. So performing regular aqua aerobic exercise stimulates baroreflex system and with this mechanism regulate and reset medullary brain regions set points.

In addition to performing aerobic exercise in consecutive days, performing aerobic exercise in the aquatic environment due to lower body negative pressure can also be discussed as a rational hypothesis. Li and et al (2012) mentioned that lower body negative pressure stimulation from entering in lower body negative pressure chamber results to cortical activation of limbic and prefrontal cortex and subsequently lead to osmopressor response in cardiac central autonomic systems. Osmopressor response with mechanism of improvement in orthostatic tolerance mediated vasovagal reactions (33). As a complement to these findings, in a field study, Franke and et al(1996) reported that in comparing female runners and swimmers total peripheral resistance index was significantly higher in runners than swimmers (34). These researchers believed that exercise mode affected on cardiac pulse pressure responses from lower body negative pressure. Thus, performing aerobic exercise in the aquatic environment results to lower total vascular peripheral resistance and reductions in cardiac preload. Schmid and et al (2007) noted that exposure to thermoneutral water environment increase in central venous pressure and leads to hiegher cardiac output. So these adaptive changes from exposure to aquatic environment and performing aerobic exercise modulated a reference set point of heart rate from arterial baroreflex stimulation. Cortical structures, including the medial prefrontal cortex and insular cortex, are connected with medullary brain regions that involved in baroreceptor heart rate reflex and cardiovascular responses (9).

our second hypothesis was that the relationship between blood pressure and heart rate variability before and after performing aqua aerobic exercise in college male students. According to Mäki-Petäjä and et al (2016) study autonomic nervous system affected on pulse wave velocity in vascular and with this mechanism regulate aortic stiffness in young subjects' (9). In another related study, Saito and et al (2018) indicated that impaired parasympathetic nervous system activity associated with increased mean atrial blood pressure. In Saito and et al study the role of baroreflex sensitivity in regulating mean atrial blood pressure and heart rate variability consider as the main mechanism in the relationship of blood pressure and heart rate variability (35).

In this regard, some studies (36) investigate the relationship between blood pressure and heart rate variability and indicated that systolic blood pressure has a positive correlation with both LF and LF/HF norms and negative correlation with HF norm. Diastolic blood pressure has a positive correlation with LF/HF and a negative correlation with both LF and HF. Also, high means atrial blood pressure was associated with Low HF and mean atrial blood pressure has a positive correlation with LF/HF. These authors mentioned that lower HRV reduced vagal tone and higher sympathetic function associated with higher blood pressure values.

According to a new idea from Lutfi et al, individuals with low heart rate variability at baseline will susceptible to hypertension in 9 years of follow up (36), improving heart rate variability with participated in regular aerobic exercise may be known as an importance factorial mechanisms of blood pressure control in early stages of hypertension. In this regards, our results showed that VLF and rMSSD variables of heart rate variability has been correlations with blood pressure after participated in regular aerobic exercise. It means that cardiovascular nervous system plays an important role in blood pressure control (37). Yoshimoto and et al (2011) investigated the frequency components of systolic blood pressure variability in conscious rats and concluded that the HF component of systolic blood pressure variability reflects b-adrenoceptor-mediated cardiac sympathetic function. It means that heart rate and blood pressure variability almost have a similar neural mechanism (38).

Some studies observed that time-domain heart rate variability indices were directly correlated with blood pulse pressure amplification and believed that this association was stronger in obese compare in lean people (39) and reported that autonomic nervous system activity is a critical determinant of BP rhythmic fluctuations. Xie and et al (2012) determine the relationship between heart rate variability and blood pressure in Chinese children and indicated that compared to normal blood pressure children, children with hypertension had reduced heart rate variability and weakened circadian rhythm (38). Liakos and et al (2015) reported a negative correlation between blood pressure and heart rate. This results constantly with many of heart rate variability indices outcomes in our study (40). Furlan and et al reported that spontaneous fluctuations of BP variability similar to those in muscle sympathetic nerve activity (MSNA) at low frequencies (41). A more novel observation of our study is that performing regular aqua aerobic exercise associated with HRV and BP rhythmic fluctuations. Other studies reported that variations in autonomic nervous system not associated with blood pressure regulations, Graff et al (2013) investigate the relationship between blood pressure and heart rate variability in healthy subjects and concluded that incomplete oxygen breathing, and the autonomic nervous system might not be the main affecter factor for cardiovascular changes (42). The results of Graff and et al study constant with our study. Finally, we should be considered some limitations of this study included monitoring of blood pressure variability concurrently with monitoring heart rate variability, measurement of the activity of the baroreceptor system.

Conclusion

Performing regular aqua aerobic exercises modulate barore flex sensitivity and improve cardiac autonomic function. This mechanism considers as the main mechanism in relationships of blood pressure and heart rate variability central regulations in college male students. Participation in regular aqua aerobic exercise improved cardiac autonomic function and results in controlling blood pressure and society healthy lifestyle. It seems that cardiac neurovascular controlling of blood pressure is one of the main important factors that modulate with aqua aerobic exercise. In sum, our findings suggest improving cardiac autonomic function with performing the regular aqua aerobic exercise as a promising treatment approach in college male students to prevent the development of initial stages of hypertension. In this line, future studies need to focus on exercise parameters (e.g., intensity, duration and mode of exercise, etc.) to further boost the magnitude, and duration of effects in these groups of society and even on other physiological parameters (43,44).

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Conflict of interest: none

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چکیده فارسی

تاثیر فعالیت ورزشی ایروبیک در آب بر عملکرد سیستم اتونوم قلبی و فشار خون در دانشجویان مرد دانشگاهی

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عملکرد سیستم اتونوم قلبی ممکن است از اجرای تمرینات هوازی منظم در آب تغییرات سازگاری داشته باشد. در این پژوهش ما اثرات فعالیت ورزش هوازی منظم در آب را بر تغییرپذیری ضربان قلب و فشار خون در دانشجویان مرد دانشگاهی بررسی کردیم. صد و چهل و هشت نفر به طور تصادفی به تمرینات هوازی درآب (تعداد = ۷۴) و گروه کنترل (تعداد = ۷۴) تقسیم شدند. گروه فعالیت ورزشی در آب به مدت سه هفته متوالی (۶۵ تا ۷۵٪ از ضربان قلب ذخیره) فعالیت ورزشی هوازی در آب را اجرا کردند. فشار خون و تغییرات ضربان قلب قبل و بعد از مداخله در گروه های تجربی و کنترل اندازه گیری شد. از آزمون t مستقل و همبسته برای تجزیه و تحلیل اختلافات درون و بین گروهها استفاده شد. جهت تحلیل همبستگی بین متغیرها از آزمون همبستگی پیرسیون استفاده شد. تحلیل درون گروهی و بین گروهی نشان داد که اجرای فعالیت ورزشی هوازی منظم در آب تأثیر معنی‌داری بر فشار خون و تغییرپذیری ضربان قلب(p ≤ ۰/۰۰۱) و تعادل سیستم‌های عصبی سمپاتیک و پاراسمپاتیک(p ≤ ۰/۰۵) دارد. همچنین ، نتایج نشان داد که بین میانگین ریشه مربعات از نظر اختلاف در فواصل متوالی موج های R و فشار خون سیستولیک همبستگی منفی معنی داری وجود دارد(بعد p ≤ ۰/۰۰۳، r=-۰/۳۴۸؛ قبل p ≤ ۰/۲۳، r=-۰/۱۳۹)، همبستگی مثبت بین فشار خون دیاستولیک و فرکانس بسیار پایین(بعد p ≤ ۰/۰۱۰، r=-۰/۳۴۸؛ قبل p ≤ ۰/۹۹، r=-۰/۰۰)، همیستگی مثبت بین فشار خون متوسط و فرکانس بسیار پایین(بعد p ≤ ۰/۰۲۱، r=-۰/۲۶۹؛ قبل p ≤ ۰/۶۷، r=-۰/۰۵۰) و همبستگی منفی بین فشار خون متوسط و میانگین ریشه مربعات از نظر اختلاف در فواصل متوالی موج های R (بعد p ≤ ۰/۰۴۸، r=-۰/۲۳۲؛ قبل p ≤ ۰/۷۵، r=۰/۰۳۷) بعد از اجرای تمرین هوازی در آب مشاهده شد. اجرای تمرین هوازی منظم در آب باعث بهبود عملکرد سیستم اتونوم قلبی و سطوح فشار خون در دانشجویان مرد دانشگاهی می‌گردد. همچنین کنترل سطوح فشار خون ناشی از تمرین هوازی در آب با برخی پارامترهای تغییرپذیری ضربان قلب مرتبط می‌باشد.

واژگان کلیدی: فشار خون ، عملکرد اتونوم قلبی ، فعالیت ورزشی هوازی درآب