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Modulation of Heart Rate Variability through Breathing Exercise in Stressed Medical Students

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Abstract

Objective: To determine the effect of blowing balloon exercise in the modulation of heart rate variability.

Design: Pretest-posttest quasi-experimental study.

Subjects and methods: Sixty students diagnosed with moderate stress based on Depression Anxiety Stress Scale (DASS) proforma were enrolled in the study. Before and after a supervised blowing balloon exercise, the participants pulmonary function tests, electrocardiograms, and DASS scores were recorded. Participants' ECGs were recorded for ten minutes using the power lab model yam 4/25T.

Results: Blowing balloon exercise resulted in a significant reduction of DASS score (p<0.001), significant improvement in pulmonary function tests (p<0.001). Among heart rate variability parameters, the participants' standard deviation of successive N-N interval, high-frequency component, and high frequency normalized units were significantly increased (p<0.05) after blowing balloon exercise. Heart rate, low-frequency normalized units, and the ratio of low-frequency normalized value to high-frequency normalized value were significantly reduced (p<0.05) after blowing balloon exercise.

Conclusions: Blowing balloon exercise enhances heart rate variability and pulmonary function tests in medical students while reducing their stress levels.

Keywords: Heart rate variability; Lab chart; Pulmonary function tests; Power lab; Stress

Introduction

Heart Rate Variability (HRV) is a physiological phenomenon reflecting the fluctuation in time interval amid successive heartbeats. HRV is a sign of healthy cardiac tissue and is essential for restoring cardiovascular homeostasis [1]. It gives people the ability to respond better and adapt to various environmental and physiological conditions [2]. Reduced HRV is associated with psychopathological problems and cardiovascular diseases, including decreased cognitive function, emotional deregulation, psychiatric disorders, hypertension, diabetic autonomic neuropathy, and sudden cardiac death [3-6].

Cardiac Vagal Neurons (cVPNs) originate from the Dorsal Vagal Motor Nucleus (DVMN) and Nucleus Ambiguous (NA) of the brainstem [7]. The respiratory rhythm of the body influences Pattern of discharge of cardiac vagal neurons. These neurons receive inhibitory input from pulmonary stretch receptors during inspiration; as a result, vagal nerve activity is reduced during inspiration. While they receive powerful excitatory input from pulmonary stretch receptors during the post inspiration state, as a consequence, vagal nerve activity is increased [8]. This cyclical oscillation of the vagal nerve activity results in heart rate variability [9].

Stress is a psychological condition that disrupts the body's internal homeostasis and directly impacts several physiological systems [10]. Review of the literature shows that 7.5% of medical students suffer from low levels of stress, while 71.67% suffer from moderate levels of stress and 20.83% of students suffer from high levels of stress [11]. Stress upsurges the cardiac sympathetic fiber's activity and reduces the cardiac vagal fiber's activity [12]. Decreased cardiac vagal tone is a prognostic marker for various cardiovascular diseases. It is linked with childhood behavior problems, anxiety, and impulsive control disorders [13,14].

HRV can be used to study stress-induced sympathovagal imbalance. Calculating R-R intervals (RMSSD), a time-domain component of HRV, reveals the overall effect of the sympathetic or parasympathetic nervous system on heart rate. HRV spectral analysis can analyze beat to beat frequency variations in terms of HF and LF components [15]. Vagal tone regulates HRV high-frequency component. Changes in the lower frequency component of HRV reflect changes in vagal and sympathetic tone outflow. Sympathovagal balance is reflected by LF/HF ratio. Stress increases LF/HF ratio and reduces the HF component of

HRV [16]. To reduce distribution scenes, HRV LF and HF components are measured in terms of normalized units.

An individual's capability to cope with stress is known as resilience. Stress resilience levels fluctuate within a person and from person to person because of the variation in the basal level of an individual's vagal tone [17]. Individuals with enhanced resting cardiac vagal tone and HRV are considered more resilient and exhibit speedy recovery towards basal cardiac functioning after a stressful event [18].

Various strategies can be used to enhance stress resilience levels of an individual, including group discussions, counseling sessions, and physical exercises, including cycling, jogging and running [19]. Literature has shown that breathing exercises reduce stress on the body and enhance mental and physical health. Breathing exercises improve respiratory and cardiovascular functions of the body by strengthening the parasympathetic tone and reducing the sympathetic tone [20]. The goal of breathing exercises is to relax quickly and improve respiratory efficiency. Breathing exercises have been shown to enhance pulmonary function tests [21].

Breathing exercises include yoga, blowing a balloon, slow lip pursing, and other exercises. Blowing balloon therapy has been used in oral gymnastics to improve pulmonary function tests in smokers, treat obstructive sleep apnea syndrome, reduce stress in medical students, and rehabilitate stroke patients [22,23]. Respiratory muscles strengthen by the balloon-blowing exercise result in an increase in lung compliance and an increase in VC, FVC, and FEV1/FVC [24]. However, the role of blowing balloon therapy in increasing heart rate variability has not yet been studied. So, the current study aims to determine the effect of blowing balloon exercise in the modulation of heart rate variability.

Materials and Methods

This pretest-posttest quasi-experimental study was conducted in the power lab room at Islamic international medical college, Rawalpindi, with the ethics review committee's consent. Two hundred MBBS students of the Islamic international medical college were given a 21 items DASS questionnaire. Students aged 18-25 with a DASS proforma score of 19-25, no oral lesions, and no history of bronchodilators was eligible. 86 out of 200 students were found eligible. Amid the eligible candidates, 60 students were included in the study by using the balloting method. After informed written consent, all research participants were requested to come to the department's Power Lab Room between 9.00 and 11.00 a.m. They were told not to consume tea or coffee. Participants were asked to sit and relax for five minutes at first. Participants were asked to take off their belts, keys, and other metal objects. There was a concerted effort to keep the room as quiet as possible.

According to North American Society of pacing electrophysiology and American thoracic society guidelines, the Yam 4/25T power lab model recorded a ten-minute ECG and pulmonary function test of subjects in a seated position. Recorded ECGs of participants were analyzed for heart rate, Root Mean Square of the Successive R-R interval Differences (RMSSD), the low-frequency component (both absolute and normalized units), high-frequency component (both absolute and normalized units), and the ratio of low to high-frequency components normalized units using fast Fourier transform technology. Amid pulmonary function tests, tidal volume, vital capacity, forced vital capacity, forced expiratory volume in one second, and the ratio of forced expiratory volume in one second to forced vital capacity was measured.

The participants were subsequently put to supervise blowing balloon exercise three days a week for six consecutive weeks. The participants were instructed to maintain an upright posture, inhale fully, and then exhale fully into balloon mouths. With this practice, one mini-set of blowing balloon exercises was completed. The repetition of mini-sets three times results in the completion of one set. Participants completed three sets of the blowing balloon exercise in a single day. The balloons used by all participants were of the same quality. Participants were given a 2 to 3 minute rest between each set to avoid fatigue. Participants were advised to stop exercising if they felt dizzy at any point. Participants were advised not to hold their breath for more than five seconds after exhaling to avoid valsalva. DASS score, pulmonary function tests, and electrocardiograms of study participants were measured again after completion of blowing balloon exercise. The statistical analysis of the data was carried out with the help of the SPSS version 21. Statistical results from quantitative data were described as mean plus standard deviation (mean+SD). Paired t-test was used to compare the data before and after the blowing balloon exercise. A p-value of less than 0.05 was considered statistically significant.

Results

The DASS proforma was first delivered to 200 students, with 183 students returning the proforma after receiving it (response rate 91.5 percent). Sixty individuals were chosen by a simple random sample procedure using the balloting technique out of 86 students who fulfilled the eligibility criteria. Everyone who participated in the study completed all the sessions of blowing balloon exercise without missing a single session, resulting in an overall compliance rate of 100 percent. Six weeks of blowing balloon exercise resulted in a substantial reduction in the participants' DASS score from 21.87 ± 2.01 to 13.41 ± 4.29 (p-value<0.05).

After completing the blowing balloon exercise, the indices of pulmonary function tests showed a considerable improvement. Tidal volume (milliliter's) of the participants were improved from 517.72 ± 48.57 to 638.65 ± 86.02 (p value<.000*). Vital capacity (liters) of the participants were improved significantly from 3.51± 0.56 to 4.83 ± 0.77 (p value<.000*). Forced vital capacity (liters) of the participants were improved significantly from 3.09 ± 0.57 to 4.45 ± 0.78 (p value<.000*). Forced expiratory volume in one second (liters) of the participants were improved significantly from 2.76 ± 0.54 to 4.13 ± 0.77 (p value<.000*). Forced expiratory volume in one second/Forced vital capacity (%) of the participants were improved significantly from 89.36 ± 4.54 to 92.66 ± 4.27 (p value<.000*).

Among the time domain components of HRV, heart rate and Standard deviation of successive N-N interval of the participants was significantly improved (P<0.05) after blowing balloon exercise, as depicted in Table 1. Among the frequency domain parameters of heart rate variability, high-frequency component and high frequency normalized units of the participants were significantly increased. In contrast, low-frequency normalized units and the ratio of low-frequency normalized value to high-frequency normalized value was significantly decreased after blowing balloon exercise. No significant change was observed after blowing balloon exercise in the low-frequency component (Table 1).

Table 1: Comparison of heart rate variability parameters before and after blowing balloon exercise.

Heart rate variability parameter	Values before blowing balloons exercise Mean ± S.D N=60	Values afterblowing balloons exercise Mean ± S.D N=60	p-value
Heart rate (beats/min)	80.30 ± 4.60	73.45 ± 3.43	<0.05*
SDNN (msec)	77.21 ± 9.82	74.75 ± 9.46	<0.05*
LF component (ms^2)	840.69 ± 367.47	824.53 ± 312.72	>0.05
High component frequency (ms^2)	593.26 ± 318.12	851.21 ± 452.26	<0.05*
Low frequency normalized units	61.64 ± 15.27	52.89 ± 15.12	<0.05*
High frequency normalized units	33.25 ± 10.52	46.22 ± 13.37	<0.05*
LF/HF nu	2.29 ±1.02	1.29 ± 0.74	<0.05*
*p value<0.05 is significant.			

Discussion

Medical students often experience stress and it is a significant issue throughout the globe. It impacts the functioning and effects of the autonomic nervous system. Heart rate variability components, including time and frequency domain components; represent the activity of the autonomic nervous system. Breathing exercises help to obtain better autonomic function in our body. This research aims to investigate whether or not the blowing balloon exercise improves the time and frequency components of heart rate variability.

Results of this study are in line with findings which showed that blowing balloon exercise for four weeks by elderly smokers increased VC, FVC, FEV1, FEV1/FVC, PEF [24]. Compared to these studies, this study was conducted on stressed otherwise healthy nonsmoker medical students.

Researched healthy subjects and performed Bhastrika pranayama exercise five times a day for three months [25]. In this exercise, participants took slow and deep inhalation from the nose, followed by forceful exhalation, which improved study participants' TV, FVC, and FEV1/FVC (p<0.02). Pulmonary function indices (TV, VC, FVC, FEV1, FEV1/FVC) of the participants of this study showed significant improvement (p<0.000). While used a simple, forceful exhalation for their Bhastrika pranayama exercise, our study participants exhaled against resistance with a blowing balloon.

Enhanced pulmonary function tests are associated with increased HRV. A literature review shows that several pulmonary function parameters, for example, FEV1 and FVC, are significantly correlated with enhanced vagal activity (HRV) [26,27]. The current study showed that blowing balloon exercise increased pulmonary function tests and improved heart rate variability parameters towards parasympathetic dominance. This study's findings support those of Cheng ST, et al. who concluded that bicycling exercise improved HF components (absolute and normalized), reduced LF components (absolute and normalized), improved LF/HF ratio, and improved pulmonary function tests.

Our study also supports the findings of Tulppo M, et al. which concluded that exercise training (treadmill) for four weeks resulted in a significant enhancement of HF component and reduction in heart rate and LF/HF ratio, indicating that exercise resulted in the shift of autonomic balance towards parasympathetic dominance [28]. However, Cheng ST, et al. and Tulppo M, et al. also reported that bicycling exercise and treadmill exercise resulted in a significant decrease in the LF component of heart rate variability, which was not reduced due to blowing balloon exercise done by our participants. Review of the literature shows that exercises like treadmill and bicycling alter the sympathovagal balance towards parasympathetic dominance by reducing sympathetic activity. In contrast to these studies, the blowing balloon exercise alters sympathovagal balance towards parasympathetic dominance by enhancing parasympathetic activity. Blowing balloon increases the afferent cardiac vagal nerve fibers activity *via* stimulating slow adapting pulmonary stretch receptors, which might be the possible reason why the LF component of HRV was not reduced as a result of blowing balloon exercise.

Poyhonen M, et al. conducted a study to investigate the effect of respiratory patterns on HRV and concluded that voluntary increase in tidal volume enhances the HF component of HRV, indicating vagal dominance [29]. Blowing balloon exercise conducted in our study also resulted in significant improvement in tidal volume and HF component of HRV.

Hepburn H, et al. mentioned in their study that respiratory training for six weeks by using Hepburn Heart and Lung Exerciser (HHALE) increased pulmonary function tests (FVC, FEV1), HF component of HRV, and a decrease in heart rate, LF/HF ratio of HRV [30]. Our study is in line with this study as blowing balloon also increases pulmonary function tests and alters HRV parameters towards parasympathetic dominance. HHALE increases resistance to airflow and ventilation depth. Increased depth of respiration favors parasympathetic dominance. Blowing balloon exercise also increased airflow resistance, which increased depth of respiration and parasympathetic nerve activity. Rather than a special exercise machine, our participants used inexpensive balloons. Blowing a balloon increases excitatory signals from slowly adapting pulmonary stretch receptors to the preganglionic cardiac vagal nerve. Increased vagal nerve activity favors parasympathetic dominance.

Conclusion

According to our findings, blowing balloons exercise increases heart rate variability and pulmonary function tests in medical students while decreasing their stress level.

Conflict of Interest

Authors declare no conflict of interests.

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