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CLINICAL & BASIC RESEARCH

Effects of Pranayam Breathing on Respiratory Pressures and Sympathovagal Balance of Patients with Chronic Airflow Limitation and in Control Subjects

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آثار تنفس البرانايام على ضغط الجهاز التنفسي وعلى التوازن الودّي المُبهمي للمرضى الذين يعانون من ضيق التنفس المزمن وغيرهم من الطبيعيين

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الملخص:الهدف: مقارنة آثار تنفس البرانايام على قوة عضلات التنفس كمقياس للحد الأقصى لضغط عمليات الشهيق والزفير، و قياسات التنفس ذات العلاقة لدى المرضى المصابين بالانسداد الرئوي المزمن و غيرهم من الطبيعيين مع التوازن المبهمي لكلا المجموعتين. **الطريقة:** تم إجراء هذا البحث في قسم علم وظائف الأعضاء السريرية بمستشفى جامعة السلطان قابوس في سلطنة عُمان. خضع للبحث أحد عشر مريضا (متوسط أعمارهم بين 20.56 ± 43.91 سنة، ومؤشر كتلة أجسامهم 21.9 ± 5.5 كجم/م^2)، وستة أشخاص طبيعيين (متوسط أعمارهم بين 43.5 ± 14.6 سنة، ومؤشر كتلة أجسامهم 25.4 ± 3.2 كجم/م^2) تم تعليمهم و تدريبهم على تنفس البرانايام ، وقمنا بتسجيل قياسات الجهاز التنفسي والقلبي الوعائي. ولوحظت صحة التنفس كمقياس الإبصار المضاهي. كما تم قياس مؤشرات قيم التنفس المتوقعة بالنسب المئوية. **النتائج:** كانت مؤشرات التنفس لمرضى الجهاز التنفسي أدنى بكثير من غيرهم من الطبيعيين ولم يتحسن الحد الأقصى لضغط التنفس عند المرضى حتى بعد تنفس البرانايام ، إلا أنهم أبدوا تحسنا واضحا من خلال مقياس الإبصار المضاهي (5.4 ± 2.4 إلى 7.2 ± 1.2) ($P < 0.03$) . أما الأشخاص الطبيعيين فقد أبدوا زيادة واضحة في ضغط الشهيق الأقصى بعد تمرين البرانايام، بينما لم تكن هناك تغيرات في مؤشرات قياس التنفس الأخرى. أظهر الأشخاص الطبيعيون ارتفاعا واضحا في ضغط الدم الانقباضي ومنسب السكتة بعد قيامهم بالتمرين . كما تحول التوازن الودي المبهمي إلى ودي في كلتا المجموعتين بعد ممارستهم للتمرين. **الخلاصة:** يدل التحسن في ضغط الشهيق الأقصى على التأثير الايجابي لتمرين البرانايام عند الأشخاص الطبيعيين، إلا أنه قد لا يكون التمرين المناسب لإحداث تغيرات في مؤشرات الجهاز التنفسي عند المرضى المصابين بالانسداد التنفسي المزمن. أما التحسن في مقياس الإبصار المضاهي الإيجابي عند المرضى فهو مؤشر على تحسن في ضيق التنفس وجودة الحياة.

مفتاح الكلمات: مرض الانسداد الرئوي المزمن؛ تمرين ؛ الجهاز العصبي المستقل ، ضغط الجهاز التنفسي ؛ الإبصار المُضاهي الإيجابي.

ABSTRACT: ***Objectives:*** The objective of this study was to compare the effects of Pranayam breathing on respiratory muscle strength measured as maximum expiratory and inspiratory pressures (MEP and MIP) and relevant spirometry parameters in patients with chronic obstructive pulmonary disease (COPD) and in control subjects, and on the sympatho-vagal balance in both the groups. ***Methods:*** The research was performed in the Clinical Physiology Department, Sultan Qaboos University Hospital, Oman. Eleven patients (mean age 43.91 ± 20.56 yr; mean BMI 21.9 ± 5.5 kg/m^2) and 6 controls (43.5 ± 14.6yr; 25.4 ± 3.2 kg/m^2) learnt and practised Pranayam. Their respiratory and cardiovascular parameters were recorded. Their respiratory "well being" was noted as a visual analogue score (VAS). The respiratory parameters were expressed as a percentage change of predicted values. ***Results:*** Patients' respiratory parameters were significantly lower than those of controls. Patients' maximum respiratory pressures did not improve after Pranayam; however, they showed significant improvement in VAS 5.4 ± 2.4 to 7.2 ± 1.2 ($P < 0.03$). Controls showed significant increase in MIP after Pranayam exercises. There were no changes in other spirometry indices. Controls showed significant increase in their systolic blood pressure and stroke index after exercise. The vago-sympathetic balance shifted towards sympathetic in both patients and controls after exercise. ***Conclusion:*** The improvement in MIP in controls indicated the positive effect of Pranayam exercise; however, it may not be an adequately stressful exercise to produce changes in the respiratory parameters of COPD patients. The increase in VAS in patients suggested improvement in respiratory distress and quality of life.

Keywords: COPD; Pranayam Exercise; Autonomic Nervous System; Respiratory Pressures; VAS

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Advances in Knowledge

1. *This paper contributes to advancing understanding of the haemodynamic and autonomic reflex responses to Pranayam exercise in chronic obstructive pulmonary disease (COPD) /chronic airflow limitation patients.*

Application to Patient Care

1. *Regular Pranayam breathing exercise may improve the respiratory distress and quality of life of patients having COPD/ chronic airflow limitation.*
2. *Regular Pranayam breathing exercise may improve the inspiratory muscle strength in control subjects.*

By definition, chronic obstructive pulmonary disease (COPD) is "a state that is characterised by the presence of airflow limitation which is not fully reversible. The airflow limitation is usually progressive and associated with an abnormal inflammatory response of the lung to noxious particles or gases. COPD is a preventable and treatable disease with significant extrapulmonary effects that may contribute to its severity in individual patients. The chronic airflow limitation characteristic of COPD is caused by a mixture of small airway disease (obstructive bronchiolitis) and parenchymal destruction (emphysema). The relative contribution of these may vary from person to person".[1,2] COPD has also been associated with inspiratory and expiratory muscle weakness which may contribute to the sensation of dyspnea.[3-5] Respiratory muscle weakness was confirmed by the low maximal inspiratory (MIP) and expiratory (MEP) pressures generated by patients with COPD.[6] Enhancing respiratory muscle strength with physical training has been found to have some success in alleviating the respiratory distress of such patients.[7,8] Most of this training involved breathing against pressure loads or endurance training.[9] Respiratory muscle training in patients of COPD decreased the sense of dyspnea during exercise and improved tolerance to exercise, but the effect on MEP and MIP was contradictory.[10,11] The intense training may have caused distress to the already compromised patients.

A respiratory manoeuvre which does not accentuate the respiratory distress of COPD patients, but at the same time improves respiratory muscle strength and spirometry parameters while allaying the sense of dyspnea and fatigue, would be a more acceptable proposition.

Sub-clinical cardiovascular autonomic neuropathy has been known to occur in patients of COPD[12] even in the early stages of the disease.[13] The basic pathophysiology involved is likely to be chronic hypoxia as autonomic modulation could be brought about by supplemental oxygen breathing.[14] Patients with chronic airflow limitation are thus under a constant physiological stress which needs to be alleviated if their quality of life is to be improved.

Pranayam is a non-distressing, slow, yogic breathing exercise which modifies autonomic functions in control subjects.[15] Others have used it with varying success as an adjunct to existing therapy for COPD patients.[16-18] However, respiratory pressures were not measured in any of the studies involving Pranayam. We hypothesised that Pranayam breathing exercises might lead to clinical provement with positive changes in MIP and MEP as well as readjustments of the vago-sympathetic balance of the cardiovascular system. This study aimed to examine this hypothesis and compare their respiratory, haemodynamic and autonomic parameters with control subjects who also undertook Pranayam breathing exercises.

Methods

Eleven patients (7 males; 4 female; mean ± standard deviation (SD): age 43.9 + 20.6 yr; body mass index (BMI) 21.9 + 5.52 kg/m2) and 6 control subjects (6 males; 2 female; 43.5 + 14.6yr, BMI 25.4 + 3.2 kg/m2) volunteered for the study which was approved by the Ethical Committee of the College of Medicine & Health Sciences at Sultan Qaboos University (SQU). Written consent was obtained from all participants. Inclusion criteria for patients were: 1) registered as patients of COPD/chronic airflow limitation with the Respiratory Clinic at SQU Hospital; 2) forced expiratory volume 1 sec (FEV_1) < 60% of predicted, and forced expiratory flow (FEF) of 25–75% at < 40% predicted. None of the selected patients suffered from diabetes mellitus, hypertension or congestive cardiac failure. They continued with their prescribed treatment, if any, throughout the experiment. The control subjects were volunteers from among departmental staff.

The patients and the control subjects were asked to follow the breathing sequence as per Pal *et al.*[13] as follows; Close one nostril with the thumb; Inhale slowly over a count of 6 seconds; At the end of the inhalation, close both the nostrils; Count to 6; Open the second nostril and exhale slowly over a count of 6 seconds; Inhale with the same nostril slowly over 6 seconds; This constituted a single sequence. This was to be repeated for 30 minutes each day for at least 5 days a week for 3 months.

Spirometry indices were measured using Medgraphics (Elite Dx, USA) which was calibrated daily at the start of the day, and zero flow of the pneumotach was confirmed prior to testing. All measurements were performed by one/two trained technologists, and measurements were made using standard procedures.[19] Minimum and maximum respiratory pressures (MIP, MEP)[20] were measured as described in the American Thoracic Society/European Respiratory Society statement.[21] To elaborate, for the measurement of the MEP, after connecting to the pneumotach, the subjects breathed normally at tidal volume for six breaths. Following this, s/he inspired maximally to total lung capacity (TLC). At this point, the shutter of the body box was occluded, and the patient breathed out using maximal force which could be sustained for at least 3 seconds against the closed shutter.

At least three to four satisfactory attempts were recorded, and the best effort was included for the analysis. For recording the MIP, the patient/subject started the manoeuvre at the end of a maximal expiration to residual volume (RV), and inhaled maximally against the closed shutter. Follow-up lung function testing was done after three months practice of Pranayam breathing. Most studies also have this time sequence in assessing effects of respiratory training in COPD patients.[22] The VAS (visual analogue score) for respiratory well being (scale 0–10) was recorded at the first visit and after 3 months of breathing exercise.

Haemodynamic and autonomic measurements were taken as follows. Beat-to-beat haemodynamic and autonomic parameters were obtained non-invasively at rest using Task Force Monitor (TFM) (CNSystems, Graz, Austria). Haemodynamic measurements of heart rate and R-R interval were acquired with a 6-lead electrocardiogram. Beat-to-beat blood pressure (BP), systolic and diastolic, (SBP and DBP) was measured with the vascular unloading technique using finger cuffs. Beat-to-beat BP was automatically counterchecked and corrected every minute by the oscillometric BP measurements recorded from the contralateral upper arm.[23]

Impedance cardiography measurements were also taken. Derived haemodynamic parameters were computed from continuous BP and heart rate (HR) and the impedance signal.[23] The latter was acquired from a small constant sinusoidal alternating current passing through the thorax between an electrode placed around the neck and another placed at the lower end of the sternum. The voltage between the electrodes is proportional to the thorax impedance. Left ventricular ejection time (LVET), the time between points ‘B’ and ‘X’ (opening and closure of aortic valve, respectively) of the impedance signal, was considered in further calculations of haemodynamic parameters using the standard Kubisek’s formula. The haemodynamic parameters calculated and indexed for body surface area were stroke index (SI), cardiac index (CI) and total peripheral resistance index (TPR, TPRI).

Autonomic measurements were made as follows. An adaptive autoregressive model (AAR) was used to compute online beat-to-beat time varying spectral analysis of the heart rate variability (HRV) in the frequency domain. Very low frequency (VLF 0.01-0.05 Hz band); low frequency (LF 0.05-0.17 Hz band), and high frequency (HF 0.17-0.5 Hz band) were calculated in absolute values (ms^2) and in normalised units: low frequency (LFnu) and high frequency (HFnu).[23,24] There is a general agreement that HF, HFnu reflect the parasympathetic or vagal activity, and LF, LFnu reflect the sympathetic modulation of the sinoatrial node and vasomotion.[25] The change in status of the sympatho-vagal balance was indicated by the LF/HF ratio.[25]

All experiments were done in the morning at a comfortable room temperature of 27 ^{0}C. An informed consent was obtained after explaining the procedure. All subjects underwent the same protocol. After spirometry and respiratory pressure measurements, subjects were connected to the TFM with electrodes. They were made to rest supine on a comfortable bed in a quiet room. Beat-to-beat recordings of haemodynamic and autonomic parameters were obtained at rest for 10 mins. All

Table 1: Baseline haemodynamic and autonomic parameters, respiratory pressures and spirometry indices in control subjects and patients — value (standard deviation)

Anthropometric, haemodynamic and autonomic parameters			
	Controls n = 6	Patients n = 11	*P*
Age	43.5 (14.5)	43.9 (20.5)	NS
BMI	25.4 (3.2)	21.9 (5.4)	NS
VAS	7.0 (2.1)	5.4 (2.3)	0.03
HR	72.0 (13.6)	78.6 (13.4)	NS
SBP	108.8 (15.5)	112.3 (14.5)	NS
DBP	78.6 (9.3)	74.5 (7.3)	NS
SI	47.4 (12.9)	47.4 (7.5)	0.05
TPRI	2218.5 (639.2)	1885.4 (431.5)	NS
LFnu	56.8 (13.7)	41.5 (26.1)	NS
HFnu	43.1 (13.7)	60.3 (23.2)	NS
VLF	102.3 (102.7)	113.6 (117.8)	NS
LF/HF	1.5 (0.9)	1.1 (0.9)	NS
PSD	731.0 (103.6)	677.4 (313.4)	NS

Respiratory pressures and spirometry indices			
	Controls n = 6	Patients n = 11	*P*
MEP	153.5 (32.4)	98.5 (27.1)	0.001
pcMEP	79.5 (18.6)	60.8 (16.3)	0.05
MIP	113.5 (34.1)	65.4 (37.7)	0.02
PcMIP	106.0 (21.3)	57.8 (26.5)	0.0001
FVC	4.0 (1.3)	2.4 (0.8)	0.01
pcFVC	95.8 (9.5)	73.2 (10.5)	0.0001
FEV_1	3.1 (0.9)	1.5 (0.7)	0.01
$pcFEV_1$	90.5 (5.8)	58.2 (12.6)	0.001
FEV_1/FVC	78.6 (5.7)	63.8 (12.3)	0.001
pc FEV_1/FVC	98.3 (6.3)	80.2 (15.0)	0.001
FEF25-75%	2.75 (0.8)	0.9 (0.4)	0.0001
pcFEF25-75%	68.1 (12.3)	25.5 (12.4)	0.0001
PEFR	9.0 (1.3)	4.4 (1.4)	0.0001
pcPEFRc	112.7 (14.5)	61.4 (15.5)c	0.0001

*Legend: Age (years); BMI = body mass index (kg/m^2); VAS = visual analogue score; HR = heart rate (bpm); SBP = systolic blood pressure (BP) (mmHg); DBP = diastolic BP (mmHg); SI = stroke index (ml/m^2); TPRI = total peripheral resistance index (dyne*S*M2/cm^2); LFnu = low frequency normalized units (%); HFnu = high frequency normalized units (%); VLF = very low frequency (ms^2); LF/HF = sympatho-vagal balance; PSD = power spectral density (ms^3); MEP = maximum expiratory pressure (cmH2O); pcMEP = % predicted of MEP (cmH2O); MIP = maximum inspiratory pressure (cmH2O); pcMIP = % predicted of MIP (cmH2O); FVC = forced vital capacity (L); pcFVC = % predicted of FVC; FEV_1 = forced expiratory volume 1 sec (L); $pcFEV_1$ = % predicted of FEV_1; FEV_1/FVC = ratio of FEV_1 to FVC (%); $pcFEV_1$/FVC = % predicted of FEV_1/FVC (%); FEF25-75% = forced expiratory flow 25-75% (L/sec); pcFEF25-75% = % predicted of FEF25-75%; PEFR = peak expiratory flow rate (L/sec); pcPEFR = % predicted of PEFR (L/sec); NS = not significant, P >0.05.*

subjects were asked to mark on the VAS scale. The same protocol was repeated on subsequent visits. Compliance of Pranayam breathing was confirmed verbally on each revisit. All subjects confirmed that they had carried out the exercise as instructed.

Descriptive and comparative analyses were performed using the Statistical Package for the Social Sciences (SPSS, Version 13.0). Parametric data were expressed as means $\pm$ SD. A probability value of <0.05 was considered statistically significant.

Beat-to-beat measurements obtained with TFM were averaged for time periods of 10 mins of rest. The unpaired two tailed student's 't' test was used to compare anthropometric measurements, baseline haemodynamic and autonomic parameters and respiratory pressures and spirometry indices between the 2 groups (control and patients). The paired 't' test was used to compare these cardiovascular and respiratory parameters before and after Pranayam exercise separately between control subjects and patients.

The difference between baseline and post Pranayam values of cardiovascular and respiratory parameters was taken as measure of responses to Pranayam exercises. This estimated reactivity was compared between control subjects and patients using the Wilcoxon rank test for non-parametric samples.

Results

Anthropometric and baseline cardiovascular and respiratory parameters for control subjects and patients are given in Table 1. Both groups were comparable for age and BMI. The VAS was significantly lower in the patients (*P* = 0.03). There were no differences in haemodynamic and autonomic parameters between two groups [Table 1]. All respiratory pressures and spirometry indices were within normal physiological range in control subjects and were significantly lower in patients [Table 1]. This confirmed the impaired pulmonary

Table 2: Differences in visual analogue score (VAS), haemodynamic and autonomic parameters, respiratory pressures and spirometry indices in control subjects before and after Pranayam exercise — value (standard deviation)

VAS, haemodynamic and autonomic parameters				**Respiratory pressures and spirometry indices**			
Controls	**Before Pranayam n = 6**	**After Pranayam n = 6**	***P***		**Before Pranayam n = 6**	**After Pranayam n = 6**	***P***
VAS	7.0 (2.1)	7.5 (2.2)	NS	**MEP**	153.5 (32.4)	170.3 (27.5)	NS
HR	72.0 (13.6)	72.2 (12.8)	NS	**pcMEP**	79.5 (18.6)	84.7 (4.9)	NS
SBP	108.8 (15.5)	118.2 (6.9)	0.01	**MIP**	113.5 (34.1)	134.7 (35.6)	0.03
DBP	78.6 (9.3)	78.5 (5.7)	NS	**pcMIP**	106.0 (21.3)	123.7 (19.5)	NS
SI	47.4 (12.9)	52.5 (22.4)	0.05	**FVC**	4.0 (1.3)	3.9 (1.0)	NS
TPRI	2218.5 (639.2)	2330.0 (419.8)	NS	**pcFVC**	95.8 (9.5)	93.2 (10.0)	NS
LFnu	56.8 (13.7)	66.6 (3.6)	NS	**FEV_1**	3.1 (0.9)	3.1 (0.7)	NS
HFnu	43.1 (13.7)	33.4 (3.6)	NS	**$pcFEV_1$**	90.5 (5.8)	90.4 (4.3)	NS
VLF	102.3 (102.7)	116.3 (138.2)	NS	**FEV_1/FVC**	78.6 (5.7)	77.5 (6.4)	NS
LF/HF	1.5 (0.9)	1.7 (0.6)	NS	**$pcFEV_1$/FVC**	98.3 (6.3)	97.5 (6.7)	NS
PSD	731.0 (103.6)	393.3 (90.8)	NS	**FEF25-75%**	2.75 (0.8)	2.6 (0.8)	NS
				pcFEF25-75%	68.1 (12.3)	64.0 (11.9)	NS
				PEFR	9.0 (1.3)	8.8 (1.2)	NS
				pcPEFR	112.7 (14.5)	106.0 (13.0)	NS

*Legend: VAS = visual analogue score; HR = heart rate (bpm); SBP = systolic blood pressure (BP) (mmHg); DBP = diastolic BP (mmHg); SI = stroke index (ml/m^2); TPRI = total peripheral resistance index (dyne*S*m^2/cm^2); LFnu = low frequency normalized units (%); HFnu = high frequency normalized units (%); VLF very low frequency (ms^2); LF/HF = sympatho-vagal balance; PSD = power spectral density (ms^3); MEP = maximum expiratory pressure (cmH2O); pcMEP = % predicted of MEP (cmH2O); MIP = maximum inspiratory pressure (cmH2O); pcMIP = % predicted of MIP (cmH2O); FVC = forced vital capacity (L); pcFVC = % predicted of FVC; FEV_1 = forced expiratory volume 1 sec (L); $pcFEV_1$ = % predicted of FEV_1; FEV_1/FVC = ratio of FEV_1 to FVC (%); $pcFEV_1$/FVC = % predicted of FEV_1/FVC (%); FEF25-75% = forced expiratory flow 25-75% (L/sec); pcFEF25-75% = % predicted of FEF25-75%; PEFR = peak expiratory flow rate (L/sec); pcPEFR = % predicted of PEFR (L/sec); NS = not significant, P >0.05.*

functions in patients.

Responses of cardiovascular and respiratory parameters and VAS to Pranayam exercise are given in Table 2 for the control subjects and in Table 3 for the patients. The comparison of cardiovascular and respiratory responses to Pranayam exercises between control subjects and patients are given in Table 4.

In the control subjects, there was a significant increase in SBP (*P* = 0.01) and SI (*P* = 0.05) after Pranayam exercise [Table 2]. There was also an increase in sympathetic parameters (LFnu and LF/HF) after Pranayam exercise; however, the difference was not significant. The MEP and MIP both increased in response to Pranayam exercise; however, the difference was significant only for MIP (*P* = 0.03). There was no difference in other respiratory pressures and indices in response to Pranayam exercise.

Patients showed significant improvement in VAS (*P* = 0.04) after Pranayam exercise [Table 3]. Paradoxically, they did not show a significant change in cardiovascular parameters, respiratory pressures and indices in response to the Pranayam exercise [Table 3].

There were no differences in cardiovascular responses to Pranayam exercises between control subjects and patients [Table 4]. Amongst respiratory pressures, the control subjects showed a significant increase in percent predicted MIP (pcMIP; control subjects 24.7 ± 18.3 versus patients 0.9 ± 19.5; *P* = 0.03) compared with patients. There were no differences in the responses of other respiratory pressures and indices between control subjects and patients [Table 4]. In patients, the measure of respiratory well being, VAS, showed a significant increase in response to Pranayam exercise (control subjects 0.5 ± 1.5 versus patients 1.8 ± 1.2; *P* = 0.05).

Discussion

The major findings of this study were, first, that Pranayam exercise produced significant increase

Table 3: Differences in visual analogue score (VAS), haemodynamic and autonomic parameters, respiratory pressures and spirometry indices in patients before and after Pranayam exercise

VAS, haemodynamic and autonomic parameters				Respiratory pressures and Spirometry indices			
Patients	**Before Pranayam n = 11**	**After Pranayam n = 11**	***P***		**Before Pranayam n = 11**	**After Pranayam n = 11**	***P***
VAS	5.4 (2.3)	7.2 (1.2)	0.04	MEP	98.5 (27.1)	99.7 (17.4)	NS
HR	78.6 (13.4)	74.4 (10.60	NS	pcMEP	60.8 (16.3)	61.4 (17.3)	NS
SBP	112.3 (14.5)	112.2 (15.7)	NS	MIP	65.4 (37.7)	66.6 (37.8)	NS
DBP	74.5 (7.3)	70.8 (11.6)	NS	pcMIP	57.8 (26.5)	59.0 (27.1)	NS
SI	47.4 (7.5)	47.2 (6.8)	NS	FVC	2.4 (0.8)	2.6 (0.7)	NS
TPRI	1885.4 (431.5)	1853.7 (400.7)	NS	pcFVC	73.2 (10.5)	76.9 (12.2)	NS
LFnu	41.5 (26.1)	47.6 (24.9)	NS	FEV_1	1.5 (0.7)	1.7 (0.4)	NS
HFnu	60.3 (23.2)	51.8 (24.9)	NS	$pcFEV_1$	58.2 (12.6)	57.13.6)	NS
VLF	113.6 (117.8)	132.4 (128.0)	NS	FEV_1/FVC	63.8 (12.3)	66.0 (8.4)	NS
LF/HF	1.1 (0.9)	1.6 (1.4)	NS	pc FEV_1/FVC	80.2 (15.0)	82.1 (9.1)	NS
PSD	677.4 (313.4)	865.0 (516.4)	NS	FEF25-75%	0.9 (0.4)	0.9 (0.2)	NS
			NS	pcFEF25-75%	25.5 (12.4)	26.2 (8.1)	NS
			NS	PEFR	4.4 (1.4)	4.7 (1.1)	NS
				pcPEFR	61.4 (15.5)	65.0 (10.0)	NS

*Legend: VAS = visual analogue score; HR = heart rate (bpm); SBP = systolic blood pressure (BP) (mmHg); DBP = diastolic BP (mmHg); SI = stroke index (ml/m²); TPRI = total peripheral resistance index (dyne*S*m²/cm²; LFnu = low frequency normalized units (%); HFnu = high frequency normalized units (%); VLF = very low frequency (ms2); LF/HF = sympatho-vagal balance; PSD = power spectral density (ms³); MEP = maximum expiratory pressure (cmH2O); pcMEP = % predicted of MEP (cmH2O); MIP = maximum inspiratory pressure (cmH2O); pcMIP = % predicted of MIP (cmH2O)); FVC = forced vital capacity (L); pcFVC = % predicted of FVC; FEV_1 = forced expiratory volume 1 sec (L); $pcFEV_1$ = % predicted of FEV_1; FEV_1/FVC = ratio of FEV_1 to FVC (%); $pcFEV_1$/FVC = % predicted of FEV_1/FVC (%); FEF25-75% = forced expiratory flow 25-75% (L/sec); pcFEF25-75% = % predicted of FEF25-75%; PEFR = peak expiratory flow rate (L/sec); pcPEFR = % predicted of PEFR (L/sec); NS = not significant, P>0.05.*

only in the MIP of control subjects; second, in patients, there were no significant changes in cardiovascular parameters, respiratory pressures and indices in response to the Pranayam exercise; and third, patients showed significant improvement in the score of respiratory well-being in response to the Pranayam exercise.

The impaired respiratory muscle function in COPD patients leading to exertional dyspnoea is well established.[22] We hypothesised that Pranayam, a non-distressing slow yogic breathing exercise, may train respiratory muscles and improve their performance. However, our study showed significant increase in MIP only in control subjects and not in patients. Inspiratory muscles of respiration are an important factor contributing to exertional dyspnoea. The improvement in MIP in control subjects suggested that Pranayam worked positively for them. It is possible that Pranayam was not a sufficiently stressful breathing exercise to produce the change in patients. However, the significant increase in VAS in our study group indicated that the Pranayam exercise improved the respiratory distress and quality of life. The positive outcome from the respiratory muscle training depends upon the overload principle applied to the training[22] which includes increase in frequency, duration and intensity of the training. The respiratory muscle training would be of benefit to patients if respiratory muscle function is a major limiting factor during performance of the training. Reid suggested that an exercise training programme should be tailored to an individual patient's needs and abilities.[22] Rigorous aerobic exercise has not consistently produced benefit on MIP and MEP values. Gemeniz *et al.* showed that maximally intense aerobic exercise significantly improved MEP and MIP and decreased dyspnoea at rest.[9] In COPD patients, however, De Lucas Ramos *et al.* found that progressive maximal exercise tolerance decreased the sense of dyspnoea, but had no effect on respiratory pressures.[11] Cooper *et al.* showed that the Buteyko breathing technique (a device that mimics paranayama) attenuated the symptoms and reduced bronchodilator use, but

Table 4: Comparison of responses of visual analogue score (VAS), haemodynamic and autonomic parameters, respiratory pressures and spirometry indices before and after Pranayam exercise between control and patients

VAS, haemodynamic and autonomic parametersControls				Respiratory pressures and spirometry indices			
Controls	**Controls n = 6**	**Patients n = 11**	***P***		**Controls n = 6**	**Patients n = 11**	***P***
VAS	0.5 (1.5)	1.8 (1.2)	0.05	**MEP**	7.5 (24.8)	0.2 (13.3)	NS
HR	3.5 (3.7)	-1.1 (14.1)	NS	**pcMEP**	4.0 (13.4)	1.2 (7.2)	NS
SBP	9.8 (3.8)	1.3 (2.3)	NS	**MIP**	25.0 (13.2)	0.1 (19.5)	NS
DBP	3.5 (6.6)	-2.7 (12.5)	NS	**pcMIP**	24.7 (18.3)	0.9 (15.5)	0.03
SI	3.4 (8.30	-0.2 (5.1)	NS	**FVC**	0.0 (0.01)	0.1 (0.20	0.04
TPRI	112.8 (445.0)	-31.6 (593.8)	NS	**pcFVC**	-0.5 (0.6)	4.0 (8.6)	NS
LFnu	10.3 (14.7)	9.9 (22.7)	NS	**FEV_1**	-0.02 (0.04)	0.2 (0.4)	NS
HFnu	-10.4 (14.6)	-12.7 (21.7)	NS	**$pcFEV_1$**	-0.8 (1.3)	3.0 (7.6)	NS
VLF	14.0 (51.0)	18.8 (90.4)	NS	**FEV_1/FVC**	-0.3 (1.3)	0.4 (6.5)	NS
LF/HF	0.3 (0.9)	0.7 (1.7)	NS	**pc FEV_1/FVC**	-0.3 (1.7)	0.6 (7.9)	NS
PSD	-337.7 (650.4)	187.8 (462.6)	NS	**FEF25-75%**	-0.05 (1.1)	-0.02 (0.3)	NS
				pcFEF25-75%	-1.5 (3.8)	1.3 (9.1)	NS
				PEFR	-0.3 (0.5)	0.3 (0.7)	NS
				pcPEFR	-3.3 (4.9)	3.0 (8.6)	NS

*Legend: VAS = visual analogue score; HR = heart rate (bpm); SBP = systolic blood pressure (BP) (mmHg); DBP = diastolic BP (mmHg); SI = stroke index (ml/m^2); TPRI = total peripheral resistance index (dyne*S*m^2/cm^2); LFnu = low frequency normalized units (%); HFnu = high frequency normalized units (%); VLF = very low frequency (ms2); LF/HF = sympatho-vagal balance; PSD = power spectral density (ms^3); MEP = maximum expiratory pressure (cmH2O); pcMEP = % predicted of MEP (cmH2O); MIP = maximum inspiratory pressure (cmH2O); pcMIP = % predicted of MIP (cmH2O)); FVC = forced vital capacity (L); pcFVC = % predicted of FVC; FEV_1 = forced expiratory volume 1 sec (L); $pcFEV_1$ = % predicted of FEV_1; FEV_1/FVC = ratio of FEV_1 to FVC (%); $pcFEV_1$/FVC = % predicted of FEV_1/FVC (%); FEF25-75% = forced expiratory flow 25-75% (L/sec); pcFEF25-75% = % predicted of FEF25-75%; PEFR = peak expiratory flow rate (L/sec); pcPEFR % predicted of PEFR (L/sec); NS = not significant, P>0.05.*

it did not change lung functions.[26] Yoga therapy which included *asanas* (body postures) and timed Pranayam breathing improved the tolerance of COPD patients for the 6 minute walk test.[27] However, Donesky-Cuenco *et al.* did not study the effect of yogic therapy on respiratory parameters. A recent meta-analysis of respiratory muscle training in chronic air flow limitation suggested that there is little evidence of clinically important benefits of respiratory muscle training in patients with chronic air flow limitation. The meta-analysis also suggested that benefit may result if resistance exercises are conducted in a fashion that ensures the adequate generation of mouth pressures.[28]

The inspiratory muscle training schedule which improves MIP is 15–50 min exercise/day 5 days a week for 1–6 months.[3,10,22] Although the schedule of the training offered in our study was adequate, the type, intensity and duration of exercise were probably not adequate to produce beneficial changes in COPD patients. Our subjects were asked to follow the schedule at home. The reliability of compliance from patients thus remains questionable. Conducting the exercises in controlled environment could have provided better results. Most studies involving respiratory muscle strength were conducted in COPD patients who had a FEV_1/FVC ratio of 50% or less. In comparison, our patients were less compromised (FEV_1/FVC ratio 63.8% ± 12.3). It is possible that patients with more severe limitation may have responded more positively to the exercise.

Our study did not find any significant differences between resting haemodynamic and autonomic parameters between patients and control subjects. The autonomic dysfunction was documented in COPD patients using interventions that excite cardiovascular reflexes like Valsalva manoeuvre, 30:15 ratio, handgrip or postural challenge.[12,13,29-31] Few studies correlated the autonomic dysfunction with hypoxaemia and severity of the disease in these patients.[12,13,29] Camillo *et al.* associated autonomic dysfunction not with severity of disease, but with a lower level of physical activity in daily life along with poor health-related quality of life, functional status and respiratory and peripheral muscle force.[30] Correction of hypoxaemia may not have any effect on improvement of autonomic functions,[12,29] but the 6 weeks aerobic exercise training significantly improved the submaximal performance in the 6 minute walk test and it was associated with increased parasympathetic activity.[31] Our study investigated the autonomic activity at rest and not during the cardiovascular challenges. The similar autonomic functions in patients and control subjects could be attributed to normal resting oxygen saturation in them (PO_2: Control subjects: 99.0 ± 1.1; patients: 97.0 ± 1.3%).

Pranayam exercise is known to activate the parasympathetic limb of the autonomic nervous system.[15] Although non-significant, we found that Pranayam exercise activated the sympathetic limb of the autonomic nervous system in both control subjects and patients. The improvement in quality of symptoms as indicated by VAS could be attributed to the correction of autonomic balance.

In this study, we compared the effect of Pranayam breathing in COPD patients and control subjects by investigating both improvement in respiratory muscle strength and also the relief of stress. The small sample size posed a limitation in drawing conclusions. In the future, a well organised clinical trial with adequate sample size and strict supervision of the breathing exercises may give a better understanding of the usefulness of Pranayam breathing exercise for these patients.

Conclusion

Our study did not show significant alterations in the autonomic studies or in the pulmonary functions status of COPD/ chronic airflow limitation patients. The improvement in MIP in control subjects indicated the positive effect of Pranayam. Although Pranayam was not an adequately stressful breathing exercise to produce the change in COPD patients, it improved the respiratory distress and quality of life as indicated by the significant increase in VAS in patients. It was also interesting to note the shift of the autonomic balance towards sympathetic which may suggest that this could be a better coping mechanism induced by Pranayam breathing.

CONFLICT OF INTEREST

The authors reported no conflict of interest.

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