ORIGINAL RESEARCH

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Effects of yoga *(pranayama)* on lung function and lactate kinetics in sedentary adults at intermediate altitude

Efectos de la práctica de yoga (pranayamas) sobre la función pulmonar y cinética del lactato en adultos sedentarios de altitud intermedia

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| Abstract |

Introduction: Clinical evidence-based medicine has found increasing benefits of yoga.

Objective: To describe the effects on lung function assessed by rest spirometry —vital forced capacity (VFC), forced expiratory volume in one second (FEV1), and FEV1/VFC ratio— in a group of apparently healthy adults, as well as to explore the effects of *pranayama* techniques in lactate kinetics.

Materials and methods: Quasi-experimental study performed in sedentary adults with no prior experience in yoga practice, who received a stimulus during 12 weeks with a minimum frequency of two sessions per week. They were divided into a yoga group (YG) and a control group (CG). Body composition, blood pressure, heart rate, double product (DP), peripheral oxygen saturation (SpO_2), blood lactate ($Lact_s$), hematocrit (Htc) by micromethod, and spirometry were determined before and after a training plan with *Pranayama*. The variables analyzed were forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC ratio.

Results: Significant differences were found in FVC, FEV1 and lactate among YG and CG ($p<0.05$), and before and after the stimulus in the YG ($p<0.05$). The double product improved in both groups.

Conclusions: Targeted practice of *pranayama* for 12 weeks improved FVC, FEV1, double product ($p<0.05$) and lactate production capacity (anaerobic capacity).

Keywords: Yoga; Lactic Acid; Spirometry; Altitude; Sedentary Lifestyle (MeSH).

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| Resumen |

Introducción. La medicina basada en evidencia clínica encuentra cada vez más beneficios del yoga en sus practicantes.

Objetivo. Describir los efectos en la función pulmonar y la cinética del lactato ocasionados por la práctica de *pranayamas* en adultos con apariencia saludable.

Materiales y métodos. Se realizó un estudio cuasiexperimental en adultos sedentarios sin experiencia en la práctica de yoga, quienes realizaron un estímulo durante 12 semanas con un frecuencia mínima de dos sesiones por semana. Se dividieron en un grupo de yoga (GY) y un grupo de control (GC). Se determinó composición corporal, presión arterial, frecuencia cardíaca, doble producto (DP), saturación periférica de oxígeno (SpO_2), lactato en sangre ($Lact_s$), hematocrito (Htc) por micrométodo, y espirometría previa y posterior a un plan de entrenamiento con *pranayamas*. Las variables analizadas fueron: capacidad vital forzada (CVF), volumen espiratorio forzado del primer segundo (VEF1) y relación VEF1/CVF.

Resultados. Los resultados de la CVF, VEF1 y lactato presentaron diferencias significativas entre el GY y el GC ($p<0.05$), antes y después del estímulo en el GY ($p<0.05$). El doble producto mejoró en ambos grupos.

Conclusiones. La práctica dirigida de *pranayamas* durante 12 semanas mejoró la CVF, el VEF1, el doble producto ($p<0.05$) y la capacidad de producción de lactato (capacidad anaeróbica).

Palabras clave: Yoga; Ácido láctico; Espirometría; Altitud; Estilo de vida sedentario (DeCS).

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Introduction

Yoga is an ancestral philosophy that developed more than 5000 years ago and is based on metaphysical dualism (*Sankhya*) (1). It promotes the harmony of the body, mind and soul with the rhythms of the universe for an integral growth (2). In Western countries, yoga is practiced by a large number of people and its popularity continues to grow. It favors diffusion and oxygenation processes in tissues, and has shown benefits in the control and management of autonomic nervous system alterations (3), high blood pressure, angina pectoris (4), bronchial asthma (5), depression (6) and oxidative stress management (7).

Yoga is represented by a tree with eight limbs (Figure 1), each symbolizing a precept: universal morality (*yama*), personal observances (*niyama*), body postures (*asana*), breathing techniques (*pranayama*), sense withdrawal (*prathyahara*), focused concentration (*dharana*), devotion or meditation (*dhyana*) and complete meditation or trance (*samadhi*) (2,3). The most popular yoga practices emphasize on postures, breathing exercises, concentration and meditation (8,9).

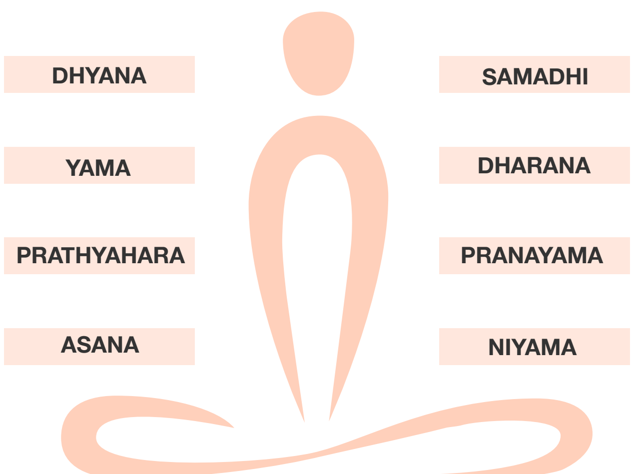

Figure 1. Eight limbs or precepts of yoga.
Source: Own elaboration based on the data obtained in the study.

The purpose of this study is to describe the effect of yoga on respiratory function at intermediate altitudes, and to assess the changes in the lactate kinetics of people who have never practiced this discipline. Each type of yoga stimulates specific physiological processes; however, the study focuses on the effect of *pranayama* on respiratory function and anaerobic capacity.

Ventilatory mechanics is a mixed process in terms of energy expenditure. While meditation decreases the metabolic rate, *pranayama* increases it (10); this phenomenon has been associated with the diversity in the composition of the fibers and the energetic pathways used by the muscles involved in ventilation (11-16). Mechanical action correlates to the energy system used as well as to the production-clearance of intermediary metabolites.

The isometric contraction of the laryngeal muscles (17) that have a high anaerobic component (19-21) and the rapid contractions of the genioglossus, genihyoid and sternohyoid muscles with type II fibers distribution pattern require a higher production of lactate (22,23). The lactate production capacity of the diaphragm varies according to:

a) The presence of different isoforms of troponin in the three portions of the diaphragm (sternal, costal and lumbar), which confers different strength capacity depending on the number of sites where Ca^{++} can be bound (fast: TnC-f with 2 binding sities; slow: TnC with 1 binding site).

b) The presence of different myosin isoforms, which allows different degrees of resistance to fatigue (resistant: IIa-$MyHC_{2A}$, intermediate: IIx$MyHC_{2x}$, and highly susceptible to fatigue with high glycolytic capacity and low oxidative activity: IIb$MyHC_{2B}$ + $MyHC_{2X}$) (12).

c) The presence of structural ($MyLC_{20}$) and regulatory ($MyLC_{17}$) myosin.

Due to immunohistochemistry, the transition from embryonic and fetal myosin isoforms to adult isoforms has been documented, but further studies are still required.

Therefore, it is possible to think that respiratory muscles can be trained (24,25) and that this training can be assessed by means of spirometry, ultrasound (26), and the determination of intermediary metabolites in the blood (such as lactate). Another determinant of respiratory muscle work is blood flow, since a limitation in respiratory muscle perfusion can affect performance and contribute to fatigue (27). The blood flow can be modified with postures and breathing techniques.

It has been estimated that energy expenditure during pranayama practice ranges from 1.91 kcal/min^1 to 3.79 kcal/min^1, with a metabolic rate between 1-2 units of metabolic equivalent of task (MET), (26,27). This fact, together with the diversity of fibers and the energetic pathways used, leads to an increase of lactate concentrations in the blood after practicing *pranayama* (29). The level of lactate depends on the type of load, the level of oxygen consumption (VO_2), and the training level of the individual (30). Although yoga practice remains below the lactic threshold (26), physical performance may improve due to increased ventilatory efficiency and increased cardiovascular reserve.

The metabolic effects observed in yoga practitioners have allowed to understand the modification mechanisms of risk factors for cardiovascular disease (31,32), as well as the metabolic pathways used during practices that require greater energy expenditure and increased accumulation of blood lactate.

The purpose of this study is to evaluate the respiratory and metabolic effects of a *pranayama* practice performed for 12 weeks by a population of adults with no prior experience in this discipline. Respiratory effects were assessed through respiratory function tests (FVC, FEV1 and FEV1/FVC). The metabolic effect was assessed by lactate variation after *pranayama* practice, and was compared to blood lactate variation after exercise on a cycle ergometer.

Materials and methods

A quasi-experimental study was conducted with 103 people, 14 men (M) and 89 women (W), living in Bogotá (altitude: 2600 m, barometric pressure: 564.9±1.05 mmHg, temperature 12.5±0.9°C). The individuals were divided into two groups: the yoga group (YG), including 72 people (M: 11, W: 61) who practiced *pranayama* for 12 weeks, and the control group (CG) with 31 people (M:3, W:28) who performed programmed physical exercise according to the physical activity plan of the neighborhood of residence. This plan included strength work through bodyweight exercises, mobility of large muscle groups for aerobic work, stimulation for cardiovascular and respiratory system maintenance, and coordination exercises.

The sample was selected for convenience, and participants enrolled voluntarily in two programs supported by the Physical Activity and Culture Training Center of SENA and offered by the Local Mayor's

Office of Kennedy. The study variables were resting spirometry (FEV 1, FVC and FEV 1/FVC ratio) for lung function, and blood lactate for blood chemistry. Control variables were age, sex, weight, height, BMI, BF% and hematocrit. Attendance to training sessions was the third variable. The analysis of data only included the information of individuals who attended 90% of the sessions in the YG and the CG.

A medical examination was performed to participants; vital signs at rest (blood pressure, heart rate, peripheral oxygen saturation) were recorded and body composition was determined by bioimpedanciometry (Fit-Scan BC-585F of Tanita®, Japan; and Harpenden anthropometer of Holtain®, United Kingdom). These measurements were taken between 7:00 a.m. and 9:00 a.m., based on a protocol of no intense physical activity 24 hours before the practice, ingestion of liquids on demand, and no intake of energy drinks, tea or caffeine. Informed consent was signed after the presentation and explanation of the study.

The next day, at 7:00 a.m., three resting spirometry measurements were taken, and the data of the best tests were retained. FVC, FEV1 and FEV1/FVC ratio were recorded using the Metamax-3B gas analyzer (Cortex®, Germany). Blood lactate from the left ear lobe (Lactate Scout+®, EKF, Germany) and hematocrit by micromethod of a blood sample obtained from the same site (Microcentrifuge CT- 1, Indulab®, Colombia) were examined at rest, 5 minutes before starting the exercise. A submaximal effort test (Cycle 4000 Ergometer, Ergo-fit®, Germany) was performed using a physical work capacity protocol (PWC-150) with a heart rate limit of 150 beats/min.

The study was approved and funded by the Technical Committee of the Physical Activity and Culture Training Center of SENA-Bogotá, and complied with the requirements of the Declaration of Helsinki (33). Exclusion criteria included previous experience in yoga practice, smoking, diabetes mellitus or uncontrolled hypertension, history of respiratory disease (tuberculosis, chronic obstructive pulmonary disease, and pulmonary thromboembolism), disabling spinal deformities, major surgery, and previous sports training. The study respected the dignity and well-being of subjects, and was in line with the ethical and scientific principles of human research. According to Resolution 8430 of 1993 of the Ministry of Health (34), the level of risk for the participants was classified as research with minimal risk. The measurements were taken by specialized medical personnel of the Physiology Research Laboratory of the Physical Activity and Culture Training Center, SENA-Bogota.

The stimulus consisted of two yoga sessions per week, 75 minutes per session, for 12 weeks, between at 6:15 a.m. and 7:30 a.m. Each session began with joint mobility exercises (*pawanmuktasanas*), accompanied by acupressure and warm-up breathing exercises followed by postures (*asanas*). All sessions began with *nadi shodhana pranayama (anuloma viloma* or alternate nostril breathing) for two minutes. During the first two weeks, *nadi shodhana pranayama* and *sheetali pranayama* were practiced (refreshing breathing in the central phase of the session). *Sheetali pranayama* and *sheetkari pranayama* (wheezing) were practiced in weeks three and four. During the fifth and sixth week, individuals practiced *sheetkari* and *bhramari pranayama* (bumblebee breath). During the eighth and ninth week, *bhramari* and *ujjayi pranayama* were performed. During weeks 10 and 11, *bhastrika* and *kapalbhati pranayama* were practiced. Finally, in the last week, individuals learned *agni pranayama* or breath of fire. On the other hand, the control group performed physical activity with a functional training plan simultaneously.

The post-stimulus control sample was performed 12 weeks later. Again, the level of lactate, hematocrit and resting spirometry were determined during the same time periods as the initial sample. After a *pranayama* session, a blood lactate control sample was taken from the left ear lobe. The blood sample was obtained 5 minutes after the end of the session.

The submaximal test was performed at 24 hours, and the blood lactate of the ear lobe was taken 5 minutes after the test was completed, at which time blood pressure was measured. Heart rate was monitored during the test, which was terminated when the patient reached a rate of 150 beats/min. The recovery heart rate was measured at minutes 1, 3 and 5 post-exercise. For the calculation of double product, the data of the resting heart rate was considered. For the statistical analysis, data normality was verified, and the ANOVA and t-Student tests were applied using the SPSS Statistics 21 program (IBM, USA).

Results

On average, the mean age of the total population was 46±14.3 years, weight was 60.7±9.6kg, height 1.6±0.06m, BMI 24.9±3.9kg/m^2 and body fat percentage 29.8±7.7%. Table 1 shows the comparative results between the yoga group (YG) and the control group (CG).

Table 1. Comparative results Yoga Group and Control Group.

Variable	CONTROL GROUP			YOGA GROUP		
	Initial measure	Final measure	Final-initial difference	Initial measure	Final measure	Final-initial difference
FCV (L)	4.1±1.19	4.2±1.13	0.1±0.23	4.2±1.13	4.3±0.88	0.3±0.38 *
FEV1 (L/s)	2.8±0.55	2.9±0.7	0.1±0.25	3.0±0.72	3.3±0.64	0.3±0.3 *
FEV1/ FCV (%)	70.8±14.5	71.8±12.5	1±7.42 *	75.5±11.2	80±8.6	2.6±8.1
SPO_2 (%)	944±2.71	94.6±1.21	0.2±2	94.7±1.3	95.4±1.2	0.2±1.2
Double product (%)	84.8±8.21	81.2±6.92	-3.6±9.08 *	86.9±18.8	80.7±12.6	-6.2±11.9 *
Lactate delta (mMol/L)	0.8±0.77	1.3±0.94	0.4±1 *	1.9±0.84	3.2±0.89	1.4±1.18 *
Hematocrit (%)	50.7±3.42	50±1.84		50.4±4.63	48.9±2.51 *	
Sub-maximal lactate (mMol/L)	1.6±0.3			2.1±0.88 †		

* Statistically significant differences were observed between the final and initial values with p<0.05.
† Statistically significant differences were observed during a submaximal cycle ergometer test with p<0.05.
Source: Own elaboration based on the data obtained in the study.

Respiratory function tests

FVC: an increase was observed after 12 weeks of practice in both YG and CG. In YG, the increase was 6.9% of the predicted value ($p<0.05$). In the CG, an increase of 2.3% was observed, which is not statistically significant (Table 1).
FEV1: an increase of 9.4% of the predicted value was observed after 12 weeks in YG ($p<0.05$). In the CG, the increase was not significant (3.4%).
FEV1/FVC: an increase in both groups was observed, but none was statistically significant (YG: 2.7%, CG: 1.4%).

Hematocrit

This variable reduced by 2.6% ($p<0.05$) in the YG. A decrease of 1.4% was observed in the CG, with no statistical significance.

Peripheral oxygen saturation

A non-significant increase of 0.2% was observed in both groups.

Lactate

Comparison between both groups: after a *pranayama* session, between weeks 1 and 12, lactate delta (ΔLac) showed an increase of 1.1mMol/L (12%, $p<0.05$) in the YG. After training at 75% of maximum heart rate (MHR), the CG showed an increase in ΔLac of 3.2% with no statistical significance.
Comparison of lactate level in the YG during two activities: At week 12, a comparison was performed between the lactate level that this group reached after a 75-minute *pranayama* session and after a 45-minute cycle ergometer session at 75% of their MHR. Greater production was observed after the *pranayama* session (3.2mMol/L vs. 2.1 mMol/L), but no statistical difference was found after the cycle ergometer session.

Double product

There was a decrease in both groups, but it was greater in the YG ($p<0.05$).

Discussion

The results of this study allow to raise a discussion about three aspects: what characteristics qualify a stimulus as adequate to improve pulmonary function? Does altitude have any effect on yoga practice? Does training of respiratory muscles increase anaerobic capacity?

Most studies agree that, by increasing intrathoracic and intraabdominal negative pressure due to a greater diaphragmatic excursion (35), yoga practice —especially *pranayama*— leads to higher FVC, FEV1 and FEV1/FVC ratio (36-38), although, some studies have not found changes in the FEV1/FVC ratio (39). Likewise, studies have not found evidence proving that the observed effects on saturation are caused by better diffusion (37), a longer length of time of erythrocytes in the recruited capillaries, or changes in the recruitment patterns of accessory muscles (36). These effects can be achieved through apnea maneuvers and increased positive pressure during exhalation, which may cause changes in volume, capacity and airflow.

Some pranayama techniques include glottal muscle contraction exercises, which have been correlated with improvement of saturation without significant changes in heart and respiratory rates (39). A better percentage of saturation, higher O_2 pressure in the alveolar gas, greater arterial content of O_2, and better delivery in the tissues allow to explain the decrease of Htc (40-42) in people trained with this technique, which was evidenced in the YG of this study (Table 1).

The stimulus observed in several series consists of periods of practice longer than 6 weeks, although changes become more evident after 10 weeks and are more relevant in people without previous experience in yoga (43). In the course of the initial phase, the stimulus used in this study included joint mobility and low impact and low energy expenditure *asana* (postures) techniques. During the central phase, *pranayama* was used in a sitting or standing position, so that the ventilation/perfusion ratio was not affected by position changes or were prone to stimuli. The CG also performed physical work in a standing position, suggesting that the observed changes may be the result of alveolar recruitment maneuvers and respiratory musculature exercise.

In relation to altitude, the results of this study coincide with findings from other series performed at intermediate altitudes (1500 to 3000masl), especially regarding FEV1 and FVC (40). At higher altitudes, people trained in yoga have a better performance in lung function tests; for example, Buddhist monks do much better than Sherpas (42,44,45). The volume of studies at intermediate altitudes is small, so there are still some gaps to explain the ventilatory response to hypoxia in this context. This could be the basis for the design of new studies.

As for anaerobic capacity and lactate production, meditation decreases the metabolic rate while *pranayama* increases it (8), which is likely to happen due to the stimulation of the fibers that use glycolytic pathways. The result is different for expert practitioners (athletes), since they accumulate less lactate with equivalent workloads (30). Although yoga practice is considered as a low intensity activity, it can increase lactate levels, even up to the lactic threshold, especially with *pranayama*, as observed in some subjects of this study.

Concerning probable biases and confounding variables, it should be mentioned that the reduced number of male participants does not allow a sex comparison. The intensity of the load in the CG was not established according to a training plan but in response to the evolution of the participants' capacities (strength, endurance, coordination). Also, it should be taken into account that the measurement of post-exercise lactate levels were performed five minutes after the end of the activity; if a clearance behavior analysis is intended, studies should be designed to include measurements of this metabolite during a longer post-exercise period.

Conclusions

Pranayama targeted practice for 12 weeks, at least twice a week, in untrained, sedentary and inexperienced subjects in yoga practice, improves FVC and FEV1. In addition, blood oxygenation and glycolytic capacity in healthy adults are stimulated, which has a favorable impact on variables that can measure cardiovascular risk, such as double product and anaerobic capacity.

This practice can produce an accumulation of lactate, equivalent to the results of work on a cycle ergometer for 45 minutes with an intensity at 75% of the MHR. Thus, yoga practice with an emphasis on *pranayama* may be considered as useful for improving lung and cardiovascular function.

Conflict of interests

None stated by the authors.

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