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Cardiorespiratory and Metabolic Changes during *Yoga* Sessions: The Effects of Respiratory Exercises and Meditation Practices

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Abstract The novelty of this study was to investigate the changes in cardiorespiratory and metabolic intensity brought about by the practice of *pranayamas* (breathing exercises of *yoga*) and meditation during the same *hatha-yoga* session. The technique applied was the one advocated by the *hatha-yoga* system. Nine *yoga* instructors—five females and four males, mean age of 44 ± 11, 6, were subjected to analysis of the gases expired during three distinct periods of 30 min: rest, respiratory exercises and meditative practice. A metabolic open circuit computerized system was applied (VO2000, MedGraphics—USA). The oxygen uptake (VO_2) and the carbon dioxide output (VCO_2) were statistically different ($P \leq 0.05$) during meditation and *pranayama* practices when compared with rest. The heart rate also suffered relevant reductions when results at rest were compared with those during meditation. A smaller proportion of lipids was metabolized during meditation practice compared with rest. The results suggest that the meditation used in this study reduces the metabolic rate whereas the specific pranayama technique in this study increases it when compared with the rest state.

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Introduction

Hatha-yoga is the best known kind of *yoga* in the West. Besides the practice of exercises which develop strength and flexibility, it also includes other important ones such as those called *pranayamas* and meditation. They can all be part of the same *yoga* session. Such practices, as already stated by the great Hindu philosopher *Patanjali*, who probably lived between 200 BCE and 200 CE, aim not only at providing physical benefits, but mainly at bringing emotional well-being and mental balance to the individual. This can be found in the classic translations of Woods (1927).

Pranayamas are respiratory techniques in which the rhythm of nose breathing and of deep abdominal predominance prevails throughout the whole process (Iyengar 2005). Some reports suggest that there is a great increase in the respiratory capacity in regular practitioners of *pranayamas*, which leads these individuals to suspend their respiratory cycles for long periods of time without any effort and also diminishing their respiratory chemiosensibility, besides activating the parasympathetic nervous system and, paradoxically, their level of alertness (Spicuzza et al. 2000; Jerath et al. 2006). On the other hand, some *pranayama* techniques use strong air exhalation through the nostrils, which could cause hypocapnia. However, Frostell et al. (1983), by studying three highly trained yogis performing intense *pranayama*, observed that the arterial oxygen and carbon dioxide tension remained normal.

Another important *yoga* practice is meditation. Speaking from the physiological point of view, meditation is an altered state of consciousness in which the body is under a hypometabolic state, controlled most of the time by the parasympathetic nervous system. Yet, the individual is consciously awake (Young and Taylor 1998).

The studies carried out with meditation practitioners point to a number of physiological changes as follows: reduction or even variability in heart rate (Peng et al. 2004; Solberg et al. 2004), alterations of the electroencephalographic activity (Arambula et al. 2001; Lutz et al. 2004), modifications in the concentrations of neurotransmitters (Infante et al. 2001), a drop in oxygen uptake as well as in carbon dioxide output (Wallace et al. 1971; Young and Taylor 1998).

Wallace (1970), in the classic report *Physiological Effects of Transcendental Meditation*, disclosed that during the meditative period a significant reduction of 20% in the oxygen uptake occurs (VO_2) when compared to the pre-meditative period. Taking into account that people also reduce their VO_2 in about 10–20% during sleep, the author concluded that meditation can lead one to reach the same level of deep relaxation he gets while sleeping, but in a shorter time and under full consciousness.

In a study in which the ventilatory response to CO_2 was measured, it was observed that transcendental meditation practice can significantly influence the respiratory drive through central chemioreceptors sensitivity to CO_2 present in the bloodstream. In contrast, the control group presented a greater chemosensitivity to respiratory stimuli generated by hypercapnia (Wolkove et al. 1984).

Material and Methods

Nine volunteer instructors of *yoga*—five males and four females participated in the study. Their mean age was 44 ± 11.6 (28–67) years, their weight 68 ± 14.6 kg (48–94) and their height was 166.7 ± 8.7 cm (154–186). All of them had a mean time of experience in *yoga* practice of 12.5 ± 8.9 (3–30) years, and they practiced an average of 3 ± 1.7 (1–7) hours weekly. The basic requirement for the individual to participate in the study was to have been doing *hatha-yoga* for at least 3 years.

All volunteers filled out a questionnaire where there were questions involving variables such as sex, age, formal education level, how often and how long the person took up *yoga*. After that, the methodology to be used in the study was presented to them. Finally, all the participants were asked to fill a consent form for experimental studies involving human beings. The present study was previously approved by the Institutional Ethics Committee - Research Center of the UNA University.

The volunteers were then submitted to the analysis of the exhaled gases by means of a metabolic open circuit computerized system. The metabolic data was obtained using the gas analyzer VO2000 (MedGraphics, USA). The device consists of a transducer connected to a computer. The transducer is a tool which contains a suction pump that collects small samples of the air exhaled by the volunteer. It also has sensors to detect oxygen and carbon dioxide concentrations; the volume of air exhaled, and the heart rate which is received through an interface with a telemetry device (Polar Oy Electro, Finland). The VO2000 generates the following information: oxygen uptake volume expressed in liters per minute (VO_2 stpd); carbon dioxide output volume produced in liters per minute (VCO_2 stpd); exhaled air volume in liters per minute (VE btps); and the average heart rate in bpm.

Having these four parameters, the *AeroGraph* software calculates several derived measures such as oxygen uptake in relation to body weight (VO_2 mL/kg/min); oxygen exhaled fraction (FEO_2); carbon dioxide exhaled fraction ($FECO_2$); the double product (DP), that is the product between the heart rate and the systolic arterial pressure; the respiratory quotient (RQ), which indirectly provides the total use of metabolic substrata (lipids and carbohydrates) expressed in grams (g); the percentage of metabolic substrata use; the energy consumed expressed in kilocalories per minute (kcal/min); the oxygen pulse, that is, the rate between oxygen uptake and heart rate (VO_2/FC) expressed in milliliters per heart beat; besides the barometric pressure and the room temperature.

A specific pneumotacograph was connected to a mask to provide a low amount of airflow that was used to collect the gases. The blood pressure present during the stages of the experiment was measured by means of an aneroid sphygmomanometer with stethoscope—model Premium (Glicomed).

The study protocol was carried out through three successive stages: rest, *pranayama* and finally meditation, each one with the duration of 30 min. All the volunteers followed the same sequence. We established a pause of 10 min between the stages in order for the volunteers to recover from the discomfort produced by the equipment we used.

1st Rest—The volunteers remained seated, in total rest and with their eyes open. They should not perform any physical or cognitive activity during this period. They should simply allow their thoughts and emotions to flow spontaneously.

2nd *Pranayama*—The *pranayama* used in this protocol is called Visamavrtti Pranayama: the subjects had to inhale (puraka), hold their breath (kumbhaka) and exhale slowly (rechaka), considering the ratio 1:4:2. It is the Visamavrtti Pranayama at a ratio of intermediate difficulty (Iyengar 2005). Since there is a large variety of pranayamas, we chose a simple practice that could be adapted to the use of a mask and the physical position required by our experiment. Another aspect that justifies the choice and the significance of this pranayama is that it can be easily performed during the 30 min proposed in our research. Moreover, it encompasses the three basic phases (puraka, kumbhaka and rechaka) that are characteristic of many pranayamas commonly used in hatha-yoga classes. There are pranayamas that cannot be performed for long periods by practitioners of intermediate level, which was the case o four volunteers, and others still that would not be adaptable to the use of the equipment involved in our experiment. The volunteers were asked to find an adequate rhythm within this pattern so that it would not cause fatigue or discomfort.

3rd Meditation—All the volunteers practiced the same kind of meditation, that is, they made an effort to remain attentive to their thoughts without, however, being led by any of them, keeping the attitude of an observer of mental events. In this sense, the volunteers were asked to perceive their thoughts as simple mental changes, abstaining from judgments such as "this is a good thought"; "this is a bad thought".

We reproduced the order in which the practices of *yoga* chosen for this work are performed in a class based on the *Patanjali's* system, that is, first the *pranayamas* and then meditation.

Since we aimed at reducing possible changes resulting from the different physical postures, all the three stages of this research were carried out with the volunteers sitting on a chair with their backs in an upright position and their feet parallel on the floor.

The blood pressure of the volunteers was measured in the first, fifteenth and thirtieth minutes in each of the three stages of the experiment.

The laboratory temperature was kept at 24°C.

The results were analyzed with the use of the Statistica release 6 program. Firstly, the variables were submitted to a univariate analysis for us to determine whether the data distribution was Gaussian or not, and also to see if it was possible to use the parametric statistical methods. After that, all data were subjected to ANOVA with repeated measures followed by Tukey's test, when necessary. The level of significance of 5% ($P < 0.05$) was adopted for all the comparisons.

Results

Neste estudo, com o tipo de *pranayama* e de meditação escolhidos, obtiveram-se os seguintes resultados: *pranayama* practice caused an increase of the VO_2 in L/min when compared with rest and meditation. Meditation practice caused reduction of the VO_2 in mL/kg/min, when compared with rest and *pranayama*. *Pranayama* practices caused a significant increase of the VCO_2 in L/min and mL/kg/min when compared with rest and meditation. On the other hand, meditation practice caused a significant reduction of these parameters when compared with *pranayama* and rest. The heart rate in bpm was reduced during meditation when compared with rest and *pranayama*. The oxygen pulse was increased during *pranayama* practices, when compared with the other two conditions. The FEO_2 (%), as well as $FECO_2$ (%) during *pranayama* were significantly different from the values observed during rest and meditation. The total caloric expenditures expressed in kcal as well as in grams of lipids were significantly lower during meditation (Table 1).

Significant data (VO_2, VCO_2, heart rate, oxygen pulse, FEO_2, $FECO_2$, total caloric expenditures and grams of lipids) are presented in Table 1. We also evaluated: pulmonary ventilation (VE), ventilatory equivalent for oxygen (VE/VO_2), ventilatory equivalent for carbon dioxide (VE/VCO_2), systolic and diastolic pressures in the first, fifteenth and thirtieth minutes as well as the double products of systolic pressures in these times, besides the grams of carbohydrates that were non significant.

Table 1 Cardio-respiratory and Metabolic Variables during Rest, *Pranayama* and Meditation (results expressed as mean ± SD)

Variables	Rest	*Pranayama*	Meditation
VO_2 (L/min)	$0.266 \pm 0.10^{\#,*}$	$0.311 \pm 0.14^{*}$	0.177 ± 0.04
VO_2 (mL/kg/min)	$4.0 \pm 1.6^{*}$	$4.8 \pm 1.8^{*}$	2.6 ± 1.1
VCO_2 (L/min)	$0.200 \pm 0.10^{\#,*}$	$0.277 \pm 0.11^{*}$	0.144 ± 0.05
VCO_2 (mL/kg/min)	$3.2 \pm 1.4^{\#,*}$	$4.0 \pm 1.8^{*}$	2.2 ± 1.2
Heart rate (bpm)	$73.3 \pm 10.4^{*}$	$73.6 \pm 9.8^{*}$	67.4 ± 9.3
Oxygen pulse, VO_2/FC	3.7 ± 2.0	$4.4 \pm 1.8^{*}$	2.5 ± 0.8
FEO_2 (%)	$16.8 \pm 0.6^{\#}$	$15.8 \pm 1.2^{*}$	17.0 ± 0.8
$FECO_2$ (%)	$3.2 \pm 0.4^{\#}$	$4.0 \pm 0.9^{*}$	3.1 ± 0.6
Total caloric expenditures (kcal)	$38.2 \pm 17.7^{*}$	$47.0 \pm 19.9^{*}$	24.6 ± 6.9
Grams of lipids	$2.6 \pm 1.1^{*}$ (43.4% of total caloric expenditures)	$2.9 \pm 1.5^{*}$ (35.8% of total caloric expenditures)	1.5 ± 0.7 (35.7% of total caloric expenditures)

* $P \leq 0.05$ differs from meditation activity

\# $P \leq 0.05$ differs from pranayama activity

Discussion

As it can be observed in Table 1, the data in the present study corroborate the ones found in literature as they emphasize the occurrence of a hypometabolic state during meditation (Wallace 1970; Wolkove et al. 1984; Young and Taylor 1998; Dusek et al. 2005; Jevning et al. 1992). However, since we aimed at assessing the cardiorespiratory and metabolic changes that took place during the same *yoga* session, we chose to reproduce the sequence of exercises proposed for one traditional *hatha-yoga* class (*pranayamas* followed by meditation). Therefore, the physiological alterations observed during meditation might have been due to the previous performance of the *pranayamas*. We should bear in mind that a 10-min pause took place between the practices and, even though it was a short pause, we should not rule out the hypothesis that it caused a partial wash out of the previous period of *pranayamas*.

Our data suggest that there was an increase in the metabolism during the practice of *pranayama* proposed in this study, unlike some other reports which state that during *pranayama* practice there is a drop in the metabolism (Spicuzza et al. 2000; Jerath et al. 2006). This apparent contradiction can be explained by the fact that, in this study, the measurements were carried out during the respiratory practices and not at the after-practice moment, which is usually followed by deep relaxation.

The VO_2 in *pranayama* practice was significantly higher than that measured in rest (20% higher) and in meditation (84% higher), since the respiratory muscles are probably more activated, therefore increasing the total caloric expenditures. Yet, it is important to stress the fact that physiological changes depend on the kind of *pranayama* performed. Telles and Desiraju (1991) investigated 10 experienced *pranayama* practitioners during the performance of *Ujjayi* (inhaling air, retaining it and slowly exhaling it with partial closure of the glottis) and found different values associated with different periods of retention of air. When the duration of the air retention phase was 22.2 per cent of the respiratory cycle, there was a significant increase in VO_2 (52%). When the period of air retention was 50.4 per cent, on the other hand, there was a statistically significant lowering in VO_2 (19%). Even though we did not use the Ujjayi technique, the period of air retention performed by our volunteers was quite extended (1:4:2). Unlike Telles and Desiraju, however, we found a metabolic increase. These results show that slightly different patterns can produce different oxygen consumption rates.

When compared with the period of rest, the VO_2 in the period of meditation presented a statistically significant drop of 35%, which is an even larger drop than that found in most of the articles available in the literature (Wallace 1970). Nonetheless, Benson and collaborators (1990) observed a drop of 64% in the metabolism of three Buddhist Tibetan monks who lived in the *Rumtek* monastery, India. This finding shows that moments of distinct metabolic variation can be observed in the same *yoga* session.

Literature has been demonstrating that VCO_2 decreases as much as VO_2 during meditation (Wallace et al. 1971). The values for VCO_2 in our study corroborate such data. Moreover, the values of VCO_2 were higher in the *pranayama* period, which was expected to happen, since in these exercises the practitioner sustains long periods of voluntary apnea. Some studies investigated the alterations in the chemiosensibility to hypoxia and hypercapnia in practitioners of *yoga* who routinely exercise through this practice of respiratory control. The evidence derived from those studies suggests that there is a reduction of the ventilatory response to these stimuli (Maclean et al. 1997; Spicuzza 2000, Miyamura et al. 2002).

During the meditation proposed in this study, the heart rate was reduced in six beats per minute (bpm) on average when compared with rest or even *pranayama*. In two occasions, Wallace found results similar to these. While studying the effect of the transcendental meditation in 15 volunteers, Wallace (1970) identified a decrease of five bpm.

The decrease of oxygen uptake due to meditative practice influenced the reduction of the total caloric expenditures that, as a variable derived from VO_2, also had a statistically significant reduction of 35%.

Udupa et al. (1975) studied six men who took a course of yoga breathing exercises (*Pranayama)* for 6 months. They report changes such as accelerated adrenocortical activity, increases in total serum protein and urinary N and decreases in fasting blood sugar and total serum lipids. However, the analysis they carried out was not adequate, since they did not compare the moments before and after the yoga practice. We did not find reports in the literature that show alterations in the use of dietary substrata during different periods. As it can be observed in Table 1, the data show that the individuals metabolized a lower amount of lipids (1.5 g) in the meditative period when compared with the period of rest (2.6 g).

The measures of blood pressure did not show significant differences. This can be explained by the fact that the individuals who took part in this study were normotensive. The other non-significant results (pulmonary ventilation (VE), ventilatory equivalent for oxygen (VE/VO_2), ventilatory equivalent for carbon dioxide (VE/VCO_2), and the grams of carbohydrates) might have been alterations in case the sample had been comprised by a larger number of subjects.

As previously stated, the protocol we used aimed at reproducing the order in which yoga practices are performed in a class. Since this is a preliminary study, we did not randomize this sequence among the volunteers. Nevertheless, we do not disregard the possibility of alterations in the results in case the randomization had been performed.

The results suggest that the meditation used in this study reduces the metabolic rate whereas the specific pranayama technique in this study increases it when compared with the rest state.

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