

## Oxygen Consumption and Respiration Following Two Yoga Relaxation Techniques

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*The present study was conducted to evaluate a statement in ancient yoga texts that suggests that a combination of both “calming” and “stimulating” measures may be especially helpful in reaching a state of mental equilibrium. Two yoga practices, one combining “calming and stimulating” measures (cyclic meditation) and the other, a “calming” technique (shavasana), were compared. The oxygen consumption, breath rate, and breath volume of 40 male volunteers (group mean  $\pm$  SD, 27.0  $\pm$  5.7 years) were assessed before and after sessions of cyclic meditation (CM) and before and after sessions of shavasana (SH). The 2 sessions (CM, SH) were 1 day apart. Cyclic meditation includes the practice of yoga postures interspersed with periods of supine relaxation. During SH the subject lies in a supine position throughout the practice. There was a significant decrease in the amount of oxygen consumed and in breath rate and an increase in breath volume after both types of sessions (2-factor ANOVA, paired t test). However, the magnitude of change on all 3 measures was greater after CM: (1) Oxygen consumption decreased 32.1% after CM compared with 10.1% after SH; (2) breath rate decreased 18.0% after CM and 15.2% after SH; and (3) breath volume increased 28.8% after CM and 15.9% after SH. These results support the idea that a combination of yoga postures interspersed with relaxation reduces arousal more than relaxation alone does.*

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**KEY WORDS:** yoga; exercise; relaxation; oxygen consumption; respiration.

### INTRODUCTION

Yoga is an ancient Indian science and way of life, which includes the practice of specific postures, regulated breathing, and meditation (Taimini, 1961). By practicing yoga a person is supposed to reach a state of mental equanimity, so that responses to favorable or unfavorable external events are well under the individual's control, and the responses are moderate in intensity. Transcendental Meditation is adapted from ancient yoga texts and involves a daily 20-min session during which an individual sits with eyes closed and repeats a *mantram* (a phrase or string of words) silently (Maharishi Mahesh Yogi, 1972). Repeated practice is

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supposed to ultimately help in reaching a state of perfect self-awareness or 'transcendence.' Transcendental Meditation done for 20 min reduced oxygen consumption by 17 percent (Wallace, Benson, & Wilson, 1971). This was believed to be due to reduced mental arousal and reduced muscular activity. Similarly, a 15 percent decrease in oxygen consumption followed meditation on a meaningful syllable (Telles, Nagarathna, & Nagendra, 1995). In contrast, two studies on a single subject practicing yoga breathing (*ujjayi pranayama*) reported increases in oxygen consumption by 19 percent and 9 percent, respectively during the practice (Miles, 1964; Rao, 1968). More recent studies on groups of yoga trainees showed that other yoga breathing practices also increased oxygen consumption by an average of 28 percent following a month of practice (Telles, Nagarathna, & Nagendra, 1994) and by an average of 17 percent as an immediate effect of 45 min of practice (Telles, Nagarathna, & Nagendra, 1996). The metabolic rate increased, both during a sitting (Rai & Ram, 1993) and a standing yoga posture (Rai, Ram, Kant, Madan, & Sharma, 1994), when these postures were compared with supine rest and with sitting in a chair. In particular, the standing yoga posture, *virasan*, induces a hypermetabolic state with increased sympathetic activity, which disappears when the subject adopts a supine posture (*shavasan*). These differences in reported levels of oxygen consumption were probably related to the use of different types of yoga practices. In general, oxygen consumption decreased following meditation and increased during or after yoga breathing practices and postures. This observation may be explained by the fact that meditation reduces muscular effort, whereas yoga breathing and yoga postures, though practiced with relaxation, may increase muscular effort, relative to meditation. These findings are in line with known reports that lowered muscular effort is associated with reduced metabolic rate. The results also suggest that though all yoga practices are supposed to increase mental relaxation, the metabolism lowering effect is better following meditation, which may be associated with greater mental calmness compared with yoga postures or yoga breathing.

On the other hand, it is worth noting that traditional yoga texts say that it may also sometimes be desirable to stimulate the mind (Chinmayananda, 1984):

In a state of mental inactivity awaken the mind; when agitated, calm it; between these two states realize the possible abilities of the mind. If the mind has reached the state of perfect equilibrium then do not disturb it again.

For most persons, the mental state while doing routine activities (not necessarily associated with yoga) is neither "inactive" nor is it "agitated," but is somewhere between these extremes and hence a combination of "awakening" and "calming" measures may be better suited to reach a balanced, relaxed state.

The foregoing idea, drawn from the traditional texts, was the basis for a yoga practice called '*cyclic meditation*.' This technique includes the practice of four yoga postures interspersed with relaxation while supine, thus achieving a combination of both "stimulating" and "calming" practices (Nagendra & Nagarathna, 1997). In the activating phase, the yoga postures are practiced about four times slower than that required by classical descriptions. This slower practice requires more effort than that required by the usual practice. We hypothesized that because cyclic meditation (CM) has repetitive cycles of 'activating' and 'calming' practices, based on the idea from the ancient texts, as discussed earlier, practicing CM would cause greater relaxation compared with supine rest in *shavasan* (SH). The present study was designed to compare the oxygen consumption and respiration after the practice of CM, with the same measurements made after a period of equal duration of supine rest. In this way, we objectively sought to evaluate the CM technique, which is based on ancient texts.

## MATERIALS AND METHODS

### Subjects

There were 40 male volunteers with ages between 20 and 47 years (group mean  $\pm$  *SD*,  $27.0 \pm 5.7$  years). The oxygen consumption, breath rate, and breath volume have been shown to vary with the phases of the menstrual cycle, both at baseline (Das & Jana, 1991) and in the response following exercise (Matsuo, Saitoh, & Suzuki, 1999), hence we included only male volunteers in the study. All subjects were in normal health, based on a routine clinical examination, and none of them had a history of smoking or of respiratory ailments. They had been practicing yoga, including both CM and relaxation in a supine position (SH, i.e., corpse posture) for periods varying from 3 to 72 months (group mean  $\pm$  *SD*,  $32.9 \pm 19.8$  months). None of the volunteers were taking any medication (allopathic, ayurvedic, or home remedies) and did not use any other wellness strategy. The subjects were told that the study intended to evaluate the physiological effects of CM and SH. Their informed consent was obtained.

### Design of the Study

Subjects were assessed in two types of sessions, namely CM and SH. For half the subjects the CM session took place on the first day, with SH the next day. The other subjects had the order of the sessions reversed. Subjects were alternately allocated to either schedule, to remove any contribution of a retest effect to results following the two sessions. Assessments were made before and after the practices, but not during them. In general, subjects were told that the experiment aimed at comparing the effects of the two yoga practices. The aim of the experiment (i.e., whether a combination of activation and relaxation, in CM, as compared with relaxation alone, in SH, would alter the metabolic and breath rates in the same or different directions) was not explained to them.

During recordings, subjects were asked to sit erect in the chair, with no specific instructions about breathing except that they were to breathe as normally as possible.

### Recording Procedure

Oxygen consumption was recorded with a closed-circuit Benedict-Roth apparatus (INCO, Ambala, India), using the standard method (Mountcastle, 1980). The subject breathed into an oxygen tank from which exhaled carbon dioxide was excluded by absorption in sodium hydroxide. The subjects were asked to breathe into a mask, which covered their nose and mouth, but were not given specific instructions about breathing except that they were to breathe as normally as possible.

### Data Extraction and Analysis

The end expiratory points of the respiratory record were joined as a slanting line, the slope of which gave the difference between initial and final volumes of oxygen in the tank in a given period, which was approximately 5 min in most cases. The breathing rate and breath volume (tidal breathing) were also obtained from the record. The height of the respiratory wave (in mm) was converted to volume (in ml), based on the calibration of the apparatus, that

is, 10 mm = 100 ml. The minute ventilation was calculated as the product of respiratory rate and breath volume. The values of oxygen consumed (in ml/min) were converted to ml/min Standard Temperature and Pressure Dry (STPD), according to the accepted method (International Union of Physiological Sciences Commission, 1991).

The data were analyzed using 2-factor analysis of variance (ANOVA), the Tukey test for multiple comparisons of mean values, and the paired  $t$  test (to compare before and after values). The ANOVA was used to determine if there was a significant difference between sessions (Factor A) and between assessments made before and after the sessions (Factor B). Pearson correlation coefficient was used to correlate percentage change after both CM and SH sessions in (1) oxygen consumption, (2) respiratory rate, and (3) breath volume, with (1) experience in yoga, (2) experience in CM, and (3) experience in SH.

### Cyclic Meditation

Cyclic meditation (CM) lasted for 22 min 30 s. Throughout the practice the eyes were closed, and subjects followed instructions given by an audio tape, to carry on the practice slowly, with awareness and relaxation. The practice began by repeating a verse from the yoga text (40 s); followed by isometric contraction of the muscles of the body ending with supine rest (1 min); standing at ease (called *tadasana*) and 'balancing' the weight on both feet (2 min); then the first actual posture, bending to the right (*ardhakatikakrasana*, 1 min 20 s); a gap of 1 min 10 s with instructions about relaxation and awareness; bending to the left (1 min 20 s); a gap as before (1 min 10 s); forward bending (*padahasthasana*, 1 min 20 s); another gap (1 min 10 s); backward bending (*ardhakakrasana*, 1 min 20 s); supine rest with instructions to relax the body in sequence (10 min). The postures were practiced slowly, with awareness of all the sensations that are felt. This slower practice required greater effort than usual. This greater effort was both physical (to do an action slowly) and mental (to resist completing the physical activity with the usual speed, a process which prevented the thoughts from 'wandering' and increased the awareness of the Self).

### Shavasana

During SH, or the corpse posture, the subject lay supine with legs apart and arms away from the sides of the body and eyes closed. This practice lasted 22 min 30 s, so that the duration was the same as for CM.

## RESULTS

The group mean values and standard error of measurement (*SEM*) for oxygen consumption, breath rate, breath volume, and minute ventilation are given in Table I.

### Two-Factor ANOVA

There was a significant difference between values recorded before and after the sessions of CM and SH (i.e., Factor B) for (1) oxygen consumption ( $F = 8.38$ , for  $DF = 1, 156$ ,  $p < .001$ ), (2) breath rate ( $F = 12.70$ ,  $DF$  as above,  $p < .001$ ), and (3) breath volume

**Table I.** Oxygen consumption and respiratory measures pre and post cyclic meditation and *shavasana*<sup>a</sup>

		Cyclic meditation	<i>Shavasana</i> (supine rest)
Oxygen consumption (ml/min)	Pre	882.1 ± 76.5	797.2 ± 63.6
	Post	599.0 ± 47.1 <sup>++</sup>	716.6 ± 60.1 <sup>+</sup>
Breath rate (cpm)	Pre	12.9 ± 0.8	12.5 ± 0.9
	Post	9.3 ± 0.7 <sup>+++</sup>	10.6 ± 0.8 <sup>++</sup>
Breath volume (ml)	Pre	922.9 ± 40.8	1014.8 ± 56.0
	Post	1189.2 ± 57.9 <sup>++++</sup>	1175.8 ± 58.2 <sup>++</sup>
Minute ventilation (ml/min)	Pre	11724 ± 4062	11440 ± 3821
	Post	11439 ± 3794	10251 ± 3999 <sup>+</sup>

<sup>a</sup> Values are group mean ± SEM.

\*  $p < .01$ , \*\*  $p < .005$  Tukey test, post compared to pre.

<sup>+</sup>  $p < .05$ , <sup>++</sup>  $p < .001$ ,  $t$  test for paired data, post compared to pre.

( $F = 15.82$ ,  $DF$  as above,  $p < .001$ ). There was no significant change in minute ventilation ( $p > .05$ ). The difference between values of the two types of sessions (i.e., CM, SH) were not significantly different (Factor A), with no significant interaction between Factors ( $A \times B$ ).

**Tukey Multiple Comparison Test**

The average respiratory rate recorded after CM was significantly lower than the average value recorded before CM ( $q = 4.65$ ,  $p < .01$ ). The respiratory amplitude, in contrast, was significantly higher after CM compared with before CM ( $q = 4.95$ ,  $p < .005$ ).

**Paired  $t$  Test**

The oxygen consumption decreased significantly after CM (32.1%,  $p < .001$ ) and SH (10.1%,  $p < .05$ ). Also, the breath rate was significantly lower after both sessions: after CM a decrease of 3.6 cycles per min ( $p < .001$ ) and after SH a reduction of 1.9 cycles per min ( $p < .001$ ). In contrast, the breath amplitude, which is related to the depth of breathing, was significantly higher after both types of sessions: after CM an increase of 28.8% ( $p < .001$ ) and after SH an increase of 15.9% ( $p < .001$ ). Minute ventilation decreased by 10.4% after SH ( $p < .05$ ).

**Pearson Correlation Coefficient**

There was no correlation between percentage change after both CM and SH sessions, in (1) oxygen consumption, (2) respiratory rate, and (3) breath volume, with (1) experience in yoga, (2) experience in CM, and (3) experience in SH ( $p > .05$ , for all comparisons).

**DISCUSSION**

There was a significant decrease in oxygen consumption and breath rate after both CM (a technique that included yoga postures interspersed with periods of supine rest) and after

SH (supine rest alone). The breath volume was raised after both practices. The magnitude of change for all three parameters was greater after CM and did not vary with the duration of experience of SH or of CM, though there was a wide range in this experience among the subjects (i.e., from 3 to 72 months).

The breath rate, depth, and breath phase duration (inspiration/expiration) are all highly sensitive to phasic changes in the psychological state (Lorig & Schwartz, 1990). Theoretical models of pulmonary response have tended to identify a single variable, typically the metabolic rate, and to attribute the majority of changes in pulmonary response to that variable. For example, early studies on Transcendental Meditation reported that the observed reduction in metabolic rate (and hence in the need of oxygen) during meditation was reflected in a decrease, essentially involuntary, in the rate of respiration and in the volume of air breathed (Wallace & Benson, 1972). The greater decrease in oxygen consumption, decrease in breath rate, and absence of change in minute ventilation (in spite of the greater breath volume) after CM, may have a similar explanation.

The greater reduction in oxygen consumption after CM and the changes in respiration suggested that in spite of the practice of yoga postures, which may be expected to be more stimulating than supine rest is, the effects suggested relaxation. These findings were opposite to a previously reported increase in oxygen consumption following *virasan*, a standing yoga posture (Rai & Ram, 1993). This standing yoga posture induces a hypermetabolic state with increased sympathetic activity, which disappears when the subject adopts a supine posture (SH). The present results also suggest that while practicing yoga postures for relaxation, two factors are important, maintaining a relaxed mental attitude and having periods of rest (no activity) following a period of activity.

The importance of interspersing exercise with periods of rest has already been described (Falk, 1995). Intermittent exercise was described as more likely to enhance enjoyment and improve compliance with the exercise plan. Yoga postures have been shown to serve as a form of mild exercise (Rai & Ram, 1993). The yoga postures practiced in CM may not have served as a form of exercise (however mild), but could be expected to be more physically activating than supine rest is. Whether this would have resulted in similar effects as exercise, though possibly of smaller magnitude, has not been evaluated. However, it has been shown that another mind-modifying Oriental practice, Tai Chi, which has been described as a 'moving meditation,' caused changes in heart rate, blood pressure, and urinary catecholamines, which were similar to walking at a speed of 6 km/hour (Jin, 1992). Because the stress reducing effects of noncompetitive, moderate exercise are well known (Shephard, 1997), we may indirectly infer that the relatively higher level of physical activity in CM as compared to SH, may explain the greater respiratory changes following CM.

During CM, subjects are given instructions to relax and maintain that mental state. It has already been shown that exercise plus cognitive strategy programs are more effective in promoting psychological benefits than are exercise programs lacking a structured cognitive component (Brown et al., 1995). Hence both cognitive and physiological factors may contribute to the greater reduction in oxygen consumption and other respiratory changes following CM as compared with supine rest.

In summary, the findings support the idea that CM, which combines "stimulating" and "calming" techniques, practiced with a background of relaxation and awareness may reduce physiological arousal better than SH can (which is calming). However, the present results require to be substantiated with added controls (e.g., studying the effect of no practice and of postures alone).

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## REFERENCES

- Brown, D. R., Wang, Y., Ward, A., Ebbeling, C. B., Fortlage, L., Puleo, E., Benson, H., & Rippe, J. M. (1995). Chronic psychological effects of exercise and exercise plus cognitive strategies. *Medicine and Science in Sports and Exercise*, 27(5), 765–775.
- Chinmayananda, S. (1984). *Mandukya upanishad*. Bombay: Sachin Publishers.
- Das, T. K., & Jana, H. (1991). Basal oxygen consumption during different phases of menstrual cycle. *Indian Journal of Medical Research*, 94, 16–19.
- Falk, B. (1995). Effect of continuous and intermittent exercise on energy expenditure and on the cardiorespiratory response. *Perceptual and Motor Skills*, 80(1), 64–66.
- International Union of Physiological Sciences Commission (1991). *Report of the IUPSC on teaching physiology*. Singapore: World Scientific.
- Jin, P. (1992). Efficacy of Tai Chi, brisk walking, meditation, and reading in reducing mental and emotional stress. *Journal of Psychosomatic Research*, 36(4), 361–370.
- Lorig, T. S., & Schwartz, G. E. (1990). The pulmonary system. In J. T. Cacioppo & L. G. Tassinary (Eds.), *Principles of Psychophysiology*. Cambridge: Cambridge University Press.
- Maharishi Mahesh Yogi (1972). *The science of creative intelligence*. New York: Age of Enlightenment Press.
- Matsuo, T., Saitoh, S., & Suzuki, M. (1999). Effects of the menstrual cycle on excess postexercise oxygen consumption in healthy young women. *Metabolism*, 48(3), 275–277.
- Miles, W. R. (1964). Oxygen consumption during three yoga-type breathing patterns. *Journal of Applied Physiology*, 19, 75–82.
- Mountcastle, V. B. (1980). *Medical physiology* (Vol. 2). St. Louis: CV Mosby.
- Nagendra, H. R., & Nagarathna, R. (1997). *New perspectives in stress management*. Bangalore: Vivekananda Kendra Prakashan.
- Rai, L., & Ram, K. (1993). Energy expenditure and ventilatory responses during virasana—a yogic standing posture. *Indian Journal of Physiology and Pharmacology*, 37(1), 45–50.
- Rai, L., Ram, K., Kant, U., Madan, S. K., & Sharma, S. K. (1994). Energy expenditure and ventilatory responses during siddhasana—a yogic seated posture. *Indian Journal of Physiology and Pharmacology*, 38(1), 29–33.
- Rao, S. (1968). Oxygen consumption during yoga-type breathing at altitudes of 520 m and 3800 m. *Indian Journal of Medical Research*, 56, 701–705.
- Shephard, R. J. (1997). Exercise and relaxation in health promotion. *Sports Medicine*, 23(4), 211–217.
- Taimini, I. K. (1961). *The science of yoga*. Madras: The Theosophical Publishing House.
- Telles, S., Nagarathna, R., & Nagendra, H. R. (1994). Breathing through a particular nostril can alter metabolism and autonomic activities. *Indian Journal of Physiology and Pharmacology*, 38, 133–137.
- Telles, S., Nagarathna, R., & Nagendra, H. R. (1995). Autonomic changes during 'OM' meditation. *Indian Journal of Physiology and Pharmacology*, 39(4), 418–420.
- Telles, S., Nagarathna, R., & Nagendra, H. R. (1996). Physiologic measures of right nostril breathing. *Journal of Alternative and Complementary Medicine*, 2(4), 479–484.
- Wallace, R. K., & Benson, H. (1972). The physiology of meditation. In *Altered states of awareness: Readings from scientific american*. San Francisco: W.H. Freeman and Company.
- Wallace, R. K., Benson, H., & Wilson, A. F. (1971). A wakeful hypometabolic physiologic state. *American Journal of Physiology*, 221, 795–799.