Applied Psychophysiology and Biofeedback, Vol. 31, No. 2, June 2006 (© 2006)
DOI: 10.1007/s10484-006-9012-8

Oxygen Consumption and Respiration During and After two Yoga Relaxation Techniques

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Published online: 13 July 2006

Cyclic meditation (CM) is a technique which combines 'stimulating' and 'calming' practices, based on a statement in ancient yoga texts suggesting that such a combination may be especially helpful to reach a state of mental equilibrium. The oxygen consumption, breath rate and breath volume of 50 male volunteers (group mean age ± SD, 27 ± 6.3 years) were assessed before, during, and after sessions of CM and sessions of supine rest in the corpse posture (shavasana, SH). The sessions were one day apart and the order was alternated. The oxygen consumption, breath rate and breath volume increased during the 'stimulating' practices of CM, returned to the baseline during the 'calming' practices, and the oxygen consumption decreased by 19.3 percent below baseline values after CM. During the SH session the oxygen consumption, breath rate and breath volume reduced; however the decrease in oxygen consumption after SH was less than after CM (i.e., 4.8 percent). The results support the idea that a combination of yoga postures with supine rest (in CM) reduces the oxygen consumption more than resting supine alone does.

KEY WORDS: yoga; postures; relaxation; respiration; oxygen; consumption.

INTRODUCTION

Oxygen consumption is generally regarded as a reliable index of physical activity and arousal (Bonnet & Anand, 2003). Transcendental meditation (TM) has been extensively researched and based on a wide spectrum of physiological data it has been hypothesized that transcendental meditation is an integrated response with peripheral circulatory and metabolic changes (evidenced by a decrease in oxygen consumption) sub-serving increased central nervous activity (Jevning, Wallace, & Beidebach, 1992). Meditation on the Sanskrit syllable *OM* also resulted in a decrease in oxygen consumption simultaneous with a decrease in cutaneous blood flow and a reduction in heart rate (Telles, Nagarathna, & Nagendra, 1998). Both TM and meditation on *OM* are practiced while seated and with eyes closed.

Another meditation technique called cyclic meditation involves the practice of yoga postures interspersed with supine rest (Nagendra & Nagarathna, 1997). This technique

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was derived from an ancient Indian text, the *Mandukya Upanisad* (Chinmayananda, 1984). The technique was based on the belief that the combination (of yoga postures with supine rest) would facilitate reaching a relaxed state more easily than either practice alone. The practice of cyclic meditation was shown to decrease the oxygen consumption, breath rate and increase the breath volume to a greater degree than a comparable duration of supine rest, in forty volunteers (Telles, Reddy, & Nagendra, 2000). The magnitude of reduction in oxygen consumption following cyclic meditation was 32.1 percent (as compared to 10.1 percent after supine rest). However the recordings were made using a closed circuit Benedict-Roth apparatus which has a number of practical disadvantages. For example, recordings were made before and after, but not during the practice. Also it is recognized that while breathing through the Benedict-Roth closed circuit apparatus some people find it hard to breathe normally (Judy, 1982). Another criticism of the method is that accuracy depends on the ability of a subject to breathe regularly. If the rate or amplitude (or both) of respiration are irregular it is difficult to decide precisely where to draw the sloping line which determines the oxygen consumption. In the closed circuit system, the person breathes from a reservoir of one hundred percent oxygen and the resistance offered by the apparatus to increase the volume of breathing required during physical activity is high so that the rate of carbon dioxide removal by absorption may be inadequate for accurate results during even moderate activity (American Association for Respiratory Care, 1994).

It has also been shown that the resistance to breathing is increased, inspiratory time is prolonged and the work of breathing may be increased by as much as 10 percent in closed-circuit systems (Branson, 1990). Generally, the open-circuit system is regarded as more accurate since the person breathes ambient air and the apparatus does not offer resistance to the flow of air (Matarese, 1997).

With this background the present study was planned to record the oxygen consumption (using an open circuit apparatus) before, during and after CM compared to an equal duration of *shavasana* (SH), (i) to understand the changes during the actual practice of CM and (ii) to compare the findings with the earlier study (cited above) which had an identical study design.

MATERIALS AND METHODS

Subjects

Fifty male volunteers with ages ranging between 18 and 48 years (group mean ± S.D., 27.0 ± 6.3 years) took part in the study. Respiratory and metabolic variables have been shown to vary with the phases of the menstrual cycle (Das & Jana, 1991), hence the study was restricted to males. The subjects were undergoing yoga training at a yoga center. All of them were in normal health based on a routine clinical examination and none of them had a history of smoking or respiratory ailments. None of them was taking any medication and they did not use any other wellness strategy. They had experience of practicing both yoga techniques (i.e., CM and SH) ranging between 3 and 60 months (group mean ± S.D., 15.3 ± 13.3 months). The variables to be recorded and the study design was described to the participants and their consent to participate was obtained. None of them was aware of the hypothesis of the study.

Design of the Study

Participants were assessed in two types of sessions, namely cyclic meditation (CM) and *shavasana* (SH). For half the subjects the CM session took place on one day, with the SH session the next time, with a one day gap between sessions. The remaining subjects had the order of the sessions reversed. Subjects were alternately allocated to either schedule to prevent the order of the sessions influencing the outcome.

For all fifty participants assessments were made throughout a session which lasted for 33 min, of which 22 min 30 s was spent in the practice of either CM or SH, preceded (pre) and followed (post) by 5 min of supine rest. For a sub-sample of ten participants additional or repeat recordings were made with the post period longer (i.e., 30 min). Hence each session lasted for 63 min, of which 22 min 30 s was spent in the practice of either CM or SH, preceded (pre) by 5 min of supine rest and followed (post) by 30 min of supine rest. These ten participants were part of the fifty whose total session duration was 33 min, and for whom the post period was 5 min.

Assessments

The assessments of oxygen consumption, minute ventilation, tidal volume and breath rate were made with the subject breathing ambient air while wearing a mask, using an open circuit apparatus (OxyconPro system, Model 2001, Jaeger, Germany). The system was calibrated for ambient temperature, humidity and barometric pressure, flow rate; and gas analysis.

Interventions

Cyclic Meditation

Cyclic meditation lasted for 22 min 30 s. Throughout the practice subjects kept their eyes closed and followed instructions from an audiotape. The instructions emphasized carrying out the practice slowly, with awareness, and relaxation.

The four phases of cyclic meditation consisted of the following practices. Phase 1 (5 min): The practice began by repeating a verse (1 min) from the yoga text, the Mandukya Upanishad (Chinmayananda, 1984); followed by isometric contraction of the muscles of the body ending with supine rest (1 min 30 s): slowly coming up from the left side and standing at ease (called tadasana) and 'balancing' the weight on both feet called 'centering' (2 min 30 s); Phase 2 (5 min): Then the first actual posture, bending to the right (ardhakatichakrasana, 1 min 20 s); a gap of 1 min 10 s in tadasna with instructions about relaxation and awareness; bending to the left (ardhakaticakrasana, 1 min 20 s); a gap of 1 min 10 s in tadasana; Phase 3 (5 min): Forward bending (padahastasana, 1 min 20 s); another gap (1 min 10 s); backward bending (ardhacakrasana, 1 min 20 s); a gap of 1 min 10 s in tadasana; Phase 4 (7 min 30 s): Slowly coming down to a supine posture for rest with instructions to relax different parts of the body in sequence (Telles, Reddy, & Nagendra, 2000).

Shavasana

During the 22 min 30 s of 'supine rest' subjects lay in the corpse posture (*shavasana*) with their legs apart and arms away from the sides of the body, with eyes closed. The state of *shavasana* was considered for analysis as four phases (the first three phases of 5 min each and the fourth phase of 7 min 30 s) to make it comparable to the state of CM practice, during the CM session. However, throughout the four phases, the subjects lay in the same posture.

Data Extraction and Analysis

The contiguous data obtained from breath-by-breath sampling were averaged for the 'pre', 'during' and 'post' states of each session. The 'during' state of the CM session had four 'phases' detailed above. These were analyzed separately and to make the analyses uniform, the 22 min 30 s of the 'during' phase of the SH session was also considered as four phases of comparable duration. Also, for the sub-sample of ten participants for whom the 'post' period was 30 min, this period was considered as six, 5 min phases.

Statistical analysis was done using SPSS (Version 10.0). Repeated measures analyses of variance (ANOVA) were performed with two Within Subjects Independent Variables, i.e., (i) Sessions with two levels; CM and SH and (ii) States with six levels; pre, during 1 (D1), during 2 (D2), during 3 (D3), during 4 (D4), and post. In the ten participants who had a longer 30 min of post recording (i.e., six phases), each post phase was compared to the respective 'pre' (hence in this case for 'States' there were eleven levels).

Post-hoc tests (with Bonferroni adjustment for multiple comparisons) were used to detect significant differences between mean values.

RESULTS

The Whole Group ($n = 50$)

The group mean values ± S.D. for oxygen consumption, breath rate, tidal volume and minute ventilation for CM and SH sessions are given in Table I.

The Sessions by States interaction was significant for: (i) oxygen consumption [$F = 193.16$, for $DF = 2.99$, 146.94, $P < .001$, Huynh-Feldt $\varepsilon = .600$]; (ii) breath rate [$F = 46.291$, for $DF = 4.18$, 205.07, $P < .001$, Huynh-Feldt $\varepsilon = .837$]; (iii) tidal volume [$F = 42.58$, for $DF = 4.17$, 204.70, $P < .001$, Huynh-Feldt $\varepsilon = .836$]; and for (iv) minute ventilation [$F = 180.27$, for $DF = 3.07$, 150.85, $P < .001$, Huynh-Feldt $\varepsilon = .616$]. This suggested that for all four measurements Sessions and States were not independent of each other (Zar, 2005).

Post-hoc tests for multiple comparisons were performed with Bonferroni adjustment. The oxygen consumption increased during the D1, D2, and D3 phases (corresponding to yoga postures) of CM but significantly reduced after CM compared to the 'pre' state ($P < .001$, for all comparisons). In the SH session oxygen consumption reduced in all the phases compared to respective 'pre' states ($P < .001$, for all comparisons). The comparison

Table I. Oxygen Consumption, Breath Rate, Tidal Volume And Minute Ventilation in Cyclic Meditation (CM) and *Shavasana* (SH) Sessions

		Phases					
Variables	Sessions	Pre	During 1	During 2	During 3	During 4	Post
Oxygen consumption	CM	219.93 ± 21.31	254.58*** ± 42.86	271.53*** ± 63.18	341.12*** ± 56.81	214.55 ± 31.42	177.28*** ± 18.14
(ml/min, STPD)	SH	212.83 ± 26.94	198.64*** ± 25.88	197.34*** ± 25.52	197.52*** ± 26.91	198.72*** ± 24.04	202.56*** ± 23.01
Breath rate	CM	15.11 ± 2.43	15.62 ± 2.77	18.10*** ± 3.32	18.25*** ± 3.45	15.64 ± 2.75	13.99*** ± 2.68
(cycles/min)	SH	14.39 ± 2.80	13.99 ± 2.67	14.26 ± 2.84	14.12 ± 2.77	14.51 ± 2.49	14.45 ± 2.66
Tidal volume	CM	0.50 ± 0.10	0.57*** ± 0.10	0.54* ± 0.10	0.61*** ± 0.10	0.50 ± 0.09	0.43*** ± 0.08
(liters, BTPS)	SH	0.50 ± 0.11	0.48 ± 0.09	0.47 ± 0.09	0.48 ± 0.09	0.47 ± 0.07	0.49 ± 0.10
Minute ventilation	CM	6.84 ± 1.00	8.16*** ± 1.26	9.15*** ± 1.86	10.35*** ± 1.82	7.08 ± 1.10	5.96*** ± 0.92
(liters//min, BTPS)	SH	6.61 ± 1.00	6.35* ± 0.93	6.32 ± 0.88	6.33 ± 0.96	6.42 ± 0.82	6.50 ± 0.92

Note. Values are group mean ± S.D.
*$P < .05$; *** $P < .001$, post-hoc tests with Bonferroni adjustment, compared with respective Pre values.

of post-measurements of the two sessions (CM and SH) showed that oxygen consumption was significantly lower after the CM session compared to after the SH session ($P < .001$).

There was a significant increase in breath rate during the D2, and D3 phases (corresponding to yoga postures) of CM and a significant reduction after CM compared to the 'pre' state ($P < .001$, for all comparisons). There was no significant change in the SH session. Also, the comparison of post-measurements of the two sessions (CM and SH) showed no significant change.

The tidal volume increased during the D1 ($P < .001$), D2 ($P < .05$) and D3 ($P < .001$) phases of the CM session and significantly reduced after CM compared to the 'pre' state ($P < .001$). There was no significant change in the SH session. The comparison of post-measurements of the two sessions (CM and SH) showed that the tidal volume was significantly lower after the CM session compared to after the SH session ($P < .001$).

The minute ventilation increased during the D1, D2, and D3 phases (corresponding to yoga postures) of CM but significantly reduced after CM compared to the 'pre' state ($P < .001$, for all comparisons). During the SH session it significantly reduced in the D1 phase compared to the 'pre' state ($P < .05$) while there was no change after SH. The comparison of post-measurements of the two sessions (CM and SH) showed that the minute ventilation was significantly lower after the CM session compared to after the SH session ($P < .001$).

Sub-Sample with a longer 'post' period ($n = 10$)

The Sessions by States interaction was significant for: (i) oxygen consumption [$F = 47.86$, for $DF = 5.01$, 45.12, $P < .001$, Huynh-Feldt $\varepsilon = .501$]; (ii) breath rate [$F = 8.58$, for $DF = 2.36$, 21.29, $P < .001$, Huynh-Feldt $\varepsilon = .237$]; (iii) tidal volume [$F = 7.51$, for $DF = 1.96$, 17.64, $P < .001$, Huynh-Feldt $\varepsilon = .196$]; and (iv) minute ventilation [$F = 8.58$, for $DF = 3.26$, 29.37, $P < .001$, Huynh-Feldt $\varepsilon = .326$].

Post-hoc tests for multiple comparisons were performed with Bonferroni adjustment. The oxygen consumption increased during the D1, D2, and D3 phases (corresponding to yoga postures) of CM ($P < .01$, for all comparisons) and reduced after CM ($P < .01$). This trend of reduction in oxygen consumption continued further throughout the 30 min of the post period compared to the 'pre' state ($P < .05$, for post 1 and post 4, and $P < .01$, for post 2, post 3, post 5, and post 6). In the post period of SH [i.e., post 2 ($P < .05$), post 3 and post 6 ($P < .01$)] session the oxygen consumption reduced compared to the 'pre' state. The comparison of post-measurements of the two sessions (CM and SH) showed that the oxygen consumption was significantly lower in all post phases of CM session compared to the respective phases of the SH session ($P < .001$). The trends of change in oxygen consumption have been shown in Fig. 1(A).

The trends of change in breath rate, tidal volume, and minute ventilation in this sub-sample are given in Figs. 1(B), 1(C), and 1(D), respectively.

DISCUSSION

The changes in oxygen consumption, minute ventilation, tidal volume, and breath rate were recorded before, during, and after the practice of cyclic meditation compared to an equal duration of supine rest in the corpse posture (*shavasana*). For analysis, the practice of

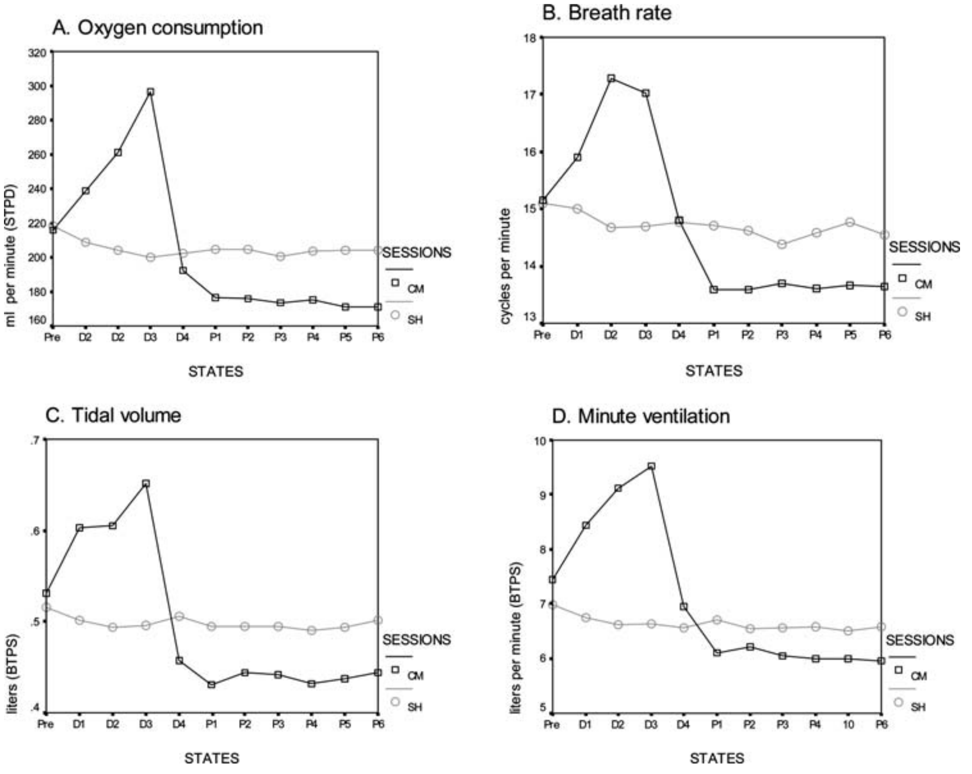

Fig. 1. Oxygen consumption, breath rate, tidal volume and minute ventilation in cyclic meditation (CM) and *shavasana* (SH) sessions with a thirty minute post period ($n = 10$).

CM was considered as four phases. The first three included the practice of yoga postures, while the fourth phase was of supine rest.

The oxygen consumption increased in the first three phases of CM, returned to the baseline in the fourth phase and reduced by 19.3 percent compared to the baseline after the practice. The changes in minute ventilation, tidal volume, and breath rate were similar to the changes in oxygen consumption during and after CM.

In the s*havasana* session of supine rest (SH) the oxygen consumption decreased during SH and also decreased after SH by 4.8 percent. The tidal volume, minute ventilation and breath rate showed no change in the SH session.

In a sub-sample of ten participants the same design was followed in a repeat session with a longer 'post' recording (i.e., 30 min). The decrease in oxygen consumption in the first five minutes after CM was 18.3 percent and between 25 and 30 min post-CM, the percent decrease was 20.8. For the *shavasana* (SH) session in this sub-sample the decrease was 6.4 percent in the first five minutes post-SH and in the last five minutes (i.e., between 25 and 30 min) post-SH there was a 6.5 percent decrease. This showed that the changes which occurred 5 min after either CM or SH carried on for 30 min post practice. A longer duration post recording would be needed to understand how long the change persists.

The changes in oxygen consumption reported here show a similar trend as those in an earlier study, which had an identical design (Telles, Reddy, & Nagendra, 2000). However in the earlier study there was a 32.1 percent decrease in oxygen consumption after CM and a 10.1 percent decrease after SH practice, compared to a 19.3 percent and a 4.8 percent decrease respectively, in the present study. The difference in magnitude of change may be due to two factors: (i) the meditators in the previous study had an average experience of meditation of 32.9 ± 19.8 months compared with the experience of the meditators in the present study which was 15.3 ± 13.3 months, on an average, and (ii) the earlier study measured the oxygen consumption using a closed circuit apparatus which has been described as less precise (Judy, 1982; American Association for Respiratory Care, 1994).

It is also to be noted that in the sub-sample of ten participants the same trend was seen during and after CM.

When considering the changes in minute ventilation, it is known that ventilation increases linearly with the oxygen intake and with the carbon dioxide output upto approximately 60 percent of the maximal oxygen consumption (Jones, 1997). Hence the similarity in the direction of change in oxygen consumption and minute ventilation during cyclic meditation is not unexpected. With regard to the changes in tidal volume and in breath rate, these may be explained by two facts (Jones & Rebuck, 1979). These are: (i) increases in minute ventilation are accompanied by an increase in tidal volume, and (ii) as the tidal volume reaches 50 to 60 percent of the vital capacity the breath rate increases as well.

The changes in tidal volume, breath rate and minute ventilation after CM were of lesser magnitude in the present study compared to the earlier study (cited above). The reasons for these differences may be related to the fact that the closed circuit apparatus used earlier is less accurate (Matarese, 1997) and some people find it difficult to breathe through the closed circuit apparatus (Branson, 1990).

During CM the yoga postures are practiced four times slower than classically described (Nagendra & Nagarathna, 1997). Practicing yoga postures slowly requires more effort than usual practice. Hence these practices were considered ‘activating’ when compared to the interspersed periods of supine rest. For this reason it is of interest to compare the post-CM changes in oxygen consumption (i.e., a 19.3 percent decrease) and breath rate (i.e., a decrease by 1.1 breaths per minute), with those known to occur after exercise. After exercise it is recognized that oxygen consumption increases (Borsheim & Bahr, 2003). This ‘excess post-exercise oxygen consumption (EPOC)’ may last for several hours after exercise or be transient and minimal. The magnitude of EPOC after aerobic exercise depends on both the duration and the intensity of exercise, as well as factors such as training status and gender. In low intensity, primarily aerobic exercise about one half of the total ‘Excess Post Exercise Oxygen Consumption (EPOC)’ takes place within thirty seconds of stopping the exercise and complete recovery can be achieved within several minutes, with the oxygen uptake returning to the pre exercise level. The EPOC was studied following a fifty minute run compared to two, twenty five minute run at seventy percent of peak oxygen consumption (Kaminsky, Padjen, & Latlam-Saeger, 1990). Following exercise, the oxygen consumption returned to baseline within thirty minutes for all three exercise trials.

There are no reports to our knowledge of a reduction in oxygen consumption post-exercise or after exercise followed by rest. The depth (and also for strenuous exercise, the rate) of breathing increases with the onset of exercise, followed by a brief pause, after which there is a further, more gradual increase (Ganong, 2005). Ventilation decreases at the end of exercise and gradually declines to pre-exercise values. Again there is no description of a decrease in breath rate following exercise. In the present study the decrease in breath rate following meditation may be a manifestation of decreased arousal (Ax, 1953). There is no evidence of it being a rebound effect as no such decrease follows exercise. It is also to be noted that the participants were not following specific instructions to regulate their breathing.

The changes which occurred after CM are more like the changes which have been described after the practice of TM i.e., a 17 percent decrease in oxygen consumption, decrease in breath rate and minute ventilation (Wallace, Benson, & Wilson, 1971). A similar trend of a decrease in oxygen consumption and in breath rate also followed meditation on *OM* (Telles, Nagendra, & Nagarathna, 1998). In the early reports on the effects of TM and in subsequent studies the hypometabolic state has been suggested to be due to decreased muscle metabolism based on decreased forearm lactate secretion and related changes (Jevning, 1988). A decrease in oxygen consumption has also been reported following the practice of the relaxation response in early and recent reports (Benson, Dryer, & Hartley, 1978; Dusek et al., 2006). The relaxation response resulted in generalized decreased sympathetic nervous system activity and more recently the response has been reported to be mediated by nitric oxide. Whether similar mechanisms as described for TM or for the relaxation response were responsible for the post-CM changes is not known.

Since CM includes the practice of yoga postures the effects were also considered worth comparing to the practice of Tai-Chi-Qui-Gong (TCQG) which includes 54 movements (Chao, Chen, Lan, & Lai, 2002). Based on energy expenditure and cardio respiratory responses TCQG was described as a low intensity exercise. The changes after the practice were not reported. Hence the changes during the practice of yoga postures in CM appear similar to those during TCQG.

In summary, the practice of CM reduces oxygen consumption compared to the preceding period, as well as compared to a period of supine rest of equal duration. Similarly a reduction in oxygen consumption has been reported following other meditation practices and the relaxation response. Hence an understanding of the physiological and clinical implications of a decrease in oxygen consumption is desirable. The oxygen consumption is considered as a general index of increased physiological activity (Bonnet & Anand, 2003). Also in an investigation of effects of psychological parameters on resting metabolic rate (RMR), a significantly greater RMR was found in a high-trait anxious group than in a low trait anxious group (Schmidt, O'Connor, Cochrane, & Cantwell, 1996). This suggests that a higher rate of oxygen consumption may be associated with higher anxiety. This is of interest as high anxiety levels are generally associated with a greater incidence of stress related ailments (Grinde, 2005). However on the other hand, it has been shown that the long-term maintenance of weight loss has been found to be associated with highly restrained eating, regular physical activity, and perhaps with increased anxiety (Sarlio-Lahteenkorva & Riassanen, 1998). Whether the practice of techniques such as CM over time modifies the ability to maintain weight or weight loss remains to be studied. Another possible benefit of reducing oxygen consumption may be extrapolated from a study on cellular metabolism (Hand & Hardewig, 1996). This report mentions that the survival time of organisms during exposure to those environmental stresses which limit energy availability is directly related to the degree to which metabolic rate decreases.

However all these possible consequences of a decrease in oxygen consumption are speculations. The present study reports a decrease in oxygen consumption consistent with the earlier study of identical design (Telles, Reddy, & Nagendra, 2000). The changes following CM may be ascribed to the traditional concept on which the technique is based says that, '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 a state of perfect equilibrium do not disturb it again.' The reduction in oxygen consumption may hence be a possible manifestation of physiological changes occurring while approaching a state of 'perfect equilibrium.' Further research is required to understand the mechanisms underlying the change and the long-term consequences of the practice.

ACKNOWLEDGMENTS

The authors gratefully acknowledge H.R. Nagendra, Ph.D. who derived the cyclic meditation technique from ancient yoga texts. The funding from the 'DST-FIST program,' Government of India and the Temple of the Universe, Alachua, FL., U.S.A. for the equipment used is also gratefully acknowledged.

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