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Original Research Article

Improved Aerobic Capacity with Progressive Incorporation of Breathing Maneuvers in Yoga Training

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Abstract

The potentiality of yoga to improve $\dot{V}O_{2max}$ is often questioned because of its low exercise stimulus. Considering the positive effects of Yoga Breathing Maneuvers (YBM) on cardio-respiratory systems, its effect on $\dot{V}O_{2max}$ needs to be studied. So, possible role of YBM in improvement in $\dot{V}O_{2max}$ in yoga training was observed.32 healthy male students of 19 to 21 years of age were divided into two equal groups of 16 each. One group (YG) practiced yoga (Yogasanas, YBM and meditation) for 40 minutes every day for 6 days per week for 3 months. YBM were progressively inducted by increasing practice duration throughout training. Other group (CG) did not practice Yoga. Their basal heart rate (HR) and respiratory rate (RR) were recorded in the morning in bed. Predicted $\dot{V}O_{2max}$ was measured on them by Queen's college step test. HR was recorded before, during and after exercise manually and with Polar sports tester. All the parameters were recorded at baseline, 6th and 12th week end of yoga training.In YG, $\dot{V}O_{2max}$ improved from baseline (47.5±3.7 ml/kg/min) to 6th week (49.4±3.3 ml/kg/min, P<0.001) and 12th week end (53.03±3.3ml/kg/min, P<0.0001). YG showed significant reduction in basal RR, HR and resting HR at 6th and 12th week end compared to their respective base line values. CG did not show such changes. $\dot{V}O_{2max}$ was correlated to basal RR(r= – 0.463, p=0.0009), HR (r= -0.235, p=0.107) and resting HR (r= -0.414, p=0.003). YBM facilitated the improvement in $\dot{V}O_{2max}$ possibly by its effects on cardiovascular and respiratory systems.

Keywords: Yoga, Physical fitness, $\dot{V}O_{2max}$, yoga breathing maneuvers.

INTRODUCTION

Traditional Indian system of Yoga is increasingly getting popular as it has positive effects on both the physical and mental level of an individual [1-3]. Yoga improves muscular endurance and strength [1, 4], body flexibility [1, 2, 5], anaerobic capacity [6] and physical performance without any exhaustive exercise as required in other form of exercise [7, 8]. Majority of studies on the effect of yoga on physical performance have observed performance improvement at submaximal level of dynamic exercise [2, 8, 9]. Only a few reported improvement in maximal oxygen uptake capacity [1, 7, 10] while other studies reported no improvement or changes like Carroll *et al*. [11]. The exercise physiologists are sceptical about the potential of yoga on the aerobic performance improvement as it does not generate sufficient exercise stimulus which is required to improve aerobic capacity as recommended by ACSM/AHM [12-14]. Apparently it looks justified as Ray *et al*. [15] have shown that in yoga practice session exercise intensity remains maximum up to 26.5% of $\dot{V}O_{2max}$ and 2.19 MET. Thus, it remains within low to moderate intensity of exercise. So to improve aerobic capacity by yoga it has been suggested to incorporate in the training schedule the yoga practices which may have comparatively higher energy cost in some postures / poses or sequences to meet energy expenditure or exercise stimulus requirement according to ACSM/AHM guide line [14, 15]. *Suryanamaskar*, a combination of different yoga postures may have comparatively higher intensity of exercise stimulus in its faster form [16-18]. So its practice has also been recommended to meet ACSM/AHM guide line [14]. Apart from this conventional approach, to understand the mechanism for aerobic capacity improvement by yoga as shown by some studies [1, 7, 10] and also to bring about a training system requiring optimum time and energy for improvement in $\dot{V}O_{2max}$, one needs to study the effect of yoga by considering different components of yoga i.e. *Yogasanas*, yoga breathing manuvers (*Pranayama* and *Kriya*) and meditation (*Dhyana*) with equal importance as those components have different as well as concerted effects on various physiological systems. Studies on Yoga breathing manuvers (YBM) have shown their direct effect on cardiac haemodynamic functions [19-21] as well as on respiration [22]. For this, the design of yoga practice schedule in training is required to focus on any one of the component without ignoring other component. So, a different proportion of each of these components with their variations needs to be incorporated in yoga training for a scientific study. So far, no study was conducted where an experimental design had been made considering this fact. This study was an attempt in this direction where yoga breathing component was introduced on incremental way on different point of time in yoga training to observe its effect on aerobic capacity.

MATERIAL AND METHODS

Subjects

The study was conducted on 32 healthy male volunteers. They were all undergraduate students of Ramakrishna Mission Vivekananda Educational and Research Institute, Belur Math, Howrah. The participants had no history of major cardio-pulmonary or metabolic disorders. They did not have any habit of smoking, taking alcohol and any other agents which affect performance. They did not have previous experience in *hatha yoga* practice. All of them were in the same hostel and had uniform pattern of daily routine activity and had same standard diet as used to be supplied from a common mess. Subjects were explained the purpose of the study in their mother tongue about yoga training and exercise tests to be conducted and risk factors involved. Their informed consent was obtained prior to the study. The experiments and training involved were conducted following the standard international norms/guidance for conducting experiments on human subjects. Approval of Institutional ethical committee was obtained. All the subjects did not practice any form of high intensity competitive athletics, games and heavy physical work during the 3 months period of this study. Subjects were divided into two groups i.e. Yoga and Control group with 16 subjects in each group. Here after, Yoga group and control group will be referred to as YG and CG respectively. Both groups' height (cm), weight (kg) and body fat (%) were measured by body composition analyser (ioi353, Poland). Physical characteristics of the subjects are given in Table 1.

Table-1: Physical characteristics of the subjects

Yoga Group	**Age(yrs.)**	**Height(cm)**	**Body weight(kg)**	**Body fat (%)**
Base line	20.3±1.3	167.5±5.27	55.2±6.09	13.31±2.33
6th week	20.3±1.3	167.5±5.27	56.13±5.13	13.56±2.2
12th week	20.3±1.3	167.5±5.27	56.7±5.10	13.74±1.74
Control Group	Age(yrs.)	Height(cm)	Body weight(kg)	Body fat (%)
Base line	21.2±1.4	166.9±5.06	55.4±4.92	13.14±2.4
6th week	21.2±1.4	166.9±5.06	56.06±5.09	13.42±2.07
12th week	21.2±1.4	166.9±5.06	56.31±4.98	13.51±1.83

Design of experiment and yoga training

YG was trained for yoga practices consisting of *yogasanas*, YBM and meditation for 45 minutes including free hand loosening exercises for 5 minutes, also meditation and OM chanting for 5 minutes every day for 6 days in a week for 3 months in the morning under the supervision of 2 qualified yoga instructors. Yogasanas as they practiced were: *Shvasana*, *Makarasana*, *Sukhasana* (Yoga relaxative postures) *Tadasana*, *Trikonasana*, *Katichakrasana*, *Saral Bhujangasana*, *Ardhasalvasana*, *Salvaasana*, *Saral dhanurasana*, *Paschimottanasana*, *Janusirasana*, *Ardha matsyendrsana*. YBM as practiced were: *Kapalbhati* (a *Kriya* in *hatha yogic* practice) and *Anulom vilom*, *Bhastrika*, *Ujjai and Bhramari pranayamas*. They followed specific yogic training schedule which was prepared to reveal the effect of YBM while keeping all major components of *hatha yoga* practice i.e. different yoga postures (*yogasanas*), YBM (*Pranayamas* and *Kriya)* and meditation (*Dhyana*) intact in the program. According to the principle of yoga practices the YBM should be introduced very slowly in the yoga program. Keeping that in mind as well as to observe the influence of YBM, only 2 YBM were introduced in the 1st and 2nd week. From 3rd week duration of those YBM practices increased along with 1 more new YBM which was introduced in each week up to 6th week as per their ability to perform those correctly. With this the duration of practicing *yogasanas* reduced. Like this, maximum 17 minutes they could devote for YBM (including rest pauses in relaxative postures like *sukhasana* or *shavasana*) and maximum time to practice yogasanas was for 18 minutes, which also included various relaxative *yogasanas* like *Shavasana*, *Makarasana* and *Sukhasana*. Subsequently, from the 7th week onwards the duration of practice of YBM component was increased further up to the 12th week, when maximum YBM practice duration was 25 minutes including relaxative postures, while the same for *yogasana* practice was for only 10 minutes which included yoga relaxative postures. The CG did not practice yoga during this period. The general physical activity pattern of both YG and CG was same from light to moderate intensity throughout the day during the study period as they used to be involved mostly in their academic schedule.

Recordings of different parameters

Recordings of basal and resting heart rate (HR), respiratory rate (RR) and predicted $\dot{V}O_{2max}$ were taken on both YG and CG at base line, immediately before the commencement of yoga training for YG, at the end of the 6th week and at the end of 12th week. HR and RR were manually taken respectively by palpation of radial pulse and by observing the movement of chest in the morning when they were in bed. Predicted $\dot{V}O_{2max}$ was measured by Queen's college step test [23]. The validity and applicability of the Queen's college step test for the population with the same ethnicity among students was tested by Chatterjee *et al*. [24]. The step test was conducted in the forenoon. There was a gap of at least 2 hours after the last meal and the test. After a brief warm up and adequate rest for minimum ½ hour to achieve resting HR in the laboratory the test was started. The step test was performed on a stool of 41.3 cm height. Duration of stepping was 3 minutes and 24 cycle steps per minute which was set by metronome. Just before, during and after exercise HR was measured by Polar Heart rate monitor V800 (Polar Electro Oy, Finland). After completion of 3 minutes of exercise their heart beat was monitored from 5th to 20th seconds of the recovery period. The 15 seconds' total pulse / heart beat was also noted with the help of the software of the heart rate monitor. Then same was multiplied by 4 to obtain heart beat for one minute. The following equation was used to calculate the predicted $\dot{V}O_{2max}$ (24)

- $P\dot{V}O_{2max}$ (ml/Kg/min) = 111.33 – (0.42 × HR in beats/min)
- Here after predicted $\dot{V}O_{2max}$ will be expressed as $\dot{V}O_{2max}$ only.

The whole experiment was performed in a room temperature varying from 25 to 28°C with relative humidity in the range between 70 % - 85%.

STATISTICAL ANALYSIS

Purposive sampling was adopted from the university student community**.** Normality of continuous variables was evaluated by Shapiro-Wilk test. Data were summarized using means and standard deviation (SD). The means obtained from different data sets were compared by one way repeated measures of analysis of variance test (ANOVA), followed by Bonferroni test. Inter group comparison was done by unpaired t test. A value of $p<0.05$ was considered as statistically significant. The statistical analyses were performed using statistical software Graph pad prism (Version 5, 2007, Sandiego, CA, USA) and SPSS (Version 25).

RESULTS

In Yoga group, the pre training base line mean value of $\dot{V}O_{2max}$ was 47.5±3.7 ml/kg/min. It increased to 49.4±3.3 ml/kg/min with statistical significance (P<0.001) at 6th week end. At 12th week end, it further increased with a significantly higher value of 53.03±3.3 ml/kg/min (P<0.0001) as compared to baseline (Fig: 1A). In CG, baseline value of VO_{2max} was 49.4±4.0 ml/kg/min which did not change significantly at the 6th and 12th week end (Fig:2A). Basal resting HR which was recorded in the morning gradually decreased in YG from 65.6±9.8 bpm at base line to 63.7±9.0 bpm at 6th week end (P<0.0001). At the 12th week end it further reduced to 58.2±6.3 bpm with very high level of significance (P<0.0001) as compared to base line value (Fig: 1C). CG did not show any reduction in the mean basal HR values both at the 6th and 12th week of study period (Fig: 2C). Resting HR values before exercise test as recorded in the laboratory in YG also followed the similar trend like basal HR. It gradually reduced from base line value of 66.9±7.9 bpm to 60.6±4.7 bpm at 12th week end which had highly significant (P<0.0001) difference (Fig: 1D) but CG did not show such reduction (Fig: 2D). Mean base line RR was15.8±2.7 per minute reduced significantly (P<0.001) to 14±1.7 at 6th week end. It further reduced with high significance (P<0.0001) to 12.8±1.2 per minute at the12th week end (Fig: 1B). In case of CG, there was no such reduction both at the 6th and 12th week end (Fig: 2B).

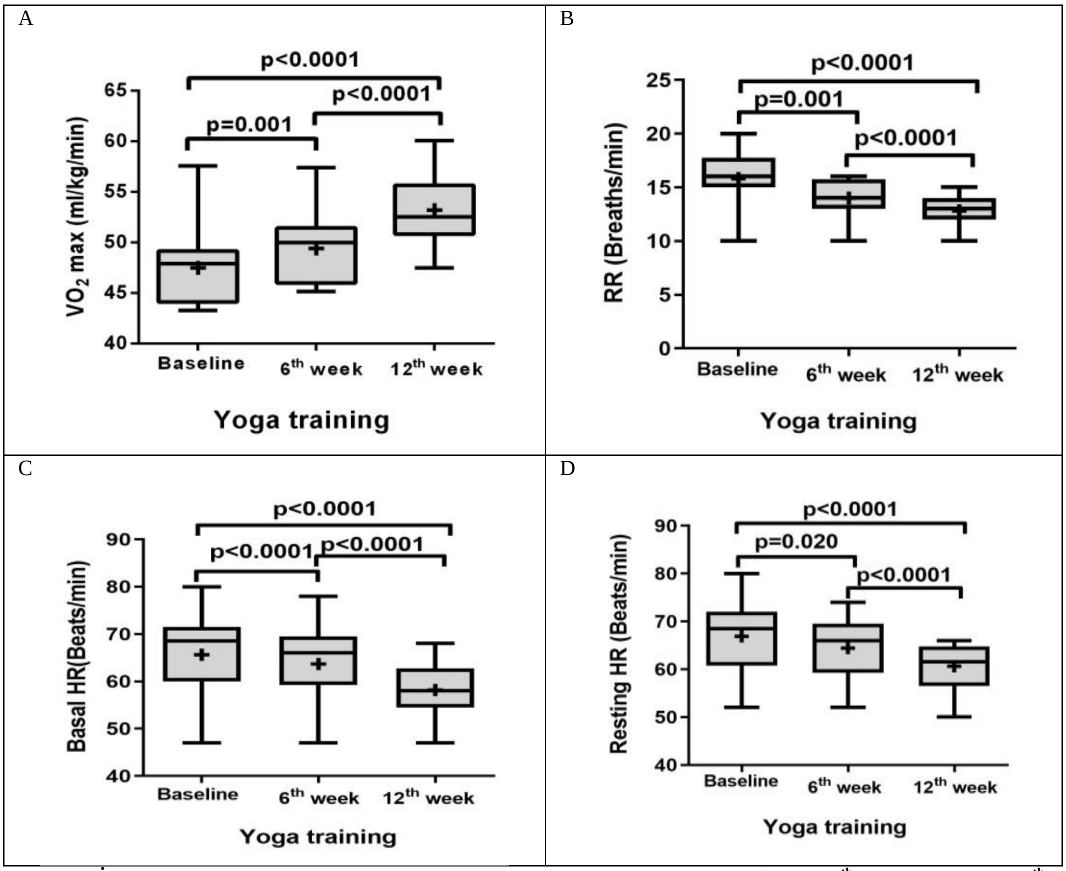

Fig-1: YG showing $\dot{V}O_{2max}$ (A), basal RR (B), basal HR (C) and resting HR (D) at baseline before, at 6th week end and at 12th end of yoga training. As compared to base line $\dot{V}O2max$ has significantly improved both at the 6th week and 12th week end while basal RR and HR, resting HR have reduced significantly both at 6th and 12th week

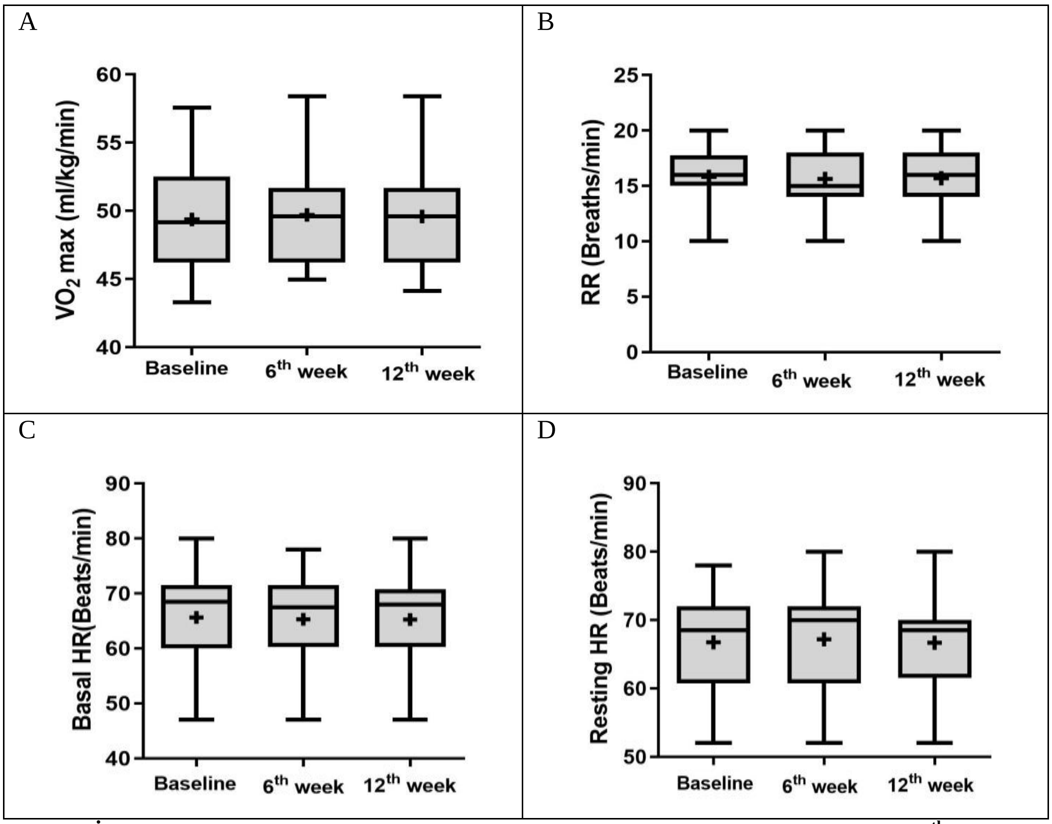

Fig-2: CG showing $\dot{V}O_{2max}$ (A), basal RR (B), basal HR (C) and resting HR (D) at baseline before, at 6th week end and at 12th end. As compared to their respective base line values all the parameters show no significant difference both at the 6th and 12th week end

As compared to CG, mean value of $\dot{V}O_{2max}$ in YG was higher at the 6th and 12th week end. But, compared to CG, mean value of RR, basal HR and resting HR in YG were lower at the 6th and 12th week end. Inter group comparison showed significantly higher value ($p<0.01$) in $\dot{V}O_{2max}$ in YG as compared to CG at the 12th week end. RR showed significantly lower value in YG as compared to CG both at 6th week end ($p<0.05$) and 12th week end ($p<0.001$). Basal HR and resting HR before exercise in YG were lower compared to those of CG at the significance level of $p<0.02$ and $p<0.01$ respectively at the12th week end.

As given in Fig-3, $\dot{V}O_{2max}$ was negatively correlated with respect to basal RR (Fig-3A), basal HR (Fig-3B) and resting HR before exercise (Fig-3C),were r= - 0.463 (p=0.0009), r= -0.235 (p=0.107) and r= - 0.414 (p=0.003) respectively.

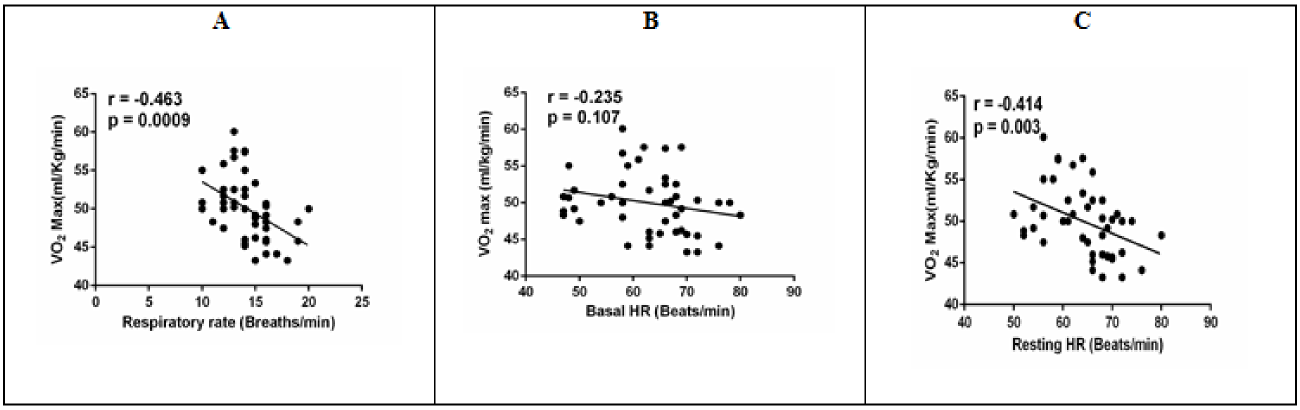

Fig-3: Correlation between $\dot{V}O_{2max}$ with respect to basal RR (A), basal HR (B) and resting HR before exercise (C) showing that both basal RR and resting HR are highly correlated with $\dot{V}O_{2max}$

DISCUSSION

Present study clearly indicates significant improvement in aerobic capacity even after 6 weeks of yoga training with progressive incorporation of YBM. As both the groups have similar activity pattern except the YG practicing yoga, the improvement in $\dot{V}O_{2max}$ may be attributed to yoga practice. To the best of our knowledge no other previous study has shown improvement in aerobic capacity with one and half months of yoga training. From 7th week onwards of yoga training after increasing the practice of YBM in greater proportion i.e. almost 50% of the total time of yoga practice, $\dot{V}O_{2max}$ improves further in very highly significant way. Again to the best of our knowledge no study has so far demonstrated the role of YBM in the improvement of aerobic capacity within this much time period of yoga training. The reason for this improvement is possibly the better cardiovascular conditioning by yoga and this has been facilitated by YBM. Through indirect evidence, 17% improvement in cardiac output after YBM (*Ujjayi pranayama*) was shown by Mesian and Bhole [19] in a single subject by using radioactive isotope method. Ray *et al*. [20] reported significantly greater mean value of stroke volume (134.3±11.4 ml/beat) and cardiac output (12±0.99 l/min) during the actual practice of *Kapalbhati* (YBM, *Kriya*), than comfortable sitting (*Sukhasana*) posture in a study on 20 young subjects by using impedance cardiograph. Similarly in other YBM also they saw a significantly higher value of stroke volume and cardiac output. The reason for this has been attributed to improved venous return to the heart due to reduced intrathoracic pressure during YBM practice. This in turn would increase end-diastolic volume leading to greater stroke volume due to Frank Starling mechanism; consequently cardiac output would also increase. So the practice of YBM repeatedly for days together helps to have a better cardiovascular conditioning with improved cardiac reserve. Udupa *et al*. [21] in their young healthy subjects, after 3 months practice of different *pranayamas* (types of YBM), have found reduced Rate Pressor Product (RPP) indicating reduction in cardiac load with significant changes in systolic time interval (increased QST2, PEP and PEP/ LVET), an indirect evidence of changes in cardiac haemodynamics [25]. They attributed this better ventricular performance to decreased sympathetic and increased parasympathetic activity due to *pranayama* practice. In study [26], YBM training on elderly persons has shown better sympathovagal balance in heart along with improvement in respiratory function.

Yoga also helps in the improvement of cardiovascular function among persons with cardiovascular abnormalities. *Yogasanas* and slow breathing and relaxation through meditation for long duration reduces HR and ventricular after load and thus modulate cardiac function positively by enhancement of left ventricular relaxation with improved diastolic function among elderly persons having high pulse pressure [27]. Pullen PR *et al*. [28, 29] have shown improved endurance in heart failure patients by the increase in Peak$\dot{V}O_{2max}$ and other biochemical parameters with better quality of life by the practice of *pranayama* with warm up exercise for 5 minutes, 40 minutes of *yogasana* and 15 minutes relaxative postures for 8-10 weeks indicating the effect of yoga as such for physically vulnerable persons with weak heart. These studies on elderly persons with high pulse pressure and on heart failure patients also indicates the potentiality of yoga to directly influence cardiac function but the specific role of slow breathing could not be separated out due to the study design.

The improvement in ventilatory capacities by YBM due to respiratory muscle training and its control have also been reported [26, 30, 31]. This cannot be a reason for the improvement of aerobic capacity achieved by yoga, as in maximal exercise the maximal ventilation which could be achieved in a normal healthy subject in all out exercise is always lower than an individual's Maximal voluntary ventilatory capacity. Due to this good ventilatory reserve in a normal healthy person the factor of better respiratory muscle training by YBM and its effect through better pulmonary ventilation to improve $\dot{V}O_{2max}$ may be ruled out.

Bernardi *et al*. [32] have reported that the practice of yoga based slow breathing as in pranayama (6 cycles per minute) in heart failure patients have reduced dysponea, improved resting arterial oxygen saturation and improved exercise performance. This shows the slow YBM as in *anulom- vilom* and *Ujjayi pranayama* which were practiced by our subjects might have role in aerobic performance improvement. Basal RR and resting HR have both reduced significantly in YG in our study indicating reduced sympathetic activity which is a well-established effect of yogic practices [33]. During slow deep breathing in *pranayama* as in case of *Ujjayi pranayama* the tidal volume increases with concomitant reduction in respiratory rate [15, 34]. This in turn results in efficient ventilation with better oxygen saturation. Improvement in both respiratory and cardiovascular function with improved baroreceptor sensitivity and blood oxygen saturation by simple slow breathing with equal duration of inspiratory and expiratory phase (*anulom vilom pranayama)* and *Ujjayi pranayama* has also been reported earlier in normal healthy persons among novice yoga practitioners [22]. Thus, regular practice of YBM helps the physiological systems to get entrained for better cardiovascular and respiratory coupling for efficient oxygenation [35]. This leads to a condition with better cardiovascular and respiratory reserve for a better oxygenation during maximal exercise. The reduced basal RR and resting HR in this study by yoga training with significant correlation with the values of VO_{2max} are the evidences to indicate a better cardio-respiratory conditioning by YBM which may be responsible for the improvement in aerobic capacity in YG.

No study so far studied separately the role of YBM on the aerobic capacity in normal healthy subjects. This is true also for cardiac haemodynamics, as none of the reported studies linked it to the aerobic performance improvement by YBM in general. Rather, the potentiality of yoga to improve aerobic capacity has been doubted on the basis of the low to moderate intensity of exercise stimulus in yoga which does not conform to the prescribed exercise intensity as given by ACSM [11, 13]. Ray *et al*. [7] have shown the intensity of exercise in terms of oxygen consumption, energy cost and $\%\dot{V}O_{2max}$ which indicate that in yoga practice session exercise intensity remains within maximum 26.5% of $\dot{V}O_2$max. They have also hypothesised the possibility of the YBM with its direct effect on cardiac haemodynamics with improvement in cardiac function, which in turn may help to improve $\dot{V}O_{2max}$. Carrol *et al*. [11] in a study on the effect of *Vinyasa yoga* practice, which is almost similar to *Suryanamaskar*, a combination of specific yoga postures with some variations, on aerobic capacity, have not found any positive effect. In the faster form of *Suryanamaskar* there is a scope to improve exercise intensity further which may satisfy ACSM guidelines. Larson-Meyer [14] in a more recent review on energy cost and exercise intensity of yoga practice also concluded in a similar way. So, most of the researchers directed attention to explore the yoga practices which could increase the exercise intensity but the prospective role of YBM in improvement of $\dot{V}O_{2max}$ through better cardiac haemodynamics, better cardiovascular and respiratory coupling with better oxygenation, has been almost ignored.

Raju *et al*. [9] have shown in a limited number of young sports men (8 athletes) a significant reduction in oxygen consumption per unit of work with reduced blood lactate at the submaximal level of exercise (60-70% of heart rate max) as a result of practicing only *pranayama* (name not mentioned) along with usual workout for one year. Subsequently the subjects (6 athletes) continued same training for another year when in maximal exercise test no significant improvement in $\dot{V}O_{2max}$ was observed other than the shift of anaerobic threshold to higher work load and the similar findings as observed in submaximal test. They attributed this effect to the hormonal, biochemical and physiological changes due to yoga without going into more specifics. Ray *et al*. 2001 [7] have reported significant improvement in $\dot{V}O_{2max}$ along with significant reduction in perceived exertion in a training program on young soldiers where the proportion of duration for practicing *yogasanas*, YBM and meditation in each practice session was uniformly maintained for 6 months in a yoga training program. So, for them it was not possible to identify the specific component of yoga practice which was responsible for the improvement in $\dot{V}O_{2max}$ considering the fact that *yogasanas* do not generate sufficient exercise stimulus to improve $\dot{V}O_{2max}$ according to ACSM guide line. In a very recent study (10) another group of researchers have shown on a large number subjects (40 male and 20 female young medical students) the improvement of predicted $\dot{V}O_{2max}$ by practicing yoga consisting of *yogasanas*, YBM and prayer where the time spent for practice of each component of yoga has been kept uniform from the beginning to the end of 3 months training. In the same study also the identification of specific contribution of YBM in the improvement of aerobic capacity of the subjects could not be established. Thus, the basic question as raised earlier i.e. why and how even with low to moderate intensity of exercise stimulus as in yoga practices the improvement in aerobic capacity takes place could not be answered. Again, the role of YBM to improve aerobic capacity by better cardiovascular and respiratory conditioning with at least its facilitatory influence on other factors becomes a best option to explain aerobic performance improvement by *Hatha yoga*.

CONCLUSION

YBM may help to improve aerobic capacity by improving the cardiac haemodynamic functions as well as by its role on the cardiorespiratory system in general with better autonomic nervous control and oxygenation leading to improved oxygen delivery to the muscles. The contradictory results obtained by various studies on the effect of yoga practice on $\dot{V}O_{2max}$ are due to different combinations of the components of yoga i.e. *yogasanas*, YBM and meditation are being used in different studies. The basic scientific issue of low to moderate exercise intensity in yoga practice, which cannot improve $\dot{V}O_{2max}$, may be considered in Yoga with its other components, specifically so with respect to YBM. There remains also a possibility that YBM may help to augment the training process along with other conventional exercises to achieve faster the improvement in aerobic capacity. With growing scientific inputs based on the studies conducted among diseased, sedentary and active persons in the area of YBM, more emphasis is required on YBM in physical training program to make it more efficient in terms of intensity of exercise and duration of training. More studies are required in this area by considering various combinations of the components of *hatha yoga* practice which may be useful to various target populations.

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REFERENCES

1. Lau, C., Yu, R., & Woo, J. (2015). Effects of a 12-week hatha yoga intervention on cardiorespiratory endurance, muscular strength and endurance, and flexibility in Hong Kong Chinese adults: a controlled clinical trial. *Evidence-Based Complementary and Alternative Medicine*, *2015*.
2. Ray,U.S., Purkayastha, S., Asnani, V., Tomer, O., Prashad, R., Thakur, L., & Selvamurthy, W. (2001). Effect of yogic exercises on physical and mental health of young fellowship course trainees. *Indian J Physiol Pharmacol*, *45*(1), 37-53.
3. Tran, M. D., Holly, R. G., Lashbrook, J., & Amsterdam, E. A. (2001). Effects of Hatha yoga practice on the health- related aspects of physical fitness. *Preventive cardiology*, *4*(4), 165-170.
4. Ray, U. S., Hegde, K.S., & Selvamurthy, W. (1986). Improvement in muscular efficiency as related to a standard task after yogic exercises in middle aged men. *Indian J Med Res*, *83*, 343-348.
5. Bal, B. S., & Kaur, P. J. (2009). Effects of selected asanas in hatha yoga on agility and flexibility level. *Journal of Sport and Health Research*, *1*(2), 75-87.
6. Pal, R., Saha, M., Chatterjee, A., Halder, K., Tomer, O. S., Pathak, A., & Basavaraddi, I. V. (2013). Anaerobic power, muscle strength and physiological changes in physically active men following yogic practice. *Biomedical Human Kinetics*, *5*(1), 113-120.
7. Ray, U. S., Sinha, B., Tomer, O. S., & Pathak, A. (2001). Aerobic capacity & perceived exertion after practice of Hatha yogic exercises. *Indian J Med Res*, *114*, 215.
8. Selvamurthy, W., Ray, U. S., Hegde, K. S., & Sharma, R. P. (1988). Physiological responses to cold (10^0 C) in men after six months' practice of yoga exercises. *International Journal of Biometeorology*, *32*(3), 188-193.
9. Raju, P. S., Madhavi, S., Prasad, K. V. V., Venkata Reddy, M., Eswara Reddy, M., & Sahay, B. K. (1994). Comparison of effects of yoga & physical exercise in athletes. *Indian J Med Res*, *100*, 81-81.
10. Doijad, V. P., Kamble, P., & Surdi, A. D. (2013). Effect of Yogic exercises on aerobic capacity ($\dot{V}O2$ max). *International journal of physiology*, *1*(2), 47-50.
11. Carroll, J., Blansit, A., Otto, R. M., & Wygand, J. W. (2003). The metabolic requirements of vinyasa yoga. *Med Sci Sports Exerc*, *35*(5), S155.
12. Clay, C. C., Lloyd, L. K., Walker, J. L., Sharp, K. R., & Pankey, R. B. (2005). The metabolic cost of hatha yoga. *J Strength Cond Res*, *19*(3), 604.
13. Hagins, M., Moore, W., & Rundle, A. (2007). Does practicing hatha yoga satisfy recommendations for intensity of physical activity which improves and maintains health and cardiovascular fitness?. *BMC complementary Altern Med*, *7*(1), 40.
14. Larson-Meyer, D. E. (2016). A Systematic Review of the Energy Cost and Metabolic Intensity of Yoga. *Med Sci Sports Exerc*, *48*(8), 1558-1569.
15. Ray, U. S., Pathak, A., & Tomer, O. S. (2010). Hatha yoga practices: energy expenditure,

respiratory changes and intensity of exercise. *Evid-Based Complement and Alternat Med*, *2011*, 50.
16. Bhutkar, P. M., Bhutkar, M. V., Taware, G. B., Doijad, V., & Doddamani, B. R. (2008). Effect of suryanamaskar practice on cardio-respiratory fitness parameters: A pilot study. *Al Ameen J Med Sci*, *1*(2), 126-129.
17. Sinha, B., Ray, U. S., Pathak, A., & Selvamurthy, W. (2004). Energy cost and cardiorespiratory changes during the practice of Surya Namaskar. *Indian J Physiol Pharmacol*, *48*(2), 184-190.
18. Sinha, B., Sinha, T. D., Pathak, A. and Tomer, O.S., (2013). Comparison of cardiorespiratory responses between Surya Namaskar and bicycle exercise at similar energy expenditure level. *Indian J Physiol Pharmacol*, *57*(2), 169-76.
19. Mesian, J., & Bhole, M. V. (1979). Cardiac Output in Normal, Deep and Ujjayi (Pranayamic) Breathing. *Yoga Mimasa*, *19*, 11-17.
20. Ray, U. S., Pathak, A., & Tomer, O. S. (2011). Hatha yoga practices: energy expenditure, respiratory changes and intensity of exercise. *Evid-Based Complement and Alternat Med*, *2011*.
21. Udupa, K., Bhavanani, A. B., Vijayalakshmi, P., & Krishnamurthy, N. (2003). Effect of pranayam training on cardiac function in normal young volunteers. *Indian J Physiol Pharmacol*, *47*(1), 27-33.
22. Mason, H., Vandoni, M., Debarbieri, G., Codrons, E., Ugargol, V., & Bernardi, L. (2013). Cardiovascular and respiratory effect of yogic slow breathing in the yoga beginner: what is the best approach?. *Evidence-Based Complementary and Alternative Medicine*, *2013*.
23. McArdle, W., Katch, F., Pechar, G., Jacobson, L., & Ruck, S. (1972). Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. *Med Sci Sports Exerc*, *4*(4), 182-186.
24. Chatterjee, S., Chatterjee, P., Mukherjee, P. S., & Bandyopadhyay, A. (2004). Validity of Queen's College step test for use with young Indian men. *Br J Sports Med*, *38*(3), 289-291.
25. Weissler, A. M., Peeler, R. G., & Roehll Jr, W. H. (1961). Relationships between left ventricular ejection time, stroke volume, and heart rate in normal individuals and patients with cardiovascular disease. *American heart journal*, *62*(3), 367-378.
26. Santaella, D. F., Devesa, C. R., Rojo, M. R., Amato, M. B., Drager, L. F., Casali, K. R., & Lorenzi-Filho, G. (2011). Yoga respiratory training improves respiratory function and cardiac sympathovagal balance in elderly subjects: a randomised controlled trial. *BMJ open*, *1*(1).
27. Patil, S. G., Patil, S. S., Aithala, M. R., & Das, K. K. (2017). Comparison of yoga and walking-exercise on cardiac time intervals as a measure of cardiac function in elderly with increased pulse pressure. *Indian Heart Journal*, *69*(4), 485-490.
28. Pullen, P. R., Nagamia, S. H., Mehta, P. K., Thompson, W. R., Benardot, D., Hammoud, R., ... & Khan, B. V. (2008). Effects of yoga on inflammation and exercise capacity in patients with chronic heart failure. *Journal of cardiac failure*, *14*(5), 407-413.
29. Pullen, P. R., Thompson, W. R., Benardot, D., Brandon, L. J., Mehta, P. K., Rifai, L. U. A. Y., ... & Khan, B. V. (2010). Benefits of yoga for African American heart failure patients. *Med Sci Sports Exerc*, *42*(4), 651-657.
30. Madanmohan, T., Jatiya, L., Udupa, K., & Bhavanani, A. B. (2003). Effect of yoga training on handgrip, respiratory pressures and pulmonary function. *Indian J Physiol Pharmacol*, *47*(4), 387-392.
31. Vempati, R., Bijlani, R. L., & Deepak, K. K. (2009). The efficacy of a comprehensive lifestyle modification programme based on yoga in the management of bronchial asthma: a randomized controlled trial. *BMC Pulm Med*, *9*(1), 37.
32. Bernardi, L., Spadacini, G., Bellwon, J., Hajric, R., Roskamm, H., & Frey, A. W. (1998). Effect of breathing rate on oxygen saturation and exercise performance in chronic heart failure. *The Lancet*, *351*(9112), 1308-1311.
33. Wenger, M. A., & Bagchi, B. K. (1961). Studies of autonomic functions in practitioners of yoga in India. *Behavioral science*, *6*(4), 312-323.
34. Stanescu, D. C., Nemery, B., Veriter, C. L. A. U. D. E., & Marechal, C. L. A. U. D. E. (1981). Pattern of breathing and ventilatory response to CO2 in subjects practicing hatha-yoga. *Journal of Applied Physiology*, *51*(6), 1625-1629.
35. Russo, M. A., Santarelli, D. M., & O'Rourke, D. (2017). The physiological effects of slow breathing in the healthy human. *Breathe*, *13*(4), 298-309.