Effect of yoga and swimming on cognitive function in healthy adults: A randomized controlled trial

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ABSTRACT

Background: Improvement in cognitive function has been linked to physical activity as well as yogic exercises. Studies have investigated the effect of acute exercise on cognition after acute single bout of exercise; however, comparison of effect of endurance exercise and yoga on resting cognitive function and resting oxygen consumption has not been studied. **Objectives:** To compare the improvement in cognitive function by auditory reaction time and visual reaction time (ART and VRT) with yoga module and swimming in relation with metabolic efficiency studied by resting oxygen consumption. **Materials and Methods:** Healthy males and females included in study were randomly assigned to yoga and swimming group, and respective interventions were given for 12 weeks. Pre- and post-intervention comparisons were made for ART and VRT and for resting oxygen consumption. **Results:** Both ART and VRT time showed a statistically significant reduction in both interventions. However, better improvement was found with yoga for ART. Average resting oxygen consumption decreased significantly in yoga group only as compared to swimmers ($P < 0.05$). **Conclusion:** Reaction time indicating integration of information in central nervous system seems to respond to both yoga and swimming almost equally though yoga has slight advantage in improving ART and VRT times. Yoga practice improves metabolic efficiency as suggested by reduced resting oxygen consumption. Improved metabolic efficiency may improve the synaptic plasticity as shown by earlier research resulting in enhanced cognitive function.

KEY WORDS: Auditory Reaction Time; Cognitive Function; Resting Oxygen Consumption; Swimming; Visual Reaction Time; Yoga

INTRODUCTION

Lifestyle modification with adoption of physical activity is being advocated for primary and secondary prevention of lifestyle diseases. Logically, the research is being focused on finding out the modality of exercise that is most beneficial and economic for the masses in developing countries. There is increased awareness as well as research on benefits of yogic exercises. However, comparative studies of yogic exercises module with endurance exercises are very less.

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Improvement in brain function and cognition is being linked to physical activity as well as yogic exercises.[1] Reaction time changes seem to account for most of the exercise's observed effects on cognition with exercise modality being one of the most important factors deciding impact of exercise on cognition.[2,3] Several studies have investigated the effect of acute exercise on cognition after an acute single bout of exercise has been concluded. Few cross-sectional studies have demonstrated that the long-term practice of yoga leads to lower metabolic rates and greater metabolic efficiency.[4,5] However, comparison of improvement in cognitive function at rest after a period of intervention (like 12 weeks) of endurance exercise and yogic exercises has not been studied in prospective studies.

Although mechanisms of synaptic plasticity involved in cognitive improvement with exercise are not clearly understood, research has put forward a role of coupling of energy metabolism to synaptic plasticity with physical exercise leading to cognitive enhancement.[6] We tried to study metabolic efficiency after 12 weeks of intervention of yoga and swimming by studying resting oxygen consumption pre- and post-intervention as our secondary objective.

With this background, this research work was conducted with an aim to compare cognitive function improvements with yoga module and swimming in relation with metabolic efficiency studied by resting oxygen consumption.

MATERIALS AND METHODS

Healthy males and females with normal physical examination and with sedentary occupations between 18 and 40 years of age were included in the study. The volunteers from the sociocultural gathering of general populations were motivated to participate in the study by explaining plan of the study to them. The recruitment was purely on the voluntary basis. After screening and fulfillment of inclusion and exclusion criteria, volunteers were recruited in the study. Initially, 100 volunteers were recruited, but at the end of the study, yoga group consisted of 41 subjects (n = 41), out of which 16 were males and 25 females. Swimmer group comprised 40 subjects with 18 males and 22 females. Volunteers had not been engaged in yoga practice or swimming in the past nor were they doing any physical exercise at least during 3 years preceding the study as assessed by enquiring in detail. Smokers, subjects consuming alcohol even occasionally, subjects who were in non-sedentary occupations, post-operative patients, and subjects suffering from any hernia, pregnant females, subjects with a history of any cardiovascular disorder, subjects with a history of respiratory tract infection symptoms during previous 6 weeks, and subjects suggestive of any active respiratory disorders were excluded by thorough history and clinical examination.

Study Protocol

The screening of subjects was done and clearance of the institutional ethics committee was obtained. After selection of the subjects, they were explained about the detailed plan of work and aim of present research project. The volunteers were briefed about the study protocol; they were motivated for the training and for compliance needed till the end of the study and written informed consent was obtained from them. The appointments for recording of study parameters were given to each subject.

A total of 100 volunteers were divided into cohorts of 10 subjects each and were randomly assigned by block randomization method to undergo either yogic training or swimming for a duration of 12 weeks. Before the actual training period, baseline cognitive function was assessed by VRT and ART. All the subjects of that cohort were motivated for the exercise regimen they had to follow during the entire 12-week period. After 12-week exercise by all 10 subjects in that cohort, cognitive function was reassessed. After baseline parameters were recorded for one cohort and the training started for that cohort, the next cohort was subjected to same treatment. For women, both pre- and post-training recordings were postponed; in case, they were menstruating till their menstruation stopped. Due to overlapping of training duration for cohorts, the baseline and post-exercise evaluation became easy.

Of the 100 subjects, 9 from the yoga group and 10 from the swimmer group dropped out in due course of the study. As subjects who dropped out were non-compliant, per-protocol analysis method was used to analyze the data. Thus, at the end of the study, data of 41 subjects from yoga group and 40 subjects from swimming group were analyzed [characteristics of the population shown in Table 1].

The yoga group subjects were instructed not to practice any yogic technique other than the prescribed ones, and swimmer group was advised to refrain from other physical exercises during the study. We supervised the subjects early in the morning (5.00–6.00 a.m.) during yoga classes and swimmers from 6.00 to 7.00 a.m. every day during the training period. Participants of both the groups were allowed to do their routine activities during the study.

The subjects were taught yogasanas and pranayamas, and then they practiced the same, 6 days/weeks for 60 min daily, for a total duration of 12 weeks. Iyengar yoga techniques were followed by the yoga trainers.[7] Different yogasanas (yogic postures), namely, tādāsana, konāsana, utkatāsana, sarvāngāsana, halāsana, chakrāsana, padmāsana, dhanurāsana,

Table 1: Composition of yoga and swimming groups

Parameters	Yoga (n=41)	Swimming (n=40)	Statistical significance
Age (years)	28.439±1.41	27.7±1.35	t-test, P value 0.7067
Height (cm)	159.21±1.50	159.4±1.54	t-test, P value 0.9335
Weight (kg)	55.12±1.80	58.375±1.76	t-test, P value 0.2021
Males n (%)	16 (39.0)	18 (45)	Chi-square test P>0.05
Females n (%)	25 (61.0)	22 (55)	

makarāsana, pashchimottānāsana, vajrāsana, virāsana, and shavāsana were practiced for 40 min and pranayamic breathing exercises with purak, rechak and kumbhak, anulom-vilom, bhastrikā, bhramari prānāyām, and kapalbhāti were practiced for 20 min. Swimming was practiced 6 days/weeks for 60 min daily. Swimming comprised freestyle in first 6 weeks (including training in 1st 2–3 weeks) and freestyle and breaststroke in last 6 weeks including 10 min of floating on the water. For novice swimmers, continuous swimming for 60 min is difficult; therefore, intermittent floating with deep slow breathing (total 10 min) was introduced. It also helped to keep similarity with yoga group who practiced shavāsana for 10 min (lying still and relaxed with slow deep breathing).

An important limitation of the methodology was inability to assess and compare the intensities of two modalities of exercise during 12-week duration. This inability was because of the fact that unlike endurance exercise, intensity of yogic asanas and pranayama is not directly related with exercise and post-exercise heart rates. Therefore, the whole module lasting for same duration for swimming and yoga was compared.

The auditory reaction times (ARTs) and visual reaction times (VRTs) were recorded by a simple audiovisual time recording device/digital display response time apparatus.

To compare the effects of yoga and swimming on the metabolic efficiency of subjects, the resting oxygen consumption of all the subjects was measured before training as well as after the training of the subjects. The subjects were given appointments and were asked to come to the laboratory in the morning hours at least 2 h after a light breakfast. They were explained that they should not perform any intervention on that day in the morning.

For this purpose, we asked the subjects to breathe into a closed circuit spirometer containing soda lime tower under the bell for a total duration of 6 min. Baseline parameters were measured in the morning hours in the human physiology laboratory. The subjects were asked to breathe through a clean mouthpiece while they were asked to close their nostrils by applying a noseclip for the required duration. Informed consent was taken from all the subjects after having explained the subjects that the test was very simple, and there were no chances of suffocation. Mock trials were given till we were satisfied that the subject could perform the test properly. The tubings were checked for leaks if any. The oxygen cylinder was checked every time before the test begun. The bell was completely lowered by pressing with the hand. Then, humidified oxygen was filled under the bell from an oxygen cylinder to raise the bell to 2/3rd the height of the outer drum.

The subjects were instructed to hold the mouthpiece properly to prevent any leak. They were asked to hold the mouthpiece tightly in the fist. They were guided to hold the mouthpiece with mouth slightly opened approximating both lips on the mouthpiece.

A recording spirometer chart was stuck to the outer drum for every subject. The movement of the drum was electrically maintained. It was switched on when the subject began respiring through the mouthpiece. A pen recorder was used to trace the curve of inspiratory and expiratory movements. Subjects were told that they were required to breathe as normally as they could without being conscious that they were breathing into an external apparatus. After gaining his/her confidence, he/she was allowed to breathe into the mouthpiece under observation. After 6 min, the mouthpiece was removed from the subject's mouth and noseclip was removed as well. The drum movements were stopped by turning the switch off. The chart paper was detached from the drum and allowed to dry. The subject was asked to sit on a chair and relax.

The soda lime granules were observed as and when required and replaced by fresh granules if they seemed to be discolored from their normal pink color to light pink or white color (Benedict Roth's apparatus).

All the end-expiratory points on the graph were joined together to get a straight line. The O_2 consumption was measured from the shift of this baseline which indicated decrease in the oxygen in the drum equal to the volume of oxygen utilized by the subject. Shift of this line during 6 min was calculated and the equivalent oxygen consumption was calculated in ml/min with correction for room temperature and relative humidity.[8]

Statistical Analysis

All the data obtained were analyzed groupwise by descriptive statistics using mean, standard deviation, and standard error of mean. For differences in sex-wise composition of two study groups, Chi-squared test was used. For each parameter in both yoga and swimming groups before and after training period of 12 weeks, data distribution was tested for normality of distribution by Kolmogorov–Smirnov test.

The paired data before and after 12 weeks of training for both yoga and swimming groups were tested by Student's paired *t*-test for parametric data with normal distribution and by Wilcoxon signed-rank test for parametric data without normal distribution.

The change in different parameters with 12 weeks of training was studied by calculating delta, i.e., difference in value before and after 12-week exercise training of both modalities. The percent change was also calculated for each parameter as percentage of change with respect to pre-exercise training level of that parameter. Increase or decrease in value of a parameter (delta) with yoga and swimming was also compared using unpaired *t*-test for parametric data with normal distribution and using Mann–Whitney U-test for parametric data without normal distribution.

The statistical significance was considered at probability value <0.05.

The statistical calculations were done using data analysis tool of Microsoft Excel and Systat 12 (Systat Software, Inc. Chicago).

RESULTS

Randomly assigned yoga and swimming groups showed statistical similarities for basic parameters such as age, sex, height, and weight [Table 1]. Even after similarities in these two groups, percentage improvements in reaction time after 12 weeks of training with respect to baseline level were considered for comparisons of efficacy of exercise modality. This reduced the effect of differences in the baseline reaction time of two groups obtained because of sampling error.

Both ART and VRT showed a statistically significant decrease with yoga as well as swimming. Mean values with standard error of mean in both groups before and after 12 weeks of intervention along with statistical significance of pre- and post-intervention difference in RT are depicted in Table 2.

ART as well VRT for red, green, and yellow light was found to decrease statistically significantly (pre-post analysis) with both yoga and swimming [Table 3]. Percentage decrease in ART as well VRT for red, green, and yellow light in both modalities of lifestyle intervention was compared and better improvement was found with yoga for ART as tested by Mann–Whitney U-test [Table 4].

Average resting O_2 consumption in yoga group significantly decreased ($P < 0.0001$) while average resting O_2 consumption in swimming group remained statistically significant unchanged ($P > 0.05$). The decrease in resting oxygen consumption after 12 weeks of yogic training was statistically significant when compared to the effect of swimming on resting O_2 consumption ($P < 0.05$) [Table 5].

DISCUSSION

After random assignment of the study subjects to either yoga or swimming modality of exercise for 12 weeks, the two groups were analyzed and were found to be comparable having similarities for basic parameters such as age, sex, height, and weight. Reduction of ART and VRT for red light was significantly better after yoga intervention than with swimming. Significant decrease in resting oxygen consumption was observed with yoga intervention in the present study.

Table 2: Effects of Exercise on ART in ms

Parameter	Exercise modality	Reaction time in ms		Wilcoxon signed-rank test/paired *t*-test
		Pre-exercise	Post-exercise	
ART	Yoga	172.42±3.572	162.0±3.183	W=756 Z=5.08****
	Swimming	173.2±3.707	168.975±3.771	*t*=4.543 *P*<0.0001

ART: Auditory reaction time

Table 3: Effects of yoga and swimming intervention on VRT

Parameter	Exercise modality	Reaction time in ms		Wilcoxon signed-rank test/paired *t*-test
		Pre-exercise	Post-exercise	
VRT (ms) (red)	Yoga	198.875±5.355	184.02±4.452	W=780 Z=5.44****
	Swimming	196.15±5.377	190.6±5.205	W=780 Z=5.44****
VRT (ms) (Green)	Yoga	191.35±3.989	178.65±3.762	W=700 Z=4.7****
	Swimming	190.525±4.343	176.75±4.770	W=820 Z=5.51****
VRT (ms) (yellow)	Yoga	188.625±4.365	176.75±3.787	*t*=6.242 *P*<0.0001****
	Swimming	182.75±4.445	171.62±4.642	*t*=10.29 *P*<0.0001****

VRT: Visual reaction time

Table 4: Comparison of effect of yoga and swimming on reaction time

Parameter	Yoga			Swimming			Mann–Whitney U-test
	Pre-exercise (Mean±SEM)	Post-exercise (Mean±SEM)	Change after training (%)	Pre-exercise (Mean±SEM)	Post-exercise (Mean±SEM)	Change after training (%)	
ART	172.42±3.572	162.0±3.183	−10.425(−6.046)	173.2±3.707	168.975±3.771	−4.225(−2.439)	U=1210 Z=−3.95 *P*=0.0001
VRT (red)	198.875±5.355	184.02±4.452	−14.85(−7.467)	196.15±5.377	190.6±5.205	−5.55(−2.829)	U=1190 Z=−3.75 *P*=0.0002
VRT (Green)	191.35±3.989	178.65±3.762	−12.7 (−6.637)	190.525±4.343	176.75±4.770	13.77 (−7.23)	U=735.5 Z=0.62 *P*=0.5353
VRT (yellow)	188.625±4.365	176.75±3.787	−11.87 (−6.295)	182.75±4.445	171.62±4.642	−11.125 (−6.087)	U=768.5 Z=0.3 *P*=0.7642

SEM: Standard error of mean, ART: Auditory reaction time, VRT: Visual reaction time

Table 5: Effects of exercise on resting oxygen consumption (ml/min) in yoga and swimming groups

Parameter	Exercise Modality	Mean±SEM		Wilcoxon signed-rank test/paired *t*-test	Change after training (%)	Mann–Whitney U-test/unpaired *t*-test
		Pre-exercise	Post-exercise			
Resting O_2 Consumption	Yoga	256.6±4.643	242.8±4.444	W=697 Z=4.86****	−13.8 (−5.378)	U=1045 Z=−2.35 *P*=0.0188
	Swimming	257.0±5.668	252.75±6.050	W=284 Z=1.92 (*P*=0.0561)	−4.25 (−1.653)	

SEM: Standard error of mean

Earlier researchers have demonstrated that pranayama produces a significant decrease in VRT as well as ART. A decrease in reaction time indicates an improved sensory-motor performance and enhanced processing ability at the primary thalamocortical level of central nervous system. This may be due to greater arousal, faster rate of information processing, improved concentration, and/or an ability to ignore extraneous stimuli. Pranayamic/yoga practitioners are known to have better attention and less distractibility. It has been reported that this form of yoga practice results in a decrease in mental fatigability and an increase in performance quotient.[9-12]

Reaction time indicating integration of information in central nervous system seems to respond to both yoga and swimming almost equally though yoga has slight advantage in improving ARTs and VRTs.

Slow and deep respiration is characteristic of the yoga module, which is also seen to large extent in swimming. This similarity may be the common factor giving similar advantage in both the groups.

Significant decrease in resting oxygen consumption observed with yoga intervention in the present study has also been demonstrated in earlier study.[5] The changes due to practice of pranayama are comparable to physical training which influences neurological, hormonal, biochemical, and physiological mechanisms.[13] Yoga training is known to achieve a stable autonomic balance, a relative hypometabolic state, and improvement in physical efficiency.[5,14] Such improvement in metabolic efficiency may be due to central and peripheral cardiovascular adaptation or local muscular adaptation or due to both these factors.[15-17]

Pranayama training produces an overall reduction in oxygen consumption, metabolic rate, and load on the heart. There is a shift of the aerobic/lactate threshold to higher workload due to improvement in aerobic capacity during yoga practice. This may be due to the deep psychosomatic relaxation produced by pranayama.[15,18]

Volunteers are able to perform the same workloads of work without getting exhausted with decreased oxygen consumption and also postponement of fatigue (anaerobic threshold) within 20 days of yoga training as well as 90 days training.[19]

Research has demonstrated that physical activity uses specific aspects of energy metabolism to alter brain-derived neurotrophic factor (BDNF)-mediated plasticity in central nervous system. Exercise influences energy metabolism by involving mitochondrial oxidative phosphorylation. It is proposed that exercise may support BDNF-mediated synaptic plasticity by limiting oxidative stress to increase efficiency of energy production from mitochondria. It has also been shown in other studies that exercise increases mitochondrial uncoupling protein (UCP2). It has been proposed that UCP2 may contribute to the mechanism by which exercise uses the mitochondrion to limit oxidative stress.[4] Similar effects may be seen during yoga practice, but evidences for such mechanisms are lacking for yoga.

CONCLUSION

Either yoga or swimming can be advocated as an exercise prescription as both the modalities of exercises cause significant improvement of cognitive functions. However, yoga module has significant advantage in optimizing metabolic efficiency, which may improve the synaptic plasticity as shown by earlier research resulting in enhanced cognitive function. Thus, yoga can be a better option for improvement in cognitive functions and should be used as regular practice. The same may be helpful in many diseases where cognitive functions are affected. Effect size of yoga intervention may be better in diseased states for improvement of cognitive functions. In our future research, we plan to study the efficacy of yoga module in various diseases.

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