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Original Article

Physiology Section

Improvement in Visual and Auditory Reaction Time with Reduced Detraining Effects of Yogic Breathing Manoeuvers- A Non Randomised Controlled Study

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ABSTRACT

Introduction: Earlier, different components of yoga i.e., asanas (static physical postures), Yoga Breathing Manoeuvers (YBM) and meditation were reported to have different magnitude of effects on reaction time. YBM showed greater magnitude of effects on Visual Reaction Time (VRT) and Auditory Reaction Time (ART), than that of asanas in different groups of subjects. So, to observe the effect of different proportions of asanas and YBM in a yoga program on reaction time, with its possible applications in training and in detraining management, the study was undertaken.

Aim: To study the effects of asanas and YBM in different proportions on VRT and ART among the same subjects to explore the magnitude of its effects for applications in training and detraining management.

Materials and Methods: This interventional non randomised controlled study was conducted in the Department of Sports Science and Yoga, Ramakrishna Mission Vivekananda Educational and Research Institute, Belur Math, West Bengal, India, from July to September 2019 on 32 healthy male, undergraduate student volunteers in the age group of 19-21 years. Subjects were divided into two groups i.e., Yoga Group (YG) and Control Group (CG). CG did not practice yoga. YG practiced yoga for 45 minutes daily, six days per week for 12 weeks. Total time of practicing YBM gradually increased every week. For the first two weeks, it was a session of 45 minutes and from 3rd week YBM was increased by one to two minutes every week up to 6th week. Then, at 7th week it increased by eight minutes. From 8th week to 10th week it increased by one to two minutes in every week. On 11th and 12th week it increased 10-12 minutes on average. Up to 6th week they practiced mostly all asanas. From the 7th week to 12th week mostly YBM were practiced. Thus, at the end of 6th and 12th week, effect of greater duration of mostly all asanas and YBM, respectively were available. Measurements of VRT and ART were taken by 'Audio-visual reaction timer', at baseline, 6th week and 12th week end of training on both groups. Study design helped to observe separately the effect of greater duration of asana and YBM practice on same group of subjects. Intragroup and intergroup comparisons were done by repeated measures of Analysis of Variance (ANOVA) and unpaired t-test, respectively.

Results: Both YG and CG had similar age, body weight and body fat percentage and activity pattern. So, groups were homogeneous in nature. VRT and ART were improved significantly (p-value <0.001) by greater practice of asanas for six weeks. Similarly greater YBM practice on subsequent six weeks showed further improvement (p-value <0.001) in both parameters, which even masked the natural detraining effects of these parameters due to withdrawal of asana practice, which was reflected in the magnitude of improvement (as obtained from the percentage calculation from difference of mean values between two time points like baseline to 6th week end) at the 6th week end (VRT: 7.4%, ART: 7.8%) as compared to that of 6th to 12th week end (VRT: 10.4%, ART: 11.6%). YG showed significantly (p-value <0.001) faster VRT and ART than those of CG at the 6th and 12th week end.

Conclusion: Judicious selection of the proportion of asanas, YBM and meditation in a yoga program, optimise Central Nervous System (CNS) arousal with better VRT and ART. YBM helped to reduce detraining effects of reaction time due to the curtailment of asana practice. This might have application in any training and also to counteract detraining effects in sports and among recuperative patients.

Keywords: Asana, Detraining, Kriya, Pranayama, Reaction time, Training, Yoga

INTRODUCTION

Ancient Indian system of yoga consisted of three major components known as asanas (physical postures), Yoga Breathing Manoeuvers (YBM) (Pranayama and kriya). It was wellknown that all of those components as a whole or exclusively one of them promote both physical and mental health. Cognitive performance depended on mental health, which depended on Central Nervous System (CNS) function. Reaction time was one of the indicators of CNS function. The improvement in reaction time in both Auditory Reaction Time (ART) and Visual Reaction Time (VRT) mode by yogic practices were reported by various researchers [1-5]. The effects of yoga on both ART and VRT were attributed to all three major components of Hatha yoga i.e., asana (different static physical postures), YBM consisting of pranayama and Kriya as called according to yoga parlance and meditation [6]. The effect of asana, YBM and also both asana and YBM on ART and VRT were studied on separate groups of subjects [7,8]. Yoga practice for only one week (total five sessions of 60 minutes) among female subjects showed faster VRT and ART among exclusively YBM practiced group than the group practicing only asanas [8]. Both faster YBM like Bhastrika and slow YBM like Anulom Vilom pranayama had positive effects on reaction time [1,9]. Again, faster YBM practice was reported to make better effects than those with slow YBM [9]. Six months yoga practice by male police trainees for four days in every week showed the subjects practicing both asanas and YBM could improve VRT and ART in a better way than those practicing exclusively asanas or pranayama [7]. The studies on reaction time on same subjects in a study design, which included yoga practices with all its major

components, considering the duration of the practice of asana and YBM practice in different proportions are available in scarcity. The literature showed that majority of studies reported greater role of YBM, particularly the faster ones, to improve ART and VRT [1,8-10]. No studies are available to find out, possible role of YBM in counteracting the detraining effects due to discontinuation of asana practice or any other reaction time promoting practices. Even for partial withdrawal the particular type of physical training leads to detraining effects which affect performance [11]. This might be in different types of performance measures as in neuromuscular coordination. The hypothesis of this study was that different proportions of the duration of practice of asana and YBM might have different effects on the magnitude of VRT and ART and absence of any one component might affect even that of the other. The detraining effects happen due to less asana practice, in absence of regular practice of yoga or any other ways.

So, the aim of the present study was to observe the effect of asana and YBM in different proportions in durations of their practice on ART and VRT on sane subjects. The primary objective was to find out the magnitude of training effects with respect to varying proportions in the duration of asana and YBM practice on ART and VRT. The secondary objective was to observe the possible role of YBM in the management of detraining effects due to less asana practice, in absence of regular practice of yoga or any other situations.

MATERIALS AND METHODS

This interventional non randomised controlled study was conducted in the Department of Sports Science and Yoga, Ramakrishna Mission Vivekananda Educational and Research Institute, Belur Math, Howrah, West Bengal, India, from July to September 2019. Total 32 healthy male, undergraduate student volunteers from the Sanskrit Department of the institute participated in this study. Only male subjects were taken in this study, as reaction time was sensitive to gender difference [1,12]. The study was undertaken after permission from the Departmental Research Committee (DRC). The approval of Institutional Ethical Committee (Assigned no: RKMVERI/IEC-20/SSY-6) was obtained.

Subjects were explained the purpose of the study in their mother tongue (Bengali) and their informed consent was also obtained. Both the training in yoga and experiments on reaction time were conducted following standard norms/guidance for conducting experiments on human subjects. This was as per 'Revised National Ethical Guidelines for Biomedical and Health Research involving human participants'. ICMR, 2017, New Delhi, ISBN: 978-81-91009-94 [13]. They were divided into two homogeneous groups with 16 subjects in each group, which were also age, body weight, height, body fat % and sex matched. One group practiced yoga (YG) and other group served as control, without yoga practice (CG).

Sample size calculation: Sample size was obtained from standard methods and formula [14]. For this, standard deviation (s) and margin of error (d) of the basic variables i.e., ART (d=4, s=9.0) and VRT (d=8.0, s=16.0) at 5% level of significance (p-value <0.05) were considered. This could be obtained through a 'trial-run' of recording same parameters in the departmental set up of the laboratory in the same equipment. This did not match with those of already published papers, where values of standard deviations were very much higher than that of the trial-run. So, values of basic variables, as available through 'trial-run' were considered for sample size calculation. The formula was: $n=(z^2 s^2)/d^2$, where n=number of samples, z=confidence interval, s=standard deviation and d=margin of error.

Inclusion criteria: They were supposed to be medically fit as it could be obtained through interview and medical records, without the habit of smoking, taking alcohol, previous experience in hatha yoga practice and any other agents that affect performance. They had no problem of vision and hearing which was determined by direct interview and medical records. All of them stayed in the same hostel in the university, with uniform pattern of daily routine and were having standard diet from a common mess.

Exclusion criteria: Subjects having the habit of smoking, taking alcohol or any intoxicating agents were not taken in this study. Individuals with athletic background, already a yoga performer were excluded from the study. Students having any cardiovascular, respiratory or other disorders which may affect their performance like defects in colour vision and visual acuity, problem of hearing, using hearing aids were excluded from the study.

The selected sample size was highest among the two sample sizes i.e., one calculated from basic variables of VRT and another from that of ART. Likewise, highest sample size was to be 38 considering two groups (yoga and control) to be formed. As there were much number of subjects not available, finally sample size of 32 was selected.

Samples were selected by the purposive sampling from the students of the 1st year and 2nd year undergraduate classes of the Sanskrit Department. Apart from those students, there were other students in other classes. For administrative reasons and better management of academic activities and also keeping in mind the inclusion/exclusion criteria for subjects of this study, students from other classes were not included. No other students, apart from the subjects of the present study of the department practiced yoga during that particular point of time. All the students were having daily uniform disciplined life style right from getting up from bed very early in the morning to activities throughout the day and also to go for sleep at night. They used to have same food from a common mess. All of them were physically active with a rural background. Thus, both the groups of subjects in this study were homogeneous in nature. Each YG and CG had 16 number of subjects.

Study Procedure

Yoga group practiced for 45 minutes in the morning from 6:00 to 6:45 AM, which included five minutes free hand light loosening exercises, for six days in a week for three months under the guidance of two qualified yoga instructors. Yoga training involved were asana (physical postures) and YBM (Pranayamas and Kriya), which were practiced for 30 minutes. At the end of each session they performed om chanting and meditation (Dhyana) for five minutes. The name of the asanas as they practiced is given in [Table/Fig-1].

Name of the asanas and YBM	Time duration (in minutes}
Loosening exercise or free hand exercise: Ankle up and down, side bending, shoulder rotation etc.	5
Trikonasana, Tadasana, Saral Bhujangasana, Katichakrasana, Saral dhanurasana, Ardhasalvasana, Paschimottanasana, Janusirasana, Ardha matsyendrsana and Salvaasana	25 (Approximately 2 minutes were spent to practice each asanas for two times which included relaxative asanas: Shavasanas and Makarasana. The time for holding for final posture of particular asanas varied with the progress of training)
Relaxtative asanas: Makarasana, Shavasana/Sukhasana (Sukhasana practiced only during YBM)	5
Breathing manoeuvres (YBM): Kapalabhati (Kriya); Anulom Vilom, Ujjai, Vastrika and Bhramari Pranayama	5
Meditation and 'OM' chanting	5

[Table/Fig-1]: Training programme (initially time duration was like this. Later, with progress of training duration of asanas and YBM practice varied as given in the time line.

The rationale for selection of the three months (12 weeks) for yoga training was that prior to this study some studies selected 12 weeks of yoga training period [3,4,12]. In this study, it was planned to impart asanas and YBM for equal duration for better comparison. So, up to the middle of training i.e., 6th week, subjects were practicing mostly asanas. After that, mostly YBM were practiced by them up to the 12th week. This is given in detail in the Time Line of the yoga training programme in [Table/Fig-2]. The initial six weeks

YBM (5 min)		YBM (6 min)		YBM (9-12 min)		YBM (17-20 min)		YBM (18-20 min)		YBM (30 min)	
Asanas (25 min)		Asanas (24 min)		Asanas (18-21 min)		Asanas (10-13 min)		Asanas (10-12 min)			
1st week		**3rd week**		**5th week**		**7th week**		**9th week**		**11th week**	
											
	2nd week		**4th week**		**6th week**		**8th week**		**10th week**		**12th week**
	Asanas (25 min)		Asanas (23 min)		Asanas (18-21 min)		Asanas (10-12 min)		Asanas (10-12 min)		
	YBM (5 min)		YBM (7 min)		YBM (9-12 min)		YBM (18-20 min)		YBM (18-20 min)		YBM (30 min)

[Table/Fig-2]: Time line of yoga training programme. In this only 30 minutes of yoga practice has been shown with the duration of asanas and YBM practice in a session every day in a week. Total training includes loosening exercises and Om chanting along with meditation, respectively for five minutes each in the beginning and end of a yoga session.

of training for asana practice coincided with an earlier study, where only asanas were practiced by the subjects for six weeks [5]. In another study subjects practiced only Anulom Vilom Pranayam, a slow YBM for eight weeks [15]. YBM included Kapalbhati (a kriya in hatha yogic parlance); Anulom vilom, Bhastrika, Ujjai and Bhramari (called pranayamas in hatha yogic parlance). Yogic practices were done following standard procedures [6]. Throughout, the yoga training period the duration of asana practice gradually reduced. So, in the 1st and 2nd week, only two YBMs were introduced. Subsequently, 3rd week onwards the duration of those YBM practice increased with introduction of one more new YBM, which took approximately one to two minutes more up to 5th and 6th week. From 6th week to 7th week duration of YBM practice increased by eight minutes. Thereafter, it remained almost same (only an increase of one minute) up to 10th minute [Table/Fig-2].

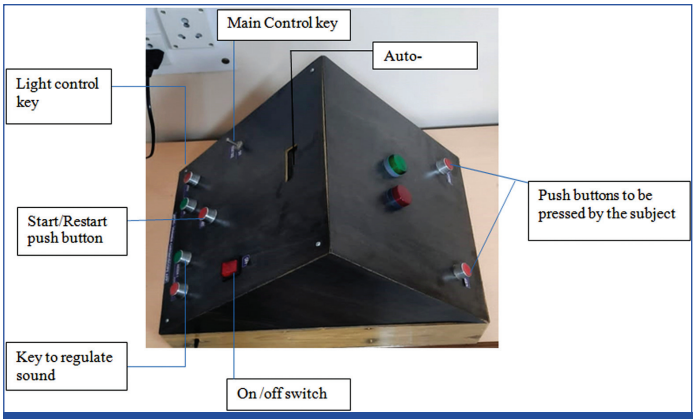
The YBMs were introduced in every week up to 6th week according to the ability of the practitioners. With this, the duration of asana practice reduced. Up to 6th week, they practiced YBM for maximum 17 minutes which included rest pauses in relaxative postures like Sukhasana and Shavasana and minimum 18 minutes for asanas, which also included various relaxative asanas like Shavasana, Makarasana and Sukhasana. Thereafter, from 7th week to 10th week, duration of asana practice gradually reduced further and maximum duration of YBM practice was 20 minutes with minimum duration of asana practice was only 15 minutes including the relaxative asanas. Last two weeks of three months training period they practiced only YBM with relaxative asanas and maintained the duration of practice of loosening exercises, Om chanting and meditation same as, it had been from the beginning. This period was actually full detraining period so far as the asanas are concerned (except relaxative asanas). In the afternoon, both YG and CG participated in recreational games for 30-40 minutes as they used to do before this study.

Recordings of Different Parameters

Their height (cm) was measured by stadiometer and body weight (kg) and fat (%) were measured by body composition analyser (ioi353, Poland). Body fat was measured by bio-impedance principle by the instrument.

Reaction times were measured by "Audio Visual Electronic Reaction Timer" which was manufactured by Education Emporium, Kolkata, India. Instrument has a four digit chronoscope with least count of 1/1000 sec. i.e. one millisecond (ms). Green light stimulus and high frequency beep stimulus were selected for recording VRT and ART respectively. VRT and ART were taken against the green light stimulus and high frequency beep stimuli respectively in milliseconds (ms) from auto display [Table/Fig-3].

During experiment, the experimenter pressed the respective push button to trigger auditory and visual stimulus. Subjects were also alerted about the impending signal, while they were ready by keeping their index finger of the dominant hand just above the



[Table/Fig-3]: Description of the Audio-Visual Reaction Timer.

push button to indicate the response. As soon as the stimulus was perceived by the subjects, they pressed the response button immediately. In this study, subjects got oriented to the test after 10-15 times practice for two days prior to the day of the study. On the day of the study also they had trial run for three times. After that the actual experiment was done for recordings of their VRT and ART for three times. For final readings the average of three readings was considered. During the experiments laboratory temperature used to be checked in every half an hour interval and room temperature varied from 25-28°C.

STATISTICAL ANALYSIS

The distribution of data was checked for normality using the Shapiro-Wilk test. After that intra group comparisons were done by Two-way Analysis of Variance (ANOVA) with repeated measure. This was followed by Bonferroni post-hoc test to determine the significant differences in mean values in VRT and ART between measurements in consecutive training phases of both groups. Inter group comparisons were done by unpaired t-test. Significance level was set at p-value <0.05. Data was analysed with Statistical Package for the Social Sciences (SPSS) software version 21.0 (SPSS Inc., Chicago, Illinois, USA). Magnitude of improvement of VRT and ART was calculated in terms of Δ%, from the differences of between means in two time points i.e., baseline vs 6th week and 6th week vs 12th week.

RESULTS

In body weight and body fat percent, the subjects of both YG and CG did not show any prominent changes [Table/Fig-4].

The distribution of data was normal based on which tests of parametric statistics were done [Table/Fig-5]. In inter group comparisons, 6th week (VRT: 250.8±13.5 ms, ART: 178.2±7.6 ms) and 12th week mean value (VRT: 224.7±11 ms; ART: 157.6±6.7 ms) of YG were significantly (p-value <0.001) lower than the respective values of CG at 6th week (VRT: 275.9±14.8; ART: 190.7±6.3) and 12th week (VRT: 272.3±12.1; ART: 191.6±6.8) [Table/Fig-6].

Yoga Group (YG)	Age (years)	Height (cm)	Body weight (kg)	Body fat (%)
Baseline	20.3±1.3	167.5±5.3	55.2±6.1	13.3±2.3
6th week			56.3±5.1	13.2±2.3
12th week			56.7±5.1	13.2±2.1
Control Group (CG)				
Baseline	20.8±1.4	166.9±5.1	55.4±4.92	13.14±2.4
6th week			56.06±5.09	13.42±2.1
12th week			56.31±4.98	13.51±1.8

[Table/Fig-4]: Physical characteristics of the subjects (Mean±SD) in yoga and control group. Results were presented as mean±Standard Deviation (SD).

Parameters	Groups	Shapiro-Wilk test		
		Statistic	df	p-value
Visual Reaction Time (VRT)				
VRT baseline	Control	0.960	16	0.658
	Yoga	0.942	16	0.373
VRT 6th week	Control	0.895	16	0.067
	Yoga	0.952	16	0.523
VRT 12th week	Control	0.939	16	0.340
	Yoga	0.934	16	0.283
Auditory Reaction Time (ART)				
ART baseline	Control	0.990	16	0.999
	Yoga	0.945	16	0.412
ART 6th week	Control	0.957	16	0.616
	Yoga	0.934	16	0.283
ART 12th week	Control	0.975	16	0.913
	Yoga	0.941	16	0.367

[Table/Fig-5]: Normality test of the data of VRT and ART by Shapiro-Wilk test, p-value <0.05 was considered as statistically significant. So, data was normally distributed.

Parameters	Study groups	Baseline (Mean±SD)	6th week (Mean±SD)	12th week (Mean±SD)	F-value	p-value (Repeated measure ANOVA)
VRT (ms)	Yoga	270.9±13.5	250.8±13.5	224.7±11	196.39	**<0.001**
	Control	271.5±15.9	275.9±14.8	272.3±12.1	3.03	0.07
	p-value*	0.914	**<0.001**	**<0.001**	-	-
ART (ms)	Yoga	193.3±6.7	178.2±7.6	157.6±6.7	577.17	**<0.001**
	Control	191.3±6.5	190.7±6.3	191.6±6.8	2.11	0.14
	p-value*	0.394	**<0.001**	**<0.001**	-	-

[Table/Fig-6]: Intra and Inter group comparisons of mean values of VRT and ART among the yoga and control group.
p-value in bold font indicates statistically significant value; *Unpaired student t-test for inter group comparisons

The pretraining baseline mean value of VRT was 270.9±13.5 ms [Table/Fig-6,7]. It decreased to 250.8±13.5 ms with statistical significance (p-value <0.001) after six weeks. After 12th weeks, it further reduced in a greater magnitude to 224.7±11.6 ms (p-value <0.001) as compared to six weeks training, indicating, progressive improvement of VRT when more time devoted to YBM practice. In CG, baseline value of VRT was 271.5±15.9 ms, which did not change significantly at the 6th and 12th week end. In YG, baseline value of ART was 193.3±6.7 ms, which reduced to 178.2±7.6 ms (p-value <0.001) after six weeks. After this, it significantly decreased further to 157.6±6.7 ms (p-value <0.001) after 12th weeks.

Magnitude of improvement of reaction time from baseline to 6th week end was first calculated by subtracting the mean values of 6th week end to that of baseline to obtain a value indicating the difference between them. From this the % change (reduction) was calculated. Thus, in VRT, it was 7.4% in case of baseline to 6th week end, while it was 10.4% in case of 6th week to 12th week end [Table/Fig-8]. Thus, the magnitude of fall in mean ART value was 7.8% after six weeks, thereafter it further reduced with greater magnitude (11.6%) after 12 weeks.

DISCUSSION

The design of this study helped to observe the effects of yoga on reaction time, when yoga training dominated with the practice of asanas (yoga physical postures) and also for the same, when YBM practice dominated in another part of training on the same subjects. This helped to avoid, intergroup variations to a greater extent, compared to other studies, where separate groups of subjects were used to impart either asanas or YBM. To the best of the authors' knowledge, no study followed similar type of protocol to identify the effect of different components of yoga on reaction time. Moreover, present study could avoid the factor of variations due to the subjects in different groups, at the same time included all the major components of yoga i.e., asanas, YBM and meditation in training regimen, which were essential for yoga training, yet could attain the study goal. This has been explained in the following paragraph.

In this study, the duration of the practice of meditation and chanting Om in Sanskrit, which had similar effects like meditation, at the end of a yoga practice session was maintained constant during both the 1st and 2nd half of yoga training period. So, the effect of meditation might be considered as a common factor. In the 2nd half of yoga training period, more YBMs were practiced. From the 7th week of training, with gradual reduction of the duration of asana practice, the partial detraining effects with respect to asanas took place, which became full (detraining) particularly during the last two weeks when subjects practiced only YBM instead of asanas. Hence, the greater improvement in ART and VRT at 2nd half of training compared to 1st half had been due to YBM. So, the present study showed

Parameters	Group	Training duration (week)		Mean difference	95% Confidence interval for difference		p-value (Repeated measure ANOVA and followed by Bonferroni post hoc test)
					Lower bound	Upper bound	
VRT (ms)	Yoga	Baseline	6th week	20.09	15.79	24.38	**<0.001**
		6th week	12th week	26.17	20.17	54.33	**<0.001**
		Baseline	12th week	46.27	38.19	32.14	**<0.001**
	Control	Baseline	6th week	-4.44	-8.92	0.04	0.062
		6th week	12th week	3.57	-1.82	8.97	0.284
		Baseline	12th week	-0.87	-6.38	4.64	1.000
ART (ms)	Yoga	6th week	12th week	15.12	12.38	17.86	**<0.001**
		Baseline	12th week	20.67	17.49	23.84	**<0.001**
		Baseline	6th week	35.79	33.19	38.39	**<0.001**
	Control	6th week	12th week	0.62	-0.36	1.59	0.33
		Baseline	12th week	-0.23	-2.07	0.38	0.25
		6th week	12th week	-0.85	-1.45	0.98	1.00

[Table/Fig-7]: Pair-wise comparison of VRT and ART values among yoga and control group.

Parameters	Study groups	Baseline (Mean±SD)	6th week (Mean±SD)	12th week (Mean±SD)	Δ% Baseline to 6th week	Δ% 6th week to 12th week
VRT (ms)	Yoga	270.9±13.5	250.8±13.5	224.7±11	7.4	10.4
	Control	271.5±15.9	275.9±14.8	272.3±12.1	-1.6	1.3
ART (ms)	Yoga	193.3±6.7	178.2±7.6	157.6±6.7	7.8	11.6
	Control	191.3±6.5	190.7±6.3	191.6±6.8	0.3	-0.5

[Table/Fig-8]: Magnitude of improvement percentage (Δ%) of VRT and ART. Note greater improvement in VRT and ART in 6th week to 12th week training than that of baseline to 6th week. Δ% was calculated in terms %, from the differences between means in two time points i.e. baseline vs 6th week and 6th week vs 12th week.

positive effect of asanas on VRT and ART (7.4% in VRT and 7.8% in ART) and also separately that of YBM in a greater magnitude (10.4% in VRT and 11.6% in ART). This indicated the potential of YBM to boost/improve VRT and ART. This was because of the fact that YBM could do this over and above, whatever happened in the 1st half of training. The usual detraining effect, which should happen after withdrawal of asana practice in the 2nd half of training as it happened after discontinuation of physical training, even if it was partial, had been masked by the greater magnitude of improvement in VRT and ART by greater YBM practice [11]. Thus, another new finding had been revealed, that in any training situation, if there was lesser improvement or if there was any detraining effect due to the absence of regular asana practice or any other practice in physical training and sports, YBM practice might help to overcome it.

Detraining happened due to loss of training induced adaptation resulting in negative changes in different physiological, metabolic, hormonal and biochemical systems in the body, which had been acquired by training. Thus, the performance level of an individual deteriorated in absence of the practice of particular exercise in certain intensities and durations. Its manifestations might be there in both at physical and mental level. In short term training/detraining, as it was observed in this study, which was from few weeks up to three months, also it was possible to happen [11]. It might be regained by same or other mode of training/intervention.

Mechanism of Improvement in ART and VRT by Yoga

Reaction time depended on afferent sensory neural processing speed with respect to specific sensory cue and central neural processing of it to trigger the appropriate specific task. This was also true for the execution of task, which depended on efferent motor conduction speed, which ultimately helped a person to complete the task (here pressing the button) as quick as possible. Studies showed improvement in motor and sensory conduction of median nerve and positive changes in visual evoked potential activity along with improved ART and VRT by yoga practices [7]. Improvement in motor nerve conduction velocity after yoga practice had also been reported [16]. There were also studies showing improvement in auditory evoked potential after practicing YBM indicating better auditory neural processing [17]. Again, attention of a person to a specific sensory cue and also concentration to perform a specific job also matters with this [18,19]. Yogic practices help to improve different psychophysiological parameters like concentration, vigilance and attention, which had applications among both normal and diseased persons [20]. Better sympathovagal balance with calming of mind, changes in various neural structures due to neural plasticity as revealed by modern imaging techniques and improvement in coordination of electrophysiological activities by yogic practices, brought about optimal arousal and those were hall mark of yoga practice [21]. Accordingly, in this study, the different components of yoga i.e., asanas and YBM helped to show improvement in VRT and ART in different magnitudes.

Effects of Slow and Faster YBM

Subjects in this study practiced both slow and fast YBM. So, the effect of both slow and fast YBM was likely to be there. Most of the previous studies with focus either on slow or fast YBM reported improvement in VRT and ART, but the magnitude of improvement was in varying degrees in each cases based on intensity and duration of practice along with types of the YBM. This also might be based on the proficiency of practicing the YBM by its practitioners.

Fast YBM: Mostly in fast type of YBM, ART and VRT improved in greater magnitude than in the slow type YBM. Both slow and fast YBM made faster VRT and ART with improved cognitive function, but percent improvement was greater in fast pranayama [9]. In addition to this, faster pranayama helped to have better executive function by the use of auditory working memory, improved central neural processing and sensory-motor activity. Improvement in ART and VRT in terms of percentage changes had been found by slow YBM without statistical significance, but in case of fast YBM (Bhastrika pranayama) best improvement (in percentage change) happened only in ART, while VRT having a very minor change [22,23]. Same study also reported greater sympathetic activity in faster YBM as compared to slow YBM and comparatively greater arousal by faster YBM.

Studies also indicated improvement in ART and VRT in fast pranayama [1,7]. Interestingly, studies with supporting evidences attributed the ART and VRT related effects of Bhastrika pranayama (a type of fast YBM) to the mechanism of the lung deflation and abdominal muscle contraction with splanchnic receptor related neural outputs to reticular system, which had effects on one hand to the cortex through neuraxis, on the other hand also to the medulla [12,17]. Like Bhastrika pranayama, Kapalbhati (another fast YBM), which showed its effect on attention and vigilance, also might have similar mechanism of effect on reaction time [24].

Slow YBM: Broker and Pedenkar, found very significant improvement in VRT and ART by slow pranayama practice for 20 minutes in the morning and afternoon for five days a week including the 20 minutes practice on sundays for four months [10]. Dhadse M and Fadia A, reported nadisuddhi pranayama (slow YBM) was very effective for the improvement in ART attributing this to relative parasympathetic dominance, the calming effect with improvement in higher brain functions, which was also helpful in overall stress management [15]. Reaction time depends on Electroencephalogram (EEG) alpha frequency, which in greater amount indicated tranquility of brain and arousal [25,26]. During the post isometric contraction period of muscle, central processing and reaction time became faster [27]. The arousal of the brain also depended on the muscle tone as it happened during normal inhalation and exhalation [28,29]. Greater activity of diaphragm and other respiratory muscles during normal slow inhalation led to moderate arousal and during exhalation opposite might happen, as normal exhalation itself was a passive process. The possible delicate balance between the arousal levels of high and low was maintained in YBM. So, during slow YBM also same mechanism might prevail. In greater arousal, reaction time tended to be slower, while at its optimum level, it became faster [8,12]. The physiological system of a yoga practitioner who repeatedly practices different YBM may possibly get entrained to achieve it in a better way. It was well established that yoga had positive effect on EEG alpha, beta and theta activity. Yoga decreased amygdala activation, which decreased negative emotion. Alternate nostril breathing influenced contralateral cerebral hemisphere. This had neurocognitive effects [30]. This was also observed in faster YBM i.e. Kapalbhati [31]. Thus, perhaps slow YBM like Anulom vilom and Ujjai pranayama and faster YBM like Bhastrika and Kapalbhati as practiced by our subjects might have same effects on ART and

VRT, but the neural mechanisms might be different. This requires further study.

Slow YBM might have soothing effect by balancing the greater arousal if there be, with attenuation of sympathetic activity and its effect on the general physiological system. Optimum arousal made one attentive, by improving the capacity to reject unnecessary sensory inputs and distracting thoughts with better neural processing, which in turn, helped to have better reaction time. Thus, slow YBM might have contributed in the improvement in VRT and ART in present study.

Apparently, it seemed that the effect of both slow and fast YBM were there in the present study; but based on the separate studies on the effect of the slow and fast YBM on ART and VRT as conducted by others, it could be stated that the fast YBM might have greater contribution for faster ART and VRT. Still, the integrated effect of both could not be ruled out. In studies on other performance related parameters under same yoga protocol; the slow YBM with its role in better oxygenation and faster YBM with its cardiorespiratory effects, with better sympathovagal balance, resulted in positive effects on aerobic capacity and other performance related parameters [32-34].

Differences in ART and VRT Responses due to Yoga Training Type and Gender

During the 1st half of yoga training period with more asana practice, both VRT and ART improved. This is due to better central neural processing as a result of cortical arousal. This was reported that by the practice of the combination of asanas and YBM, the responses in ART and VRT were significantly better, but the practice of only asanas showed statistical significance in VRT, while that of only pranayama was significant in ART. So, improvements in reaction time with respect to both the visual and auditory sensory cues were possible by combined asana and YBM practice, but that was different for each of YBM and asana practice. In present study, during the 2nd half of training period with greater YBM practice (last two weeks subjects practiced only YBM) further improvement in both the parameters were observed. Bhavanani AB et al., had similar findings as was observed in this study as they found even by one week of YBM practice the ART and VRT responses were better compared to that of asanas [8]. But, this contradicts the observation of Takroo M et al., [7]. This is possibly due to the fact that their subjects practiced only asanas and pranayama or only asana without incorporation of meditation in yoga training and also due to the intense physical training as required in police training. Incorporation of meditative component, even if for a shorter period, perhaps qualitatively differ the response pattern of VRT and ART and it was complementary to the effect of asanas or pranayama or vice versa. Attainment of optimal arousal level which was required for both better attention and sensory motor neural processing might perhaps also be maintained by the meditative component [8]. Thus, whatever happened physiologically either by asana or YBM occur in the background of the effect of meditation, which might have a role on the attenuation of arousal level to achieve the optimal and balanced arousal to bring about the improvement in VRT and ART. Lohat A et al., also reported improvement in ART and VRT by the practice of meditation [35]. Telles S et al., and Telles S et al., showed in well-designed studies that by practicing breath awareness practice (like mindful meditation) ART and VRT improved irrespective of gender [1,12]. They revealed gender differences in ART and VRT after Bhastrika pranayama (a type of YBM) in same studies, showing breath awareness helped to improve reaction time in both genders, while Bhastrika improved those only in case of male subjects. Further, differences in VRT and ART responses between the studies of Takroo M et al., and Bhavanani AB et al., possibly was due to gender difference of the subjects between two studies [7,8].

So, the initial hypothesis that different proportions of the duration of asanas and YBM practice might have different effects on the magnitude of ART and VRT and detraining happened due to less asana practice had been proved right. In general, all the components of yoga i.e., asana, YBM and meditation, each of them or various combinations, might help in the improvement of ART and VRT. This might have potential application for improvement in cognitive performance for the students to persons in various professions including sports. The potentiality of YBM to improve ART and VRT might have application to counter detraining effects on any training situation due to discontinuation/interruption of training in inadvertent situation or periodisation as in sports. In patients, this might have applications during recuperative stage to overcome deconditioning effects after prolonged bed rest or any other reason.

Limitation(s)

The randomisation at individual level of subjects for selection of samples for forming the groups could not be done. Further studies with greater sample size and randomisation at subject level may take care of this lacunae.

CONCLUSION(S)

All the components of yoga, each of them or various combinations of them, might have applications to improve reaction time both in visual and auditory mode, for students to persons in various occupations and sports. YBM improved reaction time in both of those modes to a greater magnitude, which counteracts detraining effects due to discontinuation/interruption of training. This might have application during periodisation in sports. If situation permits, patients in recuperative stage might practice YBM to overcome deconditioning effects on reaction time after prolonged bed rest or any reason.

Authors' contributions: USR initially conceived the study, both USR and GBB made the study design. GBB contributed in yoga training and data collection and analysis. USR interpreted the data and drafted the manuscript and GBB partially helped in this process. USR critically checked and revised the manuscript. Both authors approved the final version.

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