

## Changes in Reaction Time after Yoga Bellows-type Breathing in Healthy Female Volunteers

### Abstract

**Background:** Previously, yoga bellows-type breathing (*bhastrika pranayama*) reduced reaction time (RT) or reduced anticipatory responses in male participants or a mixed group of male and female participants. **Aims:** The present study as a control trial aimed to assess the effects of yoga bellows-type breathing on RT in females exclusively. **Methods:** The sample consisted of 25 healthy females, aged between 19 and 32 years (group mean  $\pm$  standard deviation,  $22.8 \pm 3.5$  years). All of them had prior minimum experience of yoga including yoga bellows-type breathing of 12 months. The RT was assessed in each participant before and after three randomized sessions differed in the intervention given held on three separate days. The sessions were (i) YOGA bellows-type breathing or *bhastrika pranayama* (BHK), (ii) Breath awareness (BAW), and (iii) Sitting quietly (CTL) as a control session. The duration of the intervention was 18 min, and the participants were assessed for RT before and after the intervention. **Results:** Repeated measures ANOVA, *post hoc* tests with Bonferroni adjusted showed that the time taken to obtain a correct response reduced significantly after 18 min of BAW ( $P < 0.05$ ) and CTL ( $P < 0.05$ ). However, no changes were seen in the RT after BHK. **Conclusions:** The results suggest that different interventions may optimize performance in tasks requiring attention in females compared to males.

**Keywords:** *Bhastrika pranayama, breath awareness, Multi-Operational Apparatus for Reaction Time, quiet sitting, reaction time*

### Introduction

Yoga practice includes physical postures (*asanas*), voluntarily regulated breathing (*pranayamas*), meditation, and specific philosophical guiding principles. There are several types of voluntarily regulated yoga breathing techniques, all of which are considered to influence the mental state.<sup>[1]</sup> *Bhastrika* or bellows-type of breathing involves a deep inhalation followed by a complete exhalation.<sup>[2]</sup> This practice has consistently been found to influence the reaction time (RT). A total of 22 schoolboys aged between 13 and 16 years, who had been trained in yoga for 3 months were assessed for the immediate effect of nine rounds of *bhastrika pranayama*.<sup>[3]</sup> Following nine rounds of *bhastrika pranayama*, there was a significant decrease in visual RT (VRT) (Cohen's  $d = 2.81$ ) and auditory RT (ART) (Cohen's  $d = 3.15$ ). In this study, there was no control group; hence, a practice effect could not be ruled out.

There have been studies on the effects of *bhastrika pranayama* on volunteers with physical and intellectual disabilities. A total of 34 adolescents whose ages were between 14 and 16 years, and who were diagnosed with intellectual disability were trained in yoga for 2 years, with a practice session at least once a week.<sup>[4]</sup> After nine rounds of *mukha bhastrika* (yoga bellows breathing through the mouth), the participants showed a decrease in both VRT (Cohen's  $d = 2.50$ ) and ART (Cohen's  $d = 2.38$ ). This study also did not have a control group for comparison. The results suggest that despite the intellectual disability participants show a comparable reduction in RT, comparable to healthy volunteers.

Multiple sclerosis is known to reduce nerve conduction velocity.<sup>[5]</sup> A combination of yoga practices including physical postures (*asanas*), voluntarily regulated breathing (*pranayamas*), meditation, and lectures on yoga philosophy were given to 11 persons (six females) diagnosed with multiple sclerosis.<sup>[6]</sup> Yoga practice sessions

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were for 5 h a day, for 5 days a week, for 3 weeks. The auditory and VRT and levels of anxiety were assessed at baseline and after 3 weeks. There was a significant decrease in VRT (Cohen's  $d = 0.569$ ) and levels of anxiety. This group also lacked a control group for comparison.

A comparison between participants who had experience in yoga and those who were naïve-to-yoga was carried out on two groups of healthy males average age 29 years.<sup>[7]</sup> The yoga group had been practicing yoga which included postures, breathing techniques, and meditation for an average of 6 months. There were 35 participants in each group. The RT was assessed in both groups. The yoga group had two experimental sessions as follows: (i) a session of *bhastrika pranayama* practiced for 18 min and (ii) a session of breath awareness, as breath awareness is part of every *pranayama* practice and has been shown to influence attention.<sup>[8]</sup> The control group was assessed after a comparable duration of time, seated comfortably, with their eyes closed. Following 18 min of *bhastrika pranayama*, there was a significant reduction in the number of anticipatory responses (The Cohen's  $d$  was  $<0.05$  though the change was statistically significant).

Hence, this study had a control group for comparison. In the study, an important point which was noteworthy is that all the participants were males. Hence, keeping the points mentioned above, the present study was planned to study the following in an all-female samples: (i) assess the effects of *bhastrika pranayama*, breath awareness, and quiet sitting in the same individuals on separate days, a design which has been used in multiple studies<sup>[9]</sup> and (ii) to study the effects on RT. Our hypothesis was that *bhastrika pranayama* would improve the RT in females as it had in an all-male sample and in studies involving both sexes.

## Methods

### Participants

A total of 25 female volunteers with ages between 19 and 32 years (group mean  $\pm$  standard deviation,  $22.8 \pm 3.5$  years) participated in the trial. The sample size was determined using G\*power software Version 3.1.9.2 was developed by Franz Faul, University Kiel, Germany, 2014,<sup>[10]</sup> to determine Cohen's formula for an effect size of 0.6 and alpha of 0.05, powered at 0.99. The required sample size was obtained 18; however, 25 was decided upon to account for attritions. Female participants alone were selected as a previous study reported the effects of yoga bellows-type breathing (*bhastrika pranayama*) on RT in male participants exclusively.<sup>[7]</sup> The participants were completing a residential course in yoga in India, and all of them had between 12 and 18 months of experience in yoga practice, including *bhastrika pranayama*. The participants were included in the trial if as follows: (i) they were the right hand dominant based on a standard handedness inventory<sup>[11]</sup> and (ii) they were able to stick to

the experimental schedule. The participants were excluded from the trial if they had any physical or psychological illness, were on medication, or on any supplements which could alter the mental state. None of the participants had to be excluded for these reasons. Recruitment was by flyers placed on the notice board of the yoga center. The participation in the trial was voluntary, and there was no incentive to take part. Each participant's signed consent was obtained. The study was approved by the Institutional Ethics committee (approval number: YRandD/16/0022).

### Study design

The participants were assessed in three different sessions conducted on separate days at the same time of the day. The sessions were as follow: (i) yoga bellows-type breathing (*bhastrika pranayama*; BHK), (ii) breath awareness (BAW), and (iii) a control session of sitting quietly (CTL). The order of the sessions was randomized for the 25 participants using a standard randomizer (www.randomizer.org). One sample of randomization is shown in Table 1. Each session consisted of three epochs: (i) Pre (5 min), (ii) During (18 min), and (iii) Post (5 min). The 18 min spent "during" a session included three 5 min epochs separated by a gap of 1 min. On 1 day "during" involved the practice of yoga bellows-type breathing (BHK), on another day the practice was of BAW, and on the 3<sup>rd</sup> day it was CTL. This order was randomized as was mentioned above. A schematic representation of the structure of the sessions is given in Figure 1.

### Assessments

The Multi-Operational Apparatus for Reaction Time (MOART: Lafayette Instrument Company, Model no. 35600, USA) with temporal resolution of 0.001 s ( $\pm 0.005\%$ ) was used to conduct the Simple Reaction Time Test. The apparatus consisted of two panels, namely, (i) the main panel (the stimulus was displayed, and participant's response was made here) and an attached (ii) display panel; PymCon interface unit, model-35500 (displays the correct/incorrect/anticipatory responses and the time taken to respond to a "GO" stimulus). The participants were seated cross legged with their back straight and at ease. The MOART was put in

**Table 1: A sample random sequence of *bhastrika pranayama*, breath awareness, and control (quiet sitting) sessions for five participants (A to E)**

Participants (example)	Sequence of the sessions		
	Day 1	Day 2	Day 3
A	BHK	BAW	CTL
B	BHK	CTL	BAW
C	CTL	BHK	BAW
D	BAW	BHK	CTL
E	BAW	CTL	BHK

BHK=*Bhastrika pranayama*, BAW=Breath awareness, CTL=Control (quiet sitting)

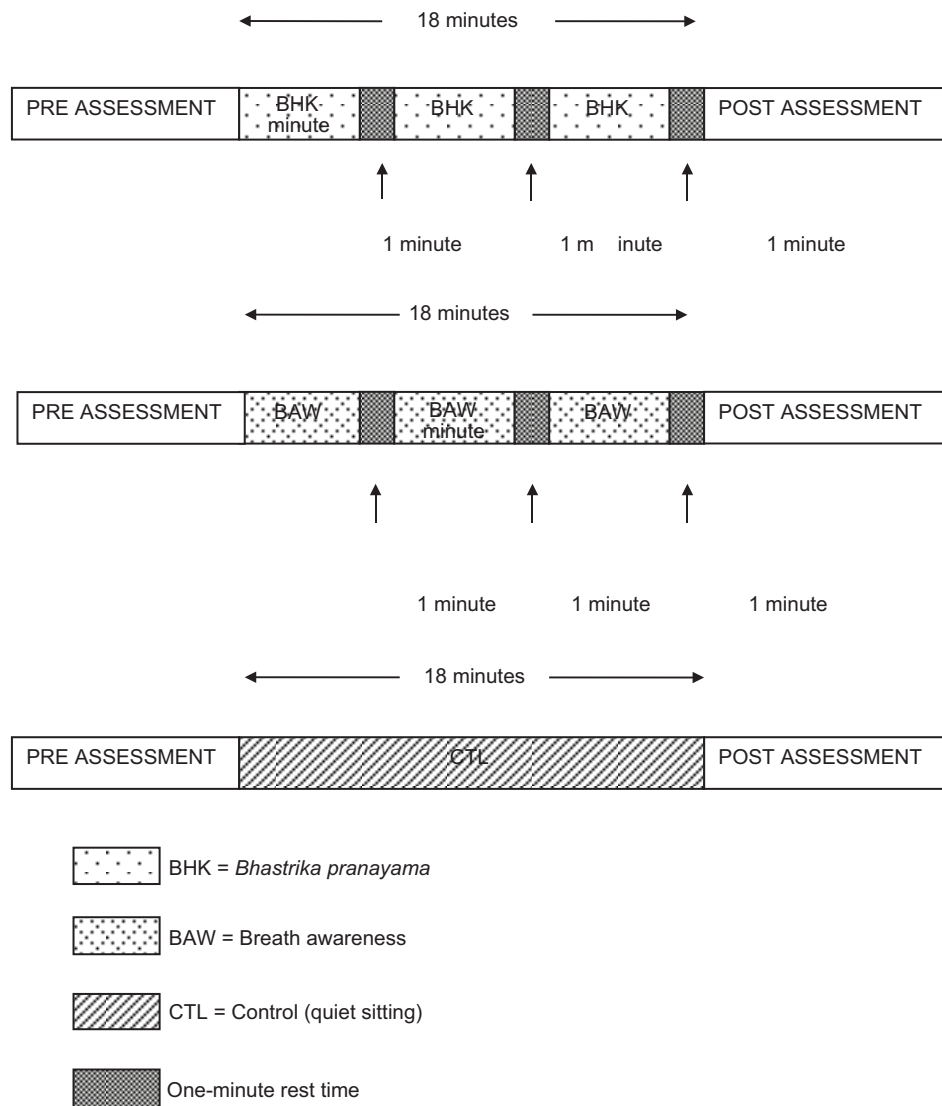


Figure 1: Schematic representation of the three sessions (BHK, BAW, and CTL)

front of them. They were told to use their right (dominant) hand and extend their right index finger about 2 cm above the response key (the button to be pressed when “GO” stimulus was displayed). The participants had to wait for a light signal located 8 inches above the response key. When the signal was amber, this was a warning sign or cue that a stimulus would be displayed. The cue delay was set at 2.5 s, i.e. after 2.5 s of the warning stimulus, the actual stimulus would be seen. If this was a red light (“GO” stimulus), participants had to press the response key with their right index finger as quickly as possible whereas if the stimulus was green, (“NO-GO” stimulus) participants had to remain in position without moving their index finger. A correct response could be as follows: (i) responding to the red light “GO” stimulus or (ii) not responding to the green light “NO-GO” stimulus. The response time (RT) would be displayed up to three decimal places after responding to “GO” stimulus in the display panel. Incorrect

responses could be as follows: (i) not responding to “GO” stimulus or (ii) responding to “NO-GO” stimulus or (iii) early or anticipatory response (a response made during the cue delay). The RT was recorded in 10 trials before the “Pre” epoch and at the end of the “Post” epoch of each intervention.

### Interventions

#### Yoga bellows-type breathing (*bhastrika pranayama*)

During this *pranayama*, the participant was seated with eyes closed and spine erect in *ardha padmasana* (the half lotus pose). The participants inhaled deeply and fully so that breathing was diaphragmatic while also expanding the chest during inhalation. Exhalation was also complete with a full out-breath. Inhalation and exhalation were through the nose.<sup>[12]</sup> The breath rate was kept at  $12 \pm 2$  breaths per min throughout the practice.

### Breath awareness

The participants would be seated with their eyes closed and spine erect in *ardha padmasana* (the half lotus pose). They would be asked to be aware of the movement of air through the nasal passages. The participants were instructed to bring their attention back to their breath if it wandered.

### Control (Seated quietly)

During the control epoch, the participants were asked to adopt the same posture (spine erect, eyes closed) and sit in *ardha padmasana* (the half lotus pose). Participants were not given specific instructions about how to direct their thoughts.

### Data extraction

The RT, the number of correct and incorrect responses, and the number of anticipatory responses were directly obtained from the display panel of the PsymCon interface unit.

### Data analysis

Separate repeated measures ANOVA were performed for (i) the RT (RT in sec.), (ii) number of correct responses to “GO” stimulus, (iii) number of correct responses to “NO-GO” stimulus, and (iv) number of anticipatory responses. For each ANOVA, there were two within-subjects factors. These were (i) sessions (BHK, BAW, or CTL) and (ii) states (Pre and Post). The interaction between sessions and states was also assessed. *Post hoc* analysis was carried using tests for multiple comparisons which were Bonferroni adjusted. The comparisons were between the “post” and “pre” data of a session as well as between “pre” data across sessions and “post” data across sessions.

### Results

The time taken to respond to a red light (“GO” or correct response) was significant reduction after BAW ( $P < 0.05$ ) and CTL ( $P < 0.05$ ). The group mean values,  $P$  values, and Cohen’s  $d$  for the following: (i) time taken to respond to “GO” stimulus (ii) number of correct response to “GO” stimulus (iii) number of correct response to “NO-GO” stimulus, and (iv) number of anticipatory responses are given in Table 2.

The details of the repeated measures analyses of variance are presented in Table 3.

### Discussion

A total of 25 healthy female volunteers showed a significant reduction in RT after a breath awareness session and after a session of quiet sitting. Contrary to the hypothesis, there was no change in RT after yoga bellows-type breathing, called *bhastrika pranayama*.

In previous studies, male volunteers<sup>[7]</sup> and a group of male and female volunteers<sup>[3]</sup> volunteers showed a decrease in RT as an acute response to *bhastrika pranayama*. The

reason why the present volunteers did not show a similar response appears to be related to gender differences in the effects of yoga breathing, as well as gender differences in the response to a stimulus. The reason for considering gender differences as the most likely factor to explain the differences in results is that in the present study most of the other experimental details were comparable to an earlier reported study conducted on male volunteers.<sup>[7]</sup>

A possible explanation may be found based on understanding how *bhastrika pranayama* may have reduced RT in earlier studies.<sup>[4]</sup> Deflation which occurs during the exhalation phase of *bhastrika pranayama*<sup>[2]</sup> may play a role in this. The link between lung deflation and attention follows. Attention is closely related to activation of the neurons within the brainstem reticular activating system (RAS).<sup>[12]</sup> Experimental lung deflation in dogs activated 47% of neurons studied using long-lasting extracellular recordings from the medial parts of the reticular formation.<sup>[13]</sup> Hence, active deflation of the lungs during *bhastrika pranayama* could be expected to excite neurons within the brainstem RAS. Stimulation of the RAS activates the respiratory system, which would possibly facilitate the practice; stimulation of the RAS also activates structures at higher levels of the neuraxis, including the thalamus and cortex; this could increase response to a stimulus. The cortical regions mentioned were especially the anterior cingulate and the orbital frontal cortex.<sup>[14]</sup> This activation of the RAS by efferents from the deflated lung could explain why active exhalation in yoga breathing is associated with better performance in attention tasks such the event-related P300<sup>[15]</sup> and in cancellation tasks.<sup>[16]</sup> The same principle may apply to *bhastrika pranayama*, with activation of the RAS during exhalation, hence, resulting in a better response to a stimulus in the RT task.

This speculation is supported by an early study which reported slower RT during inspiration.<sup>[17]</sup> The reduction in RT was attributed to inhibition brought by the vagus and the nucleus of the *tractus solitarius*. An opposite finding was reported by Beh and Nix-James (1974).<sup>[18]</sup> Here, RT was shorter during inhalation, attributed to increased tension in the diaphragmatic, and thoracic muscles. Hence, the level of respiratory muscle tension could influence the response to the RT task. RT is known to be optimal with an intermediate level of respiratory and skeletal muscle tension and deteriorates when the levels are too low or too high.<sup>[19]</sup>

In almost every age group, males have faster RTs than females.<sup>[20]</sup> Botwinick and Thomson (1966) found that the difference between males and females was accounted for by the time lag between the presentation of a stimulus and beginning of a muscle contraction, which was slower in females.<sup>[21]</sup>

The female participants in the present study showed a reduction in RT after breath awareness and after quiet sitting sessions, but not after *bhastrika pranayama*. If

**Table 2: Variables of reaction time test pre- and post-Bhastrika pranayama, breath awareness, and control (quiet sitting) sessions**

Assessments	BHK											
	Time taken to respond to "GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of anticipatory responses	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean±SD	0.46±0.16	0.43±0.14	4.92±1.91	4.76±1.27	5.12±1.56	4.68±1.87	0.00±0.00	0.08±0.40	0.38	0.33	0.00±0.00	0.08±0.40
<i>P</i>	0.26		0.69		0.38		0.33		0.38		0.00±0.00	0.08±0.40
Cohen's d	0.20		0.10		0.26		-		0.26		-	-
	BAW											
Assessments	Time taken to respond to "GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of anticipatory responses	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	Mean±SD	0.45±0.13	0.41±0.12	5.40±1.96	5.32±1.60	4.32±2.12	4.44±1.42	0.04±0.20	0.08±0.28	0.81	0.33	0.04±0.20
<i>P</i>	0.03*		0.88		0.81		0.33		0.81		0.04±0.20	0.08±0.28
Cohen's d	0.02		0.45		0.07		0.16		0.07		0.04±0.20	0.08±0.28
	CTL											
Assessments	Time taken to respond to "GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of correct responses to "GO" stimulus		Number of correct responses to "NO-GO" stimulus		Number of anticipatory responses	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	Mean±SD	0.47±0.20	0.41±0.14	5.08±1.35	5.36±2.0	4.72±1.90	4.72±1.70	0.04±0.20	0.16±0.47	1.00	0.27	0.04±0.20
<i>P</i>	0.02*		0.58		1.00		0.27		1.00		0.04±0.20	0.16±0.47
Cohen's d	0.31		0.16		0.00		0.33		0.00		0.04±0.20	0.16±0.47

\*Represents the level of significance as  $P < 0.05$ . RM ANOVA, *post hoc* tests with Bonferroni adjustment; postvalues were compared with the prevalues for three sessions, i.e., BHK, BAW, and CTL. BHK=Bhastrika pranayama, BAW=Breath awareness, CTL=Control (quiet sitting), SD=Standard deviation, RM ANOVA=Repeated-measures analyses of variance

**Table 3: Details of the four repeated measures analyzes of variance**

Variables	Sources	df	MS	F	Partial $\eta^2$
Time taken to respond to “GO” stimulus	Sessions	1.42, 34.18	0.01	0.23	0.01
	States	1, 24	0.07	11.47	0.32
	Sessions $\times$ states	1.97, 47.18	0.00	0.29	0.01
Number of correct responses to “GO” stimulus	Sessions	1.97, 47.20	3.68	1.29	0.05
	States	1, 24	0.01	0.00	0.00
	Sessions $\times$ states	2, 48	0.69	0.27	0.01
Number of correct responses to “NO-GO” stimulus	Sessions	1.81, 43.49	3.85	1.01	0.40
	States	1, 24	0.43	0.14	0.01
	Sessions $\times$ states	2, 48	1.09	0.45	0.02
Number of anticipatory responses	Sessions	2, 48	0.05	0.43	0.02
	States	1, 24	0.24	3.27	0.12
	Sessions $\times$ states	1.79, 42.97	0.02	0.24	0.01

the reduced RT found in earlier studies after *bhastrika pranayama* may be related to active deflation of the lung, it is important to note that there *are* gender differences in airway behavior throughout the human lifespan.<sup>[22]</sup> Hence, the female participants appeared to have more attentional resources active and available after breath awareness and quiet sitting sessions.

It is possible that the level of respiratory muscle tension required for forced exhalation was higher in females, during *bhastrika pranayama*. In contrast, it is possible that without any respiratory exercise, the participants were more relaxed and hence better able to respond to the RT task. There is no direct evidence to support this. Gender differences in the auditory startle reaction support a gender difference with the greater arousal and muscle tension in females compared to males in response to a sound stimulus.<sup>[23]</sup> Females also show a heightened response to stress.<sup>[24]</sup> Hence, conversely, in the absence of a respiratory task (*bhastrika pranayama*), considered to be stimulating, the female participants may have achieved an optimal level of arousal following breath awareness or quiet sitting. This speculation could be tested by having a population of both male and female participants performs the RT task after *bhastrika pranayama*, breath awareness, and quiet sitting, while simultaneously assessing the tension in the intercostal muscles through an electromyography recording.

The present study is limited by the fact that the level of stress or relaxation was not assessed after the sessions. Hence, it is a mere speculation that the female participants found *bhastrika pranayama* more exertional than breath awareness or quiet sitting. Despite these limitations, the present study unlike several previous studies<sup>[3,4,7]</sup> showed that no decrease in RT after *bhastrika pranayama*. The results suggest that different interventions may optimize performance in tasks requiring attention in females compared to males.

## Conclusion

The results suggest that different interventions may optimize performance in tasks requiring attention in females compared to males.

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## Conflicts of interest

There are no conflicts of interest.

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