Respiratory Physiology & Neurobiology 233 (2016) 41–51

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

# The effect of consistent practice of yogic breathing exercises on the human cardiorespiratory system

Joshua A.A. McKay[a], Cara L. McCulloch[a,*], Jordan S. Querido[a], Glen E. Foster[a,b], Michael S. Koehle[a,c], A.William Sheel[a]

[a] School of Kinesiology, University of British Columbia, Vancouver, BC, Canada
[b] Centre for Heart, Lung, and Vascular Health, School of Health and Exercise Sciences, University of British Columbia, Kelowna, BC, Canada
[c] Division of Sports Medicine, University of British Columbia, Vancouver, BC, Canada

ARTICLE INFO

*Article history:*
Received 19 November 2015
Received in revised form 9 July 2016
Accepted 20 July 2016
Available online 21 July 2016

*Keywords:*
Blood pressure
Chemosensitivity
Hypercapnia
Hypoxia

ABSTRACT

The purpose of this investigation was to quantify the cardiovascular, respiratory, and cerebrovascular effects of two common yogic breathing exercises (YBE): *bhastrika* and *chaturbhuj*; and to determine the effect of their consistent practice on chemosensitivity. The first study was cross-sectional and compared experienced yogic breathers (YB) with matched controls; whereas the second was a 10-week longitudinal training study. The results support four major findings. First *chaturbhuj* resulted in a hypoxic stimulus in experienced YB compared to control [end-tidal oxygen tension ($P_{ET}O_2$), YB: 77.5 ± 5.7 mmHg, $P$ < 0.05; control: 94.3 ± 12.0 mmHg]. Second, performance of *chaturbhuj* resulted in cyclic oscillations of mean arterial pressure (MAP), heart rate (HR), and middle cerebral artery velocity (MCAv) consistent with the phases of respiration. Third, post training, performance of *bhastrika* reduced $P_{ET}O_2$ (end breath-hold: 90.8 8 ± 12.1 mmHg) compared to rest (100.1 ± 7.4, $P$ < 0.05); it also resulted in significantly increased MAP at end breath-hold (96.7 ± 13.0 mmHg) compared to rest (83.0 ± 6.6 mmHg, $P$ < 0.05) and significantly increased mean MCAv (end breath-hold: 87.4 ± 23.0 cm/s, $P$ < 0.05; rest: 55.8 ± 26.3 cm/s). Fourth, experienced YB had lower central chemosensitivity than controls (YB: 3.4 ± 0.4; control: 4.6 ± 1.2 L/min/mmHg; $P$ < 0.05). In conclusion, YBE significantly alter end-tidal gases, resulting in complex oscillations of cardiovascular and cerebrovascular variables, and if practiced consistently, may reduce chemosensitivity.


## 1. Introduction

The cessation of breathing, or apnea, for long periods of time can lead to hypoxia and hypercapnia with corresponding increases in peripheral resistance and mean arterial pressure (MAP) and reductions in heart rate (HR) and stroke volume (SV) and subsequent cardiac output (CO) (Hoffmann, 2005; Lin et al., 1983a, 1983b; Craig and Medd, 1968; Song et al., 1969). In order to maintain cerebral oxygen delivery during hypoxia, there is an increase in cerebral blood flow velocity (CBFV); this increase in CBFV is also seen in response to hypercapnia in order to maintain homeostatic tissue pH (Ivancev et al., 2007). An increase in CBFV results in increased oxygen delivery and consequently extends the amount of time before hypoxic damage occurs (Foster and Sheel, 2005). However, in some pathological conditions, such as obstructive sleep apnea (OSA), this response is blunted (Foster et al., 2009).

In OSA there are cyclical cessations in airflow (i.e. recurrent nocturnal asphyxia) which lead to repetitive arterial hypoxia and hypercapnia. It is now recognized that OSA is a relatively common condition with population estimates at 10–17% for men and 3–9% for women aged 30–70 years (Freet et al., 2013; Punjabi, 2008). When untreated, OSA is associated with adverse cardiovascular and cerebrovascular effects such as oxidative stress, inflammation, atherosclerosis and endothelial dysfunction (Foster et al., 2007). Characteristic of OSA are the recurrent bouts of intermittent hypoxia (IH), which are linked to hypoxic sensitization of central chemoreceptors and increased sympathetic vasoconstrictor activity (Guyenet, 2014; Gilmartin et al., 2010). There is, however, evidence to suggest that the chronicity of apneic states influences the degree of ventilatory response; hypoxic chemosensitivity is thought to be enhanced in early stages of recurrent apnea exposure yet decreased following years of chronic exposure (Prabhakar and Kline, 2002). While exposure to IH is generally associated with pathophysiological states such as OSA, there are some otherwise healthy humans, such as breath hold divers, synchronized

* Corresponding author.
*E-mail address:* cara.mcculloch@alumni.ubc.ca (C.L. McCulloch).

http://dx.doi.org/10.1016/j.resp.2016.07.005
1569-9048/

swimmers, and those who practice certain types of yogic breathing maneuvers, who volitionally subject themselves to episodes of IH.

Yoga has been practiced for centuries (Iyengar, 1966), with recent growth in popularity in Western societies as an intervention to improve both mental and physical well-being (Cramer et al., 2014; Khalsa, 2004). Despite prevalent use as a method to treat psychiatric conditions (Li and Goldsmith, 2012), cardiovascular disorders (Cramer et al., 2015; Paprika et al., 2014; Shannahoff-Khalsa et al., 2004) and respiratory disorders (Liu et al., 2014; Prem et al., 2013; Santana et al., 2013), it's use has resulted in varying degrees of success (Khalsa, 2004). As practitioners of yogic breathing often perform sustained bouts of voluntary hypoventilation and prolonged breath-holds, it is possible that the cardiovascular response to such breathing exercises is comparable to that seen in other models of IH. For example, previous research on yogic breathing exercises (YBE) has shown that their practice can decrease the ventilatory response to hypoxia and hypercapnia through the practice slow breathing (Spicuzza et al., 2000); this suggests there is a dose-response relationship between the total amount of YBE practiced and ventilatory sensitivity to hypoxia and hypercapnia. Nevertheless, a well-controlled longitudinal YBE training study is needed to help clarify the influence YBE have on hypoxic and hypercapnic chemosenstivities. Furthermore, the effect YBE may have on cerebrovascular reactivity to hypoxia and hypercapnia has not yet been investigated. The physiological changes that occur during specific YBE need to be measured in order to determine if their consistent practiceis associated with measurable changes in cardiorespiratory function. Therefore, the purpose of this investigation was three-fold. First, to assess the changes in cardiovascular, cerebrovascular, and respiratory variables during the practice of two YBE, *bhastrika* and *chaturbhuj* (see below); second, to determine if long-term practice of YBE affects hypercapnic ventilatory threshold and sensitivity; and third, to determine if regular practice of YBE for 6 weeks is a sufficient stimulus to decrease hypercapnic ventilatory sensitivity and increase hypercapnic ventilatory threshold.

For the purposes of this investigation two common YBE practiced by intermediate yogis, *bhastrika* and *chaturbhuj*, were chosen. *Bhastrika*, consists of 1–2 min of abdominally driven hyperventilation through the nose, followed by an inspiration to total lung capacity and maximal breath-hold. *Chaturbhuj*, on the other hand, is a hypoventilation-breathing pattern through the nose in which the breath is timed and divided into four equal parts: inspiration, breath-hold, expiration, breath-hold (i.e. 1:1:1:1 ratio) at the lowest comfortable rate as determined by the breather. Experienced yoga practitioners can often tolerate a very low frequency of breathing (0.75–1 breaths per minute) compared to those who are not practiced in this method (2–4 breaths per minute) (Saraswati, 2008). As *chaturbhuj* involves low frequency breathing and *bhastrika* involves a prolonged breath-hold, it is likely that these stimuli reduce end-tidal oxygen tension ($P_{ET}O_2$) and increase end-tidal carbon dioxide ($P_{ET}CO_2$), resulting in a combined hypoxic and hypercapnic stimulus. Therefore, based on the aforementioned exercises, our hypothesis was three-fold: first, subjects experienced in YBE would have decreased hypercapnic ventilatory sensitivity and increased hypercapnic ventilatory threshold when compared to controls; second, a 6-week intervention consisting of YBE five times per week would result in decreased hypercapnic ventilatory sensitivity, increased hypercapnic ventilatory

**Study Design**

| Study 1 (Observational) | | Study 2 (Longitudinal) | | | |
|---|---|---|---|---|---|
| **Yogic breathers** | **Control** | **Week** | **Description** | **Experimental** | **Control** |
| A-F | A-F | **1** | Familiarization | C | C |
| | | **2** | Baseline testing | C, D, G | C, D, G |
| | | **3-4** | Introductory YBE training | ✓ | N/a |
| | | **5** | Baseline testing #2 | A-G | C, D, G |
| | | **6-9** | Intermediate YBE training | ✓ | N/a |
| | | **10** | Post intervention testing | A-G | C, D, G |

A. *Chaturbhuj*
B. *Bhastrika*
C. Hypoxic Duffin rebreathe test
D. Hyperoxic Duffin rebreathe test
E. Cardiorespiratory measures
F. Cerebrovascular measures
G. Breath-hold time

**Fig. 1.** Visual representation of experimental design of studies 1 and 2. Letters indicate which variables were measured for each group during each week. Checkmarks indicate attendance to the YBE training sessions.