

## Perspectives on Breathing in Sports and Health

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### Introduction

Breathing is taken for granted, seldom a conscious effort until one is “out of breath.” Breath can be held, tight, rapid and shallow, or deep and slow. There are anecdotal examples of activities that breathing interventions can support sports performance and have functional implications. Some competitors sleep with a weight on their chest to strengthen breathing muscles and increase their capacity to force air in to the lungs. For breathing enhancement, some individuals use straw breathing to restrict airflow to stimulate the impulse to inhale. Research has been done on pulmonary function and physical performance, where it may be presumed that participants have highly functional responses. Remarkably, it was noted in 1986 that a healthy pulmonary system may be a limiting factor; affecting oxygen levels plus CO<sub>2</sub> transport and elimination during high level physical exertion in well trained athletes [1]. A number of untested speculations were identified with the admonition that a bit more data would be useful.

Although there has been some research to identify pulmonary limitations in physical performance, the research has focused especially on certain cardiopulmonary ceilings or interventions attempting to enhance respiratory muscle function. The three identified areas of pulmonary limitations in physical activity are: flow limitation which includes exercise induced asthma (EIA), exercise induced arterial hypoxemia (EIAH), and fatigue of the respiratory muscles [2-5]. Interventions for enhancing pulmonary function during exercise have centered to a great degree on respiratory muscle training [5-11], and more recently on high intensity training [12,13].

Additionally, health related benefits for breathing interventions have been reported for various diseases [14-21], ubiquitously chronic obstructive pulmonary disease (COPD) [22-24]. Breathing training has been used as an adjunct therapy for some pain conditions [25-29], including childbirth labor [30,31]. The mechanisms may be direct, as an increase in pulmonary function, or elicited processes, such as neuroendocrine adjustments associated with the respiratory improvements, for efficacy in specific health disorders. Commonly available literature reviews emphasized that there is a paucity of studies which leads to insufficient evidence about intervention strategies and putative outcomes.

This commentary details some effects related to breathing facets in physical performance and health-related applications. A summary with inferences is presented and where the current evidence might lead forthcoming research.

### Breathing: Physical Performance

Physical performance is limited primarily by the muscular, cardiovascular, and respiratory systems. In healthy individuals, the systems limiting performance follow a hierarchical order from sedentary subjects being restricted by muscle function; then, generally fit individuals having cardiovascular constraints on physical efforts, with elite athletes many times reaching the ceiling effect because of pulmonary restrictions. Environmental factors may also contribute to exercise limitations, especially altitude [32,33]. However, generally reported effects of pulmonary limitations on effort are observed in healthy, high level competitors in standard environmental conditions [1-5].

Noting that the pulmonary system may be a limiting factor to high level physical performance, attention has been directed to respiratory muscle training, with emphasis on inspiratory muscle training. Sports that have competitors with large lung volumes such as cycling and rowing have been the prime attention of interventions. Inspiratory muscle training (IMT) improves cycling time-trial performance [34]. The study researchers attributed the improvement to anaerobic work capacity but not critical power. The determination of anaerobic work capacity does include an aerobic component which may have responded to the IMT. Evidence also shows that performance enhancements observed in cyclists after IMT are accompanied by a decrease in inspiratory muscle fatigue [10]. Other researchers have credited the apparent increase in respiratory function in athletes to a difference in the breathing pattern adopted rather than respiratory muscle strength or efficiency differences from intervention [35].

More recent research efforts have shown that IMT can reduce the magnitude of the VO<sub>2</sub> slow component, associated with an enhanced exercise tolerance [6,7]. The mechanisms that may elicit the outcome were postulated as reduced muscle fatigue either by improving muscle oxidative capacity or by enhancing muscle O<sub>2</sub> delivery or local matching of blood and tissue oxygen [6]. Four weeks of IMT at a load of 30 breaths twice daily at 50% of maximum inspiratory pressure (MIP) reduced inspiratory muscle fatigue and diminished the VO<sub>2</sub> slow-component amplitude in maximal cycling exercise. These factors resulted in an improved exercise tolerance. It was acknowledged that fatigue of the respiratory muscles during intense exercise might compromise leg blood flow, and this area requires further study. Future intervention enhancement to maximize IMT impact on the VO<sub>2</sub> slow component might prove valuable in sports performance and possibly greater exercise tolerance in elderly or patient populations.

Although various IMT workloads have been effective for measured outcomes, higher intensity workloads tend to show better results. Studies have shown that workloads at 80% MIP results increases in lung volumes, work capacity, power output, and decreases in exercising heart rate and perceived exertion [9,5]. Inspiratory muscle training intensities which are lower than 40% of maximal workload generally do not translate into quantitative functional outcomes in healthy subjects.

### Breathing: Health Related Applications

Breathing interventions have been applied in health care settings. The body of research on breathing effects, however, is in its nascence and interventions vary. IMT is used [15-24], as in sports performance studies, as well as other methodologies. Measured outcomes are in areas from clinical assessments such as pain [25-31] to more objective

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processes, with examples being autonomic nervous system influences and blood pressure responses [15,17,35-37].

There is a long history of pranayama breathing, without extensive supporting research literature on positive effects. Pranayamic breathing is associated with decreased oxygen consumption, heart rate, and blood pressure, with increased EEG theta wave amplitude and parasympathetic activity [38]. It is proposed that such voluntary slow deep breathing functionally resets the autonomic nervous system through stretch-induced inhibitory signals and hyperpolarization currents. Stretching of lung tissue produces inhibitory signals of slowly adapting stretch receptors and fibroblastic hyperpolarization currents. Immediate effects were reported after five minutes of pranayama exercise [39]. Diastolic pressure and mean pressure were significantly reduced. Researchers intimated that changes were elicited by parasympathetic influence on cardiovascular system.

More recently, abdominal-breathing or diaphragmatic-breathing methods have increased in acceptance. The efficacy of slow, abdominal breathing has been demonstrated in reducing blood pressure (BP) in hypertensive [35] and pre-hypertensive patients [36]. Slow breathing for three months decreased BP response in hand grip and cold pressure tests [35]. Longitudinally, slow abdominal breathing lowered systolic blood pressure 8.4 mmHg and diastolic blood pressure 3.9 mmHg in subjects with pre-hypertension, both significant effects [36]. Also, the electrocardiographic R-R interval increased significantly. Both studies showed that BP improvements may be related to autonomic nervous system effects, with reduced sympathetic activity and enhanced vagal influence. In other patient populations such as those with diabetes, the blunted baroreflex sensitivity typical in patients with diabetes was restored to the level of control subjects with slow breathing intervention [40]. These studies demonstrate that slow breathing may be efficacious treatment to assist in BP control, with putative mechanisms related to autonomic function.

Slow, deep breathing is also an ancillary application to ameliorate pain. When heat pain was induced, thermal pain threshold and pain tolerance were significantly higher during slow deep breathing, with increased amplitude of vagal cardiac markers [26]. The researchers proposed that possible cardiorespiratory processes are responsible for mediating breathing-induced analgesia. Measuring mean skin conductance levels which represent a proxy for sympathetic activity, deep and slow breathing significantly decreased sympathetic arousal and pain perception [25]. This report also supports breathing for analgesia. Breathing is effective in reducing the pain and distress associated with childhood immunizations [27] and labor during childbirth, especially in latent labor before delivery [31].

Other conditions, asthma [15], stroke [16], cystic fibrosis [17], have limited research support but there are indications that breathing may be a beneficial adjunct therapy. COPD has the most substantial support for breathing interventions [22-24]. When IMT is used, workloads are in the range of 30% to 80% MIP, depending on the patient population. The literature is fairly extensive on COPD and oxidative stress. Strategies to decrease oxidant burden in COPD has identified various antioxidant modulators and anti-inflammatory adjuncts [41]. Exercised breathing can attenuate increases in inflammatory markers such as IL-6 and TBARS, effectively influencing the cytokine response [42].

Across the literature, there are examples of breathing intervention efficacy in treatment of assorted health complications. The mechanisms by which breathing therapy ameliorates respiratory difficulties, improves disease conditions, and related pain have not been fully identified, but there appears to be a strong case for neuroendocrine adjustments.

## Data and Deductions

The literature reports show that breathing, whether it is part of the exercise response or as directed exercise training modality, not only influences the pulmonary system, but has sundry effects on other functions, in particular, neuroendocrine responses. Specifically, enhanced breathing function is associated with improved sympathovagal tone, antioxidant effects, and putative, augmented anti-inflammatory utility.

Breathing is generally regarded as an unconscious function and so basic to sustaining life that respiratory enhancements have not been adequately explored to the extent of identifying not only the pulmonary effects but uncovering other systemic influences, as well. Conceivably, more consciousness about breathing and function is warranted. Thich Nhat Hahn, a Buddhist monk and author, writes "Breathing in, I know I am breathing in; breathing out, I know that I am breathing out" denoting that breathing may be better appreciated if noticed and studied in more detail.

Future research should be directed towards the development of training effects that notably affect sports performance and the course of diseases. Although there is support for neuroendocrine effects, antioxidant enhancements, and anti-inflammatory augmentation, the mechanisms that contribute to the effects should be more clearly elucidated. Is a health benefit of exercise that it induces deep breathing? As expressed by Dempsey, a bit more data would be useful [1].

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