A review of Inspiratory muscle training. When and why does it work?

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Respiratory Muscle Fatigue, the problem?

The need to provide a training stimulus to the respiratory muscles was not considered until the late 1980’s when Professor Jerome Dempsey provided the first insight into how the physiological basis of an elite athlete may predispose their respiratory systems as a limiting factor for performance (Dempsey, 1986). This occurs as the targeted and specific adaptation that occurs within training enables physiological capabilities to be improved, however within training programmes the attention given to the respiratory system is negligible/non-existent. As a result this presents the respiratory system as a potential limitation to whole body exercise performance. The phenomena of respiratory muscle fatigue has been extensively researched by groups across the world in an attempt to understand the consequences of respiratory muscle fatigue in relation to performance. Briefly, there are a number of contributing factors which are important in the development of respiratory muscle fatigue which includes repeated, high force outputs from the diaphragm and accessory respiratory muscles during high intensity exercise tasks. The consequences of respiratory muscle fatigue has negative implications for performance on whole body exercise tasks and the onset of such fatigue prompts a series of cardiorespiratory reflexes (Dempsey et al, 2014). This process is triggered by alterations in both systemic neural and chemical stimuli which modifies the global physiological responses seeking to sustain sufficient respiratory function and locomotor function. The key mechanisms here are concerned with important changes in both cardiorespiratory and perceptual responses, identified as important factors in the early termination of exercise tasks.

Inspiratory Muscle Training, the solution?

The knowledge and understanding surrounding respiratory muscle fatigue and limitations to performance has stimulated a second body of literature that looked at strategies to overcome reductions in exercise performance. The method of training the breathing muscles has been around for over 50 years but it was not until the early 2000’s that this method of training gained any sort of traction and popularity, even now almost 20 years later this technique continues to develop an extensive evidence base that demonstrates its widespread uses within elite sport and clinical populations. Respiratory muscle training is concerned with creating a resistance to breathe and the use of progressive overloads which results in numerous beneficial adaptations and importantly results in increased exercise performance. Importantly, the use of respiratory muscle training techniques and specifically those that target the inspiratory muscles has been shown to provide an ergogenic effect to whole body performance within a host of population’s including those with; reoccurring lower back pain, wheelchair users, respiratory health conditions and the elderly (Gosselink, Kovacs, Ketelaer, Carton, & Decramer, 2000; Janssens et al., 2015; Ramirez-Sarmiento et al., 2002). Specific studies have also looked to improve exercise performance in sporting scenarios, cycling and rowing have received considerable attention from research. These sports are interesting as they pose an additional task to ventilation. These activities pose restrictions to normal breathing mechanics whilst completing sport specific actions (Bousana et al., 2003), and require increased recruitment of both obligatory and accessory muscles of inspiration due to the dual role the respiratory musculature in providing ventilation and stabilisation of the trunk (HajGhanbari et al., 2013). This combined with increased lumbar and thoracic flexion which reduces end-expiratory lung volumes and increasing diaphragmatic pressure and the work of breathing (Bousana et al., 2003). Volianitis et al., (2001) first examined the effects of six weeks inspiratory muscle training upon 6 min all out rowing performance and in a separate 5-kilometre rowing time trial performance.

To summarise the available research that has investigated the effects of inspiratory muscle training on whole-body exercise performance produce difficult interpretation of results, as they are confounded by the use of many different performance tests, differing modes of training, inappropriate sample sizes and a lack of appropriate controls. The use of well controlled placebo-
controlled methodologies have demonstrated significant improvements in both cycling, rowing and running time-trial exercise performance as well as intermittent exercise performance. Collectively the findings here illustrate an ergogenic effect of IMT on whole body performance but question the use of EMT to further improve performance. Inspiratory muscle training appears to provide an improvement in time-trial type exercise from 2 to 6% (for a full review see HajGhanbari et al., 2013; Illi et al., 2012). Romer et al., (2002) suggest that as the improvements in performance observed within literature exceed about half of the natural variance in human performance, the inspiratory muscle training mediated improvements in exercise performance present a meaningful ergogenic effect which most importantly improves athletic performance.

The mechanism by which inspiratory muscle training improves physical performance remains largely unclear. It is understood however that the adaptations are not localised to the cardiovascular system with no change in arterial blood gases; for example Inspiratory muscle training sessions pose only a moderate cardiovascular demand (Romer et al., 2002b). There is evidence to suggest the structural adaptations that occur specifically within the muscles and the neural interactions between the central and peripheral nervous systems are also altered. The key adaptations that have been observed within literature to date suggest that Inspiratory muscle training seeks to increase respiratory muscle strength and subsequently attenuate the onset of respiratory muscle fatigue, sustain locomotor muscle blood flow, via through blunted sensory motor input which attenuates feelings of exertion and discomfort, promote a change in breathing mechanics and favourable reductions in perceived exertion.

Inspiratory Muscle Training will not provide a uniform response..

The evidence base demonstrating the benefits to exercise performance is extensive and the mechanistic detailing is emerging and shows similarities to the changes observed within strength and conditioning literature. This is largely because of the similarities between the respiratory muscles and other skeletal muscles which is demonstrated in more recent observations following Inspiratory muscle training interventions. One consideration that has been highlighted within literature is the baseline respiratory muscle strength, this has gained increased attention as changes in inspiratory muscle pressure may reflect morphological adaptation of these muscles (Downey et al., 2007) and/or changes in inspiratory muscle recruitment patterns and respiratory muscle strength is frequently reported as an outcome measure that is used to quantify the efficacy inspiratory muscle training interventions. Interestingly, the between-participant improvements in inspiratory muscle pressure following training is highly variable (ranging from ~10% up to ~55%; Brown et al., 2012). Initially it was suggested that the baseline (i.e., resting and untrained) inspiratory muscle training may explain, in part, the variability in the relative increase in respiratory muscle strength following training as the window for physiological adaptation is reduced in participant’s with greater baseline strength, a principle well established within whole body resistance training (Kraemer et al., 1996). This is a notion that has gained increased support from studies demonstrating a negative relationship between the baseline and changes in inspiratory muscle pressure following a training intervention in healthy and clinical populations (Brown et al., 2008; Winkler et al., 2000). Therefore, understanding this relationship may be important when designing inspiratory muscle training interventions in order to maximise confidence in the outcomes of the intervention. Brown et al, (2014) demonstrate that baseline inspiratory muscle pressure is an important, though not the only, determinant of an inspiratory muscle training mediated increase in inspiratory pressure. Therefore, great care must be taken in standardising inspiratory muscle pressures and additional consideration must be taken when recruiting participants for training interventions.

Functional Inspiratory Muscle Training..

The use of functional inspiratory muscle training techniques has been proposed by Tong et al., (2014). This technique targets the closely integrated relationship between the muscles which comprise the abdominal complex and the muscles of inspiration. During exercise this group is tasked with assisting with ventilation and also, torso and lumbo-pelvic stiffness to increase stability and optimise the kinetic chain of upper and lower extremities. However, following high-intensity running, reductions in core muscle function suggests the presence of fatigue in this group (Tong, Wu, Nie, et al., 2014). Targeting both inspiratory/core muscle function in a holistic approach has only been demonstrated twice to date. Tong et al. (2014) demonstrated 4% increase in performance in recreational runners, where increased core muscle strength was also improved in the training group only. Unpublished from our group also demonstrates that functional inspiratory muscle training elicited a greater improvement in both inspiratory muscle pressure (6%), and performance on 2.4 km time trial whilst wearing an 25 kg
Thoracic load, as well as increase and core muscle strength (18%) relative to pre intervention values, there was no change in a control group. Although the initial findings from these studies provides a positive indication to the uses and application of the functional methods, this area is still in its infancy and requires greater research to investigate the application of the findings to different sports/exercise tasks and to outline which exercises elicit the greatest/most beneficial adaptations. The initial findings are however, positive and the use of such methods may in future studies develop the application of respiratory loading techniques and the impact this has on exercise performance. This could include more sport specific study designs and the use of sport specific exercises to determine the effects this has in differing exercise groups. Strengthening the accessory muscles using traditional strengthening exercises of the accessory muscles to coincide with functional training regimes might also be of interest.

Clinical Application of Inspiratory Muscle Training.

Respiratory muscle weaknesses has been implicated in perception of breathlessness and fatigue, both of which are common symptoms in patients affected by patients living with respiratory conditions. This is important because of the heightened work of breathing that results from the degeneration of the respiratory system, which is often regressive and cannot be cured. This increases the work required by the breathing muscles in order to provide required ventilation and by consequence increases the chemically and mechanically sensitive nerve endings found with the respiratory muscles which are important in generating the perceptual response. The foundations of inspiratory muscle training interventions are centred on increasing the strength and endurance of the inspiratory breathing muscles. The associated changes following inspiratory muscle training collectively reduce work of breathing which offsets the abnormal chest wall dynamics seen in conditions like chronic obstructive pulmonary disease, asthma and pneumonia. Inspiratory muscle training could also the dyspnoea response at rest and also during daily activities and exercise. The use of these interventions have learnt important lessons from existing literature and could have widespread implications within the clinical domain. Although there are studies that have adopted these interventions, the evidence within a clinical setting is limited but is gaining in popularity with the potential for important and impactful outcomes for patients living with respiratory issues.