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EDITORIAL

Inspiratory Muscle Training: Where are we?

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Inspiratory muscle dysfunction has been shown to be related to hypercapnia and hence, to ventilatory insufficiency in patients with chronic obstructive pulmonary disease (COPD) [1]. Accordingly, treatment of inspiratory muscle dysfunction has gained interest in the last decade. Among other treatment modalities, such as pharmacotherapy and respiratory muscle rest, training of the inspiratory muscles is frequently applied in clinical practice, but its benefits largely remain a matter of debate [2].

Since Leith and Bradley [3] showed increases in strength and endurance after training of inspiratory muscles in healthy subjects, there has been a substantial number of studies addressing the effects of inspiratory muscle training in various disorders, including: neuromuscular diseases, COPD, weaning failure, kyphoscoliosis and thoraco-abdominal surgery. These disorders all have weakness of inspiratory muscles in common and hence, are frequently associated with ventilatory failure at rest or during exercise. Although a large number of studies have been published, only a few of these studies have a randomized-controlled design. The results from other studies should be considered preliminary and interpreted with great caution. In general, most studies show improvements in strength or endurance of the inspiratory muscles [4–11]. The transfer to outcome variables relevant to patients, such as reduced dyspnoea, improved exercise tolerance, better performance of activities of daily living (ADL), reduced postoperative pulmonary complications, or successful weaning from mechanical ventilation, is less obvious.

Two types of training, *i.e.* "normocapnic hyperpnoea" (NCH) and "inspiratory resistive training" (IRT) are practiced at the present time. During NCH the patient is required to achieve a supernormal target ventilation for 15–20 min, while Pa_{CO_2} is kept constant [3]. Conceptually, NCH seems an appropriate technique to train the respiratory muscles since hyperpnoea also occurs during exercise. The equipment for this type of training is complicated and not available for home treatment. Therefore, NCH is difficult to apply on a large scale and consequently it will not be further discussed in the present editorial. During IRT the patient inspires through a mouthpiece with a two-way valve and a resistance in the inspiratory line. This resistance is usually flow-dependent. Appropriate training intensity is only achieved if an adequate target pressure is obtained [7]. A flow-independent resistance was also developed, a "threshold load". In this system a valve is opened when a critical mouth pressure is reached [12]. Strictly, this type of loading requires build up of negative pressure before flow occurs, and hence, is inertive in nature. Whether resistive loading or this inertive loading produces different training effects, remains to be studied.

In patients with tetraplegia, improvements in strength and endurance of inspiratory muscles were suggested in an uncontrolled study [13]. Estrup *et al.* [14] and recently Wanke *et al.* [11] showed improvements in strength and endurance of the inspiratory muscles in patients with progressive muscular dystrophy. Only the latter was a controlled study. Inspiratory muscle training was further studied in two cases of kyphoscoliosis and both improvements in strength and endurance were reported [15].

Inspiratory muscle training was also applied in surgical patients. Gross [16] observed improvements in endurance time and lung function (forced vital capacity and maximum voluntary ventilation) in cardiac patients who had trained their respiratory muscles prior to surgery in comparison with a control group. In addition, the post-surgical duration of mechanical ventilation was significantly less. Training of inspiratory muscles during weaning in ventilator-dependent hypercapnic patients was studied in an uncontrolled design, showing improvements in strength and endurance of the respiratory muscles [17]. It was suggested that these improvements were related to the ability to wean more than half of the patients to spontaneous breathing or nocturnal ventilation.

Most studies deal with respiratory muscle training in the rehabilitation of COPD patients. Specific effects of inspiratory muscle training such as an increase in maximum inspiratory pressure (PImax), were found in five, statistically valid studies in which training intensity was carefully controlled [4–8]. The endurance capacity of the inspiratory muscles improved in a number of studies, also suggesting a specific treatment effect [8, 9, 18].

Despite the improvements in strength of the inspiratory muscles in the above-mentioned studies, improvement in exercise capacity, a transfer effect, was only observed in two statistically valid true experiments, *i.e.* controlled randomized studies [4, 8]. Improvements in exercise capacity with IRT alone were generally smaller than with exercise conditioning and IRT combined [4, 5]. In this issue of the European Respiratory Journal, the study by Wanke *et al.* [19] supports this finding. They observed

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that inspiratory muscle training additional to general exercise conditioning, resulted in a 24% increase in maximal work load on the cycle ergonometer, whereas in the general exercise condition alone group only a 12% increase was found. The study by WANKE *et al.* is well designed, selecting patients with a ventilatory limitation, including a control group, and performing carefully supervised inspiratory muscle training as well as exercise training. A disadvantage of the inspiratory muscle training in this study, however, is the sophisticated equipment, necessary for control and feed-back of the training. Although the combination of inspiratory muscle training and exercise conditioning was studied before, most previous studies lack proper experimental design, control of training intensity or patient selection.

Transfer effects of inspiratory muscle training to ADL and dyspnoea have only scantily been studied. Two statistically valid true experiments [5, 10] showed a decrease of dyspnoea related to ADL in comparison to a placebo group. The study of PATTESIO *et al.* [6] supports this conclusion, but in their study no statistical comparison between training and control group was made. DEKHUIJZEN *et al.* [8] showed that inspiratory muscle training had no additional effects on ADL in comparison to rehabilitation without inspiratory muscle training.

What is the training stimulus required to yield effects on inspiratory muscle strength, endurance and exercise tolerance? Recently, PARDY and ROCHESTER [20] demonstrated, in a literature review, a close relationship between training intensity and percentage improvement in PImax. The data of the present study by WANKE *et al.* [19] fall within this relationship as they found a 40% increase in PImax with high imposed pressures (70% and 100% PImax). On the other hand, lower training intensities (30% PImax) in the study of LISBOA *et al.* [5] resulted in a 34% increase in PImax. Several studies demonstrated that a training intensity of 30% PImax is a minimum to obtain improvements in strength [4, 5, 7].

Endurance time was found to increase during inspiratory resistive training. The magnitude of the increase was 39% (range 15–81%) [4, 5, 7–9, 18, 19]. However, the increase was only statistically significant in the three studies [8, 9, 18]. Recently, significant hypertrophy of type IIa fibres (about 30%) in the diaphragm without significant changes in type IIb fibres (about 6%) was observed after low intensity inspiratory resistive training in rats [21].

The training intensity required to obtain improvements in exercise capacity remains unclear. It appears that in studies in which additional improvement of exercise capacity (6 or 12 min walking distance or cycle ergonometer test) was found, the training intensity was carefully monitored [8, 19] or threshold loading was applied [4, 5]. Surprisingly, improvements in dyspnoea during ADL were obtained without significant increases in inspiratory muscle strength [10].

Although most of the emphasis has been put on the inspiratory muscles, training of expiratory muscles has been studied as well. ESTENNE *et al.* [22] showed significant improvement of the isometric strength of the pectoralis major muscle and expiratory reserve lung volume in quadriplegics. Transfer of these effects to improvements of airway clearance and reductions in bronchopulmonary infects remain to be proven. VERGERET *et al.* [23] found impairment of expiratory muscle function in patients with moderate COPD and significant improvements in strength and exercise capacity after abdominal muscle training with unknown training load. The usefulness of expiratory muscle training in COPD patients, however, remains open to question.

To whom should we prescribe inspiratory muscle training in the present state of knowledge? Available evidence at present is too limited to answer this question definitely for most patient groups discussed before. On the basis of literature data, the following recommendations may be made. The strongest indication appears to be its combination with exercise reconditioning in the rehabilitation of COPD patients with a ventilatory limitation. This is seldom done in practice, but the available data suggest that it should be done more often. The case of hypercapnic respiratory failure, resulting from neuromuscular disease, kyphoscoliosis, COPD, or weaning failure, is weaker, since no randomized studies are available. The question, however, is considerably more important, since if significant improvements were to occur in these patients, it would be likely to improve their survival. Studies addressing this issue are warranted.

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