Comparison of Respiratory Muscle Training Methods in Individuals With Motor Complete Tetraplegia

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Objective: To compare the effects of inspiratory resistance training (IRT) and isocapnic hyperpnea (IH) versus incentive spirometry (placebo) on respiratory function, voice, and quality of life in individuals with motor complete tetraplegia. **Methods:** In this randomized controlled trial, 24 individuals with traumatic, motor complete (AIS A) tetraplegia (C5-C8), 6 to 8 months post injury, were randomly assigned to 1 of 3 groups. They completed either 90 repetitions of IRT, 10 minutes of IH, or 16 repetitions of placebo training in 32 supervised training sessions over 8 weeks. Before and after the training period, the following tests were performed: bodyplethysmography, inspiratory and expiratory muscle strength, subjective breathing parameters using the visual analogue scale (VAS), voice measurements, and an adapted SF-12 quality of life questionnaire. A Friedman test and Cohen's effect sizes for IRT and IH versus placebo were calculated for differences between pre- and posttraining values. **Results:** Compared to placebo training, IRT showed high effect sizes for inspiratory muscle strength ($d = 1.19$), VAS values of "cleaning the nose" ($d = 0.99$), and the physical component of subjective quality of life ($d = 0.84$). IH compared to placebo training showed only medium and low effect sizes. The Friedman analysis showed a significant effect for IRT versus placebo on inspiratory muscle strength ($P = .030$). Neither all other parameters of respiratory function nor voice measurements, subjective breathing parameters, or quality of life were significantly improved by one of the tested training methods. **Conclusion:** In individuals with motor complete tetraplegia, inspiratory muscle strength can be improved by IRT. Therefore, IRT is advantageous compared to IH for this group of patients and during the first year post injury. **Key words:** breathing exercises, quality of life, respiratory muscles, spinal cord injuries

Respiratory complications are still the leading cause of death in individuals with a spinal cord injury (SCI).¹ Haisma and colleagues showed that the risk of pulmonary infections for individuals with complete lesions is 3.5 times higher than for individuals with incomplete lesions.² The increased risk for individuals with motor complete tetraplegia seems to result from the loss of respiratory muscle innervation and the consecutive loss of lung volume.^{3,4}

First studies have shown positive effects of respiratory muscle training on respiratory function^{5,6} and respiratory complications.⁷ However, review articles on respiratory muscle training in individuals with SCI showed that most studies were of low methodological quality and that there are not yet enough data to show a clear effect of respiratory muscle training on respiratory function, respiratory complications, or quality of life.^{8,9} Additionally, there exist different methods for respiratory muscle training in clinical practice, which can roughly be scaled in respiratory resistance (strength) and respiratory muscle

endurance training methods. To our knowledge, there exists no study that compared the effects of these 2 basically different respiratory muscle training methods in individuals with SCI.

Therefore, the aim of this study was to conduct a randomized controlled trial to compare the effects of respiratory resistance and respiratory muscle endurance training with the effects of sham training on respiratory function, voice, and quality of life in individuals with motor complete tetraplegia.

Methods

This study was conducted as a randomized controlled trial with consecutive enrollment of subjects between February 2004 and October 2010 in one SCI rehabilitation center. The study was approved by the local ethics committee, and

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written informed consent was obtained from each patient before the start of the study. Twenty-four individuals with traumatic motor complete (ASIA Impairment Scale [AIS] A) tetraplegia, between C5 and C8, 6 to 8 months post injury participated in this study. They were randomly assigned to 1 of 3 study groups: (1) inspiratory resistance training (IRT); (2) respiratory muscle endurance training using isocapnic hyperpnea (IH); or (3) placebo training using incentive spirometry.

All subjects completed 32 supervised training sessions (4 x 10 minutes per week) over 8 weeks. The IRT group used an electronic inspiratory threshold device with visual feedback of achieved resistance, called Respift S (Eumedics GmbH, Purkersdorf, Austria). Subjects had to inhale with maximal inspiratory power in each of the 90 repetitions. Inhalations with less than 80% of the individual maximal inspiratory power had to be repeated. The IH group used a device called Spirotiger (Idiag AG, Volketswil, Switzerland). This device allows intensive hyperventilation as a result of partial re-breathing of ventilated air, supported by visual and acoustic feedback of breathing volume and frequency. Subjects had to hyperventilate for 10 minutes continuously at 40% to 50% of their individual maximal voluntary ventilation.¹⁰ The placebo group was instructed to do volume training with an incentive spirometry device called Voldyne 5000 (tyco Healthcare, Mansfield, UK). They had to inhale 16 times to total lung capacity with 30 to 40 s of rest in between repetitions.

Before and after the training period, the following tests were performed:

- A bodyplethysmography to measure lung volumes and flows (Master Screen Body; Viasys Healthcare GmbH, Hoechberg, Germany)
- In- and expiratory muscle strength measurements (Micro RPM; Micro Medical, Cardinal Health Germany 234 GmbH, Hoechberg, Germany)
- Subjective breathing parameters like coughing, the ability to blow one's nose, shortness of breath at rest and during physical activity, and shortness of breath during speech assessed by a visual analogue scale (VAS)

- Voice measurements like loudness of shouting and duration of speech assessed with a commercially available decibel meter and a stop watch
- An adapted SF-12 quality of life questionnaire¹¹ to assess the physical and mental component of subjective quality of life

Differences between pre- and posttraining values were calculated. A Friedman test was used to compare IRT or IH versus placebo ($P < .05$) using SPSS 18.0 (SPSS, Inc, Chicago, IL). Cohen's effect sizes (differences pre vs post training) for IRT or IH versus placebo were used as a measure of clinical relevance of changes. An effect size of less than 0.5 represents a small effect, 0.5 to 0.8 a medium effect, and greater than 0.8 a high (clinically relevant) effect.

Results

The Friedman analysis showed a significant effect ($P = .03$) for IRT versus placebo on inspiratory muscle strength (**Figure 1**). Neither all other respiratory function parameters nor subjective breathing parameters, voice, or quality of life were significantly improved by one of the tested training methods.

Further, IRT versus placebo showed high effect sizes for inspiratory muscle strength ($d = 1.19$), the VAS value of "the ability to blow one's nose" ($d = 0.99$), and the physical component of SF-12 quality of life ($d = 0.84$). IH versus placebo showed only medium and low effect sizes.

Discussion

We found a positive effect of IRT on inspiratory muscle strength (**Figure 1**) with only 4 training sessions of 10 minutes per week. Compared to other respiratory muscle training studies that showed positive effects on respiratory muscle strength or lung volumes,^{5,6,12,13} our training volume was quite low. We believe that low training volumes with high training intensities have positive effects on motivation and training compliance, especially if patients are supposed to perform the training on their own initiative.

Figure 1. Box plots for inspiratory muscle strength (Pi_{max}) pre and post respiratory muscle training. Note that the difference pre vs post IRT is significantly higher compared to placebo. IH = isocapnic hyperpnea; IRT = inspiratory resistance training.

Therefore, we recommend that patients achieve the highest possible training intensity in each single training session, because this seems to be important for an effective training stimulus. The high effect sizes of subjective parameters such as the ability to blow one's nose and the physical component of SF-12 quality of life may also be important for motivation.

The fact that lung volumes, flows, and voice measurements did not show any significant effects in all tested respiratory muscle training methods

might be related to a spontaneous increase in all 3 study groups, because the study was conducted during the first year post injury where lung volumes and flows are known to increase over time.¹⁴

We conclude that inspiratory muscle strength can be improved by high intensity IRT in individuals with motor complete tetraplegia, despite a relatively low training volume. During the first year post injury, IRT is advantageous compared to IH for individuals with motor complete tetraplegia.

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