ORIGINAL ARTICLE

Abdominal Binder Improves Lung Volumes and Voice in People With Tetraplegic Spinal Cord Injury

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ABSTRACT. Abdominal binder improves lung volumes and voice in people with tetraplegic spinal cord injury. Arch Phys Med Rehabil 2012;93:2189-97.

Objective: To investigate the effect of an elasticated abdominal binder on respiratory, voice, and blood pressure outcomes for people with a motor complete acute tetraplegia during the first year after injury.

Design: Randomized crossover study.

Setting: Large university-affiliated referral hospital.

Participants: Consenting participants (N=14, 13 men and 1 woman) with recent, motor complete, C3-T1 spinal cord injury.

Interventions: Abdominal binder on/off with participant seated in upright wheelchair, with 3 repeated measures at 6 weeks, 3 months, and 6 months after commencing daily use of an upright wheelchair.

Main Outcome Measures: Forced vital capacity, forced expiratory volume in 1 second, peak expiratory flow, maximal inspiratory pressure, and maximal expiratory pressure were measured. Mean arterial pressure, maximum sustained vowel time, and sound pressure level were also measured.

Results: Overall, an abdominal binder resulted in a statistically significant improvement in forced vital capacity (weighted mean difference .34L [95% confidence interval (CI) .10–.58], P=.005), forced expiratory volume in 1 second (.25L [95% CI −.01 to .51], P=.05), peak expiratory flow (.81L/s [95% CI .13–1.48], P=.02), maximal inspiratory pressure (7.40cmH_2O [95% CI 1.64–13.14], P=.01), and maximum sustained vowel time (3.75s [95% CI .90–6.60], P=.01). There was no statistically significant improvement in maximal expiratory pressure (5.37cmH_2O [95% CI −1.15 to 11.90], P=.11), mean arterial pressure (4.41mmHg [95% CI −6.15 to 14.97], P=.41), or sound pressure level (1.14dB [95% CI −1.31 to 3.58], P=.36).

Conclusions: An individually fitted abdominal binder significantly improved forced vital capacity, forced expiratory volume in 1 second, peak expiratory flow, maximal inspiratory pressure, and maximum sustained vowel time in people with newly acquired tetraplegia. Further study is needed into the effect of the long-term use of the abdominal binder on breathing mechanics, functional residual capacity, total lung capacity, and respiratory health.

Key Words: Orthostatic hypotension; Pulmonary function; Rehabilitation; Respiration; Speech; Spinal cord injuries.

IN 2007 TO 2008, THERE WERE 362 new cases of spinal cord injury (SCI) admitted across the 6 speciality spinal injuries units within Australia. Cervical spine injuries accounted for 53% of all those admitted, with 32% affecting the thoracic spine.[1] Complications arising from compromised respiratory function are the major cause of morbidity and mortality in people after cervical SCI.[2] This compromised respiratory function is caused by denervation of intercostal muscles, which limits inspiratory and expiratory ability, and loss of abdominal muscle function, which prevents an effective cough.[3] The vital capacity can be reduced to 50% to 80% of predicted[4] value, with a reduction in total lung capacity to 60% to 80% predicted[5] in nonventilated patients with tetraplegia.

Binding of the paralyzed abdomen has been used with the aim of increasing lung volumes and respiratory muscle strength.[6-12] A recent systematic review and meta-analysis[6] by our group concluded that there was some evidence that the use of an abdominal binder (AB) significantly improves vital capacity and significantly decreases functional residual capacity. This review found that an AB resulted in a trend toward an overall decrease in total lung capacity and had no significant effect on maximum inspiratory pressure (MIP), but the review found conflicting results for the effect of an AB on maximum expiratory pressure (MEP). There were methodologic limitations associated with the studies in this review.

The imbalance between sympathetic and parasympathetic neural control after SCI results in hypotension and bradycardia

List of Abbreviations

AB	abdominal binder
FEV_1	forced expiratory volume in 1 second
FVC	forced vital capacity
MAP	mean arterial pressure
MEP	maximum expiratory pressure
MIP	maximum inspiratory pressure
MSV	maximum sustained vowel
OH	orthostatic hypotension
PEF	peak expiratory flow
SCI	spinal cord injury
SPL	sound pressure level

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for many patients.[13] While numerous SCI textbooks[14-17] recommend the use of an AB for the management of orthostatic hypotension (OH), limited evidence exists for this application.[18] There is a similar lack of studies into voice impairment after SCI. Voice production is dependent on sufficient respiratory support (volume and pressure) to generate sound.[19,20] People with tetraplegia have impaired vocal ability and use muscle recruitment strategies during speech that are different from those used by the able-bodied person.[21] Hence, they may present with inadequate loudness, short breath groups, slow inspirations, breathiness, and decreased utterance duration.[22-24] The one study that investigated speech outcomes with the use of a nonelastic abdominal "truss" in 3 participants found increased syllables per breath and overall listener preference when trussed.[23]

Clinically, most rehabilitation centers recommend the use of an AB when first starting to use a wheelchair for those patients with tetraplegia and high paraplegia with the aim of reducing OH. The impact of an AB on breathing and voice is often a secondary consideration. No previous study has examined the effect of an AB on the main clinical indicators for the use of an AB, and in the same subject group from the acute rehabilitation phase. This randomized crossover trial aimed to determine the short-term effect of an AB on respiratory function, voice, and hemodynamics in people with acute tetraplegia and high paraplegia during the first 6 months of using an upright wheelchair.

METHODS

Participants

This study was conducted in a spinal injuries unit for adults between January 2008 and October 2009. Ethical clearance was provided through the local human research ethics committee. Patients admitted to the spinal injuries unit meeting study inclusion criteria were provided with a study information sheet and approached for consent by the principal investigator. Participants were included if they had an acute traumatic SCI with an American Spinal Injuries Association Impairment Scale of A or B (motor complete) above the T5 level, were aged between 18 and 80 years, and were English speaking. Potential participants were excluded if they had skin breakdown across their sitting surface or across the region of AB application, a traumatic brain injury, and/or active respiratory disease (chronic obstructive airways disease, asthma, lung pathology) at the time of the study. All participants approached for consent were included.

Respiratory Measures

The portable SpiroPro Spirometer[a] was used to measure peak expiratory flow (PEF), forced expiratory volume in 1 second (FEV_1), and forced vital capacity (FVC). Respiratory function tests were conducted according to the guidelines of the American Thoracic Society/European Respiratory Society[25] and modified to incorporate the limitations associated with SCI.[26,27] Participants who satisfied spirometry acceptability but not repeatability criteria had values recorded from their best acceptable curve selected for analysis. Up to 8 attempts were made in an effort to achieve repeatability. Participant ability to meet spirometry criteria was noted. Predictive values for FEV_1, FVC, and PEF were calculated using reference values supplied with the SpiroPro.[28]

Respiratory muscle strength was assessed by measuring MIP and MEP using the MicroRPM handheld respiratory pressure meter[a] with a tube-style mouthpiece. Participants were instructed to make maximum inspiratory and expiratory efforts at residual volume and total lung capacity, respectively, according to American Thoracic Society/European Respiratory Society guidelines.[29] The highest value measured within 10% of 3 previous recordings was taken, ensuring a rest time of 1 minute between tests. Up to 8 repeated measures were recorded. A nose clip was used for all respiratory measurements, and data collection was carried out at the same time of the day for all participants.

Voice Measures

Respiratory support for voice was indirectly investigated through measuring maximum sustained vowel (MSV) time and mean sound pressure level (SPL) (acoustic measure of vocal loudness) during sentence recitation. MSV was measured as the maximum length of time a participant could sustain the sound "ah" with even pitch after a large inhalation. SPL was recorded while participants recited the sentence "Combine all the ingredients in a large bowl" at maximal SPL with mean SPL across the sentence measured.[30] Standard instructions and a demonstration were provided to each participant. MSV and SPL were repeated 3 times each. The longest MSV recorded and the highest SPL samples were used. Recordings were collected using an Edirol sound recorder and a headset microphone.[b] The midpoint of the microphone of the Edirol was positioned 5 centimeters away and directly in front of each participant's mouth. Voice samples were recorded as digital .wav files at a sampling rate of 44.1 kilohertz with 16-bit quantization. Participants completed the testing with their arms resting comfortably on their laps, and all testing was completed in a quiet office with minimal noise disturbance. Data were analyzed using the TF32 time-frequency analysis software program[c] for MSV and the CSL program for SPL.[d]

Hemodynamic Measures

Blood pressure measurements were taken using the arm cuff automatic blood pressure monitor Omron IA2[e] as per manufacturer's instructions with and without the AB in place with the participant in the seated wheelchair position and also while supine after quiet rest of 5 minutes. Mean arterial pressure (MAP) was calculated from the blood pressure measures on the basis of the following formula:

$$\text{MAP} = \text{diastolic arterial pressure} + 1/3\,[\text{systolic arterial pressure} - \text{diastolic arterial pressure}]$$

after 2 measurements with 2 minutes of rest between each sample were obtained.

Abdominal Binder Design

The elasticated AB was made of polyester and 20% spandex.[f] This AB was available in several widths and lengths and was fitted to the individual so as to provide firm support around the abdomen from the anterior superior iliac crest to the costal margin of the rib cage (fig 1).

Procedure

Each participant was assessed at 3 time points with and without the AB applied while sitting in the provided upright wheelchair at 6 weeks, 3 months, and 6 months after commencing daily wheelchair use. The order of the testing condition (with AB on or off) by individual and occasion of assessment (3 assessment time points) was randomized to control for an order effect. The assessor was not blinded to the application of the AB; however, analysis of the data was completed with the data coded such that AB status was unknown.