ORIGINAL ARTICLE

Benefit of triple-strap abdominal binder on voluntary cough in patients with spinal cord injury

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Study design: A cross-sectional experimental study.

Objective: The purpose of this study is to examine the benefit of elastic abdominal binders on voluntary cough in persons with spinal cord injury.

Setting: Spinal rehabilitation unit in a teaching hospital.

Methods: We measured voluntary cough peak expiratory flow rate (in 21 subjects with spinal cord injury, (18 tetraplegia, 3 paraplegia) under three conditions: without abdominal binder as the baseline, with single-strap abdominal binder and triple-strap abdominal binder.

Results: The results showed that the mean cough peak expiratory flow rate in all subjects without abdominal binder was 277.1 l per min. There was a significant increase in flow rate with the use of abdominal binders: 325.7 l per min with single-strap abdominal binder and 345.2 l per min with triple-strap abdominal binder ($P < 0.05$, paired *t*-test). The mean cough peak expiratory flow rate in tetraplegic subjects using triple-strap abdominal binders was significantly higher compared with those using single-strap abdominal binders (322.1 l per min and 299.4 l per min, respectively).

Conclusion: Abdominal binders can be used as an effective method to improve cough ability in spinal cord injured patients, with triple-strap abdominal binder achieving greater cough peak expiratory flows. *Spinal Cord* (2011) 49, 1138–1142; doi:10.1038/sc.2011.53; published online 17 May 2011

Keywords: paraplegia; respiratory; tetraplegia; abdominal strap

Introduction

Spinal cord injury (SCI) is one of the most devastating injuries that a person can experience. It usually leads to life-long disability in young adults. One of the major consequences of SCI, especially among patients with tetraplegia and high paraplegia, is reduced respiratory effort. Patients often have paralysis of a major portion of their expiratory muscles and as a consequence, suffer from a markedly reduced ability to clear airway secretions. This can result in severe respiratory complications, leading to mortality.^{1–3} Even though this group is unable to actively contract their abdominal muscles, previous studies have shown that production of cough in this population can still be an active process, with the contraction of clavicular portion of the pectoralis major and latissimus dorsi.^{4–6}

A few studies that focus on improving cough ability among persons with SCI have been conducted. These include studies on therapeutic manoeuvres,⁷ use of abdominal binders,^{8–13} the use of electrical stimulator^{14,15} and functional magnetic stimulator.^{16,17} Studies by Jaeger *et al.*⁷ and Linder¹⁵ found

that cough efficacy produced by electrical stimulation was as effective as manually assisted cough in subjects with tetraplegia. Lin *et al.*¹⁴ found that the combination of abdominal binder and electrical stimulation caused a significant increase in peak flow expiratory rate (PEFR). However, the use of the abdominal binder by itself has not been studied.

Abdominal binders may improve the respiratory function by compressing the abdominal contents, which elevate the diaphragm into a more optimal position for breathing.¹³ Variables such as demographics of subjects, type of abdominal binders and respiratory outcome parameters in previous studies on the use of the abdominal binder were not well controlled, thus making the use of abdominal binders in SCI unclear.^{9–11,13} As there is evidence that abdominal binders may be useful for SCI patients,^{10–11,13} we chose to explore the effectiveness of different types of elastic abdominal binders (single-strap versus triple-strap abdominal binder) and their methods of application.

Materials and methods

Participants

Subjects with SCI who were attending the Spinal Rehabilitation clinic in a teaching hospital were recruited for the study.

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Received 6 December 2010; revised 12 April 2011; accepted 17 April 2011; published online 17 May 2011

Ethical approval was granted by the University Malaya Medical Centre Research Committee. Before participating, each patient was given an information sheet explaining the objectives and the procedure of the study, after which written consent was obtained.

The inclusion criteria for the sample were as follows: (1) spinal cord lesion with neurological level between C1 and T6, (2) adults of both gender aged between 18 and 65 years, (3) duration since injury of at least 2 months and (4) ability to communicate and understand the study requirements. The following reasons were considered grounds for exclusion: (1) past medical history of bronchial asthma, chronic obstructive and restrictive airway disease, end stage renal or liver failure and congestive cardiac disease, and (2) respiratory symptoms such as cough, difficulty in breathing, wheezing and chest pain within two weeks before the study. Subjects would have to withdraw from the study if they experienced respiratory distress or autonomic dysreflexia during the study or failed to complete the number of coughs required.

Each subject served as their own control. This approach was taken as it offers flexibility. It was undertaken on the understanding that there was no way of controlling the independent variables due to the group being studied.

Procedure

Application of single-strap abdominal binder (SSAB). We used MEDAC 525 Narrow binder (Medac (Pty) Ltd, Cape Town, South Africa) with pull wrap in various sizes as the SSAB in this study. The SSAB was applied between the xiphoid process and symphysis pubis with the participant lying supine. It was applied so as to decrease abdominal girth by 10% at the umbilical level.

Application of triple-strap abdominal binder (TSAB). We used MEDAC 515 Lumbar Abdominal Brace triple X-strap as the TSAB, which provided good coverage of the lower portion of the rib cage. The TSAB has three straps anteriorly, which allowed application of different tensions from top to bottom. We drew reference lines on the strap attachment vertically with the distance of 1 inch between the lines (Figure 1).

With the subject lying supine, the TSAB was applied from the lower part of the chest wall inferiorly to the symphysis pubis. The straps were initially placed on the reference line without tension and this was considered as baseline. Each strap was then applied with a different tension; the top strap was tightened one line lateral from the baseline, the middle strap two lines laterally and the bottom strap three lines laterally, giving a tension ratio of 1:2:3 from top to bottom.

For both abdominal binders, the subjects were asked if they experienced any feeling of discomfort or difficulty in breathing.

Measurement of cough PEFR. We used assess peak flow meter standard range (range from 60 to 880 l per min) to measure cough PEFR. Cough peak flow meter is a convenient means of assessing cough response in patients with ineffective cough due to neurological diseases and can serve as a check

Figure 1 Triple-strap abdominal binder with reference lines.

on the expiratory peak flow rate.^{18,19} Measurements of cough PEFR were taken under three conditions: without abdominal binder, with SSAB and with TSAB. All coughs were measured with subjects in an upright sitting position.

Analysis

Descriptive analysis was used to describe demographic profile and disease characteristics of the subjects. Paired *t*-test and Wilcoxon signed-ranks test were used to determine the significance of differences of cough PEFR between pre and post abdominal binder application. Spearman's rank correlation test and one-way analysis of variance were used to determine the correlation and association between the demographic profiles and disease description data with cough PEFR findings. Figure 2 summarizes the methodology used for this study.

Results

A total of 21 subjects were recruited for this study. Table 1 describes the subjects according to sex, age, period of time since injury, level of injury and American Spinal Injury Association Impairment Scale. Majority of the subjects (71%) had SCI due to a motor vehicle accident, followed by fall from height (24%) and remaining 5% suffered from diving related injury. As with regards to history of smoking, 14% were smokers, 43% stopped smoking after the injury and another 43% had never smoked.

Table 2 shows the mean cough PEFR of the subjects with and without abdominal binder according to the level and completeness of injury. An increase in mean cough PEFR readings with both SSAB and TSAB compared with the baseline was observed. Comparing SSAB and TSAB, our results show that the mean cough PEFR values were higher with TSAB, compared with the use of SSAB. TSAB caused an increase of 24.6% in PEFR ($P < 0.001$) whereas SSAB caused an increase of 17% ($P < 0.001$).

Figure 2 Flow chart of the study methodology. PEFR, peak expiratory flow rate; SSAB, single-strap abdominal binder; TSAB, triple-strap abdominal binder.

Table 1 Subjects' characteristics and profile

Subject no.	Sex	Age (years)	Time since injury (months)	Level of injury	ASIA Impairment Scale classification
1	M	28	18	C6	A
2	M	34	91	C8	C
3	M	27	34	C6	B
4	F	34	77	C5	A
5	M	26	12	C5	A
6	M	32	23	C6	B
7	F	63	2	T4	A
8	M	39	12	C8	B
9	M	37	126	C8	B
10	M	37	112	C5	B
11	M	32	170	T4	A
12	M	35	124	T4	A
13	M	26	31	C6	B
14	M	33	34	C6	B
15	F	22	72	C5	A
16	M	30	25	C8	A
17	M	42	35	C7	A
18	M	25	48	C5	A
19	M	26	112	C5	A
20	M	43	268	C7	A
21	M	20	30	T4	A

Abbreviation: ASIA, American Spinal Injury Association.

In the case of tetraplegic subjects, in comparison to the baseline, using SSAB increased the mean cough PEFR values by 19.2% ($P < 0.001$) whereas using TSAB increased the

Table 2 Mean cough PEFR (l per min) without AB, with SSAB and with TSAB in relation to neurological level and completeness of injury

Subjects (n)	PEFR (l/min) $\pm$ s.d.		
	Without AB	With SSAB	With TSAB
All subjects (21)	277.1 $\pm$ 116.6	325.7 $\pm$ 128.1	345.2 $\pm$ 110.1
Tetraplegia (17)	251.2 $\pm$ 94.3	299.4 $\pm$ 107.8	322.1 $\pm$ 92.7
C5 (6)	195.0 $\pm$ 45.1	231.7 $\pm$ 65.5	259.2 $\pm$ 40.3
C6 (5)	246.0 $\pm$ 129.7	288.0 $\pm$ 114.3	320.0 $\pm$ 107.7
C7 (2)	265.0 $\pm$ 91.9	300.0 $\pm$ 84.4	300.0 $\pm$ 70.7
C8 (4)	335.0 $\pm$ 54.5	415.0 $\pm$ 88.1	430.0 $\pm$ 46.9
Paraplegia (4)			
T4 (4)	387.5 $\pm$ 152.0	437.5 $\pm$ 163.8	443.8 $\pm$ 138.0
Complete injury (13)	269.2 $\pm$ 126.3	321.5 $\pm$ 142.0	332.3 $\pm$ 117.1
Incomplete injury (8)	290.0 $\pm$ 105.8	332.5 $\pm$ 110.5	366.3 $\pm$ 101.5

Abbreviations: AB, abdominal binder; PEFR, peak expiratory flow rate; SSAB, single-strap abdominal binder; TSAB, triple-strap abdominal binder.

Table 3 Differences of mean cough PEFR between SSAB and no AB, TSAB and no AB and TSAB and SSAB

Subjects (n)	Difference of mean cough PEFR $\pm$ s.d.	95% CI	P-value
All participants (21)			
SSAB and no AB	48.6 $\pm$ 40.6	30.0, 67.0	0.000
TSAB and no AB	68.1 $\pm$ 46.6	46.2, 89.3	0.000
TSAB and SSAB	19.5 $\pm$ 41.1	38.2, 80.0	0.042
Tetraplegia (17)			
SSAB and no AB	48.2 $\pm$ 42.4	26.4, 70.0	0.000
TSAB and no AB	70.9 $\pm$ 43.3	48.6, 93.2	0.000
TSAB and SSAB	22.6 $\pm$ 41.5	1.3, 44.0	0.039

Abbreviations: AB, abdominal binder; CI, confidence interval; PEFR, peak expiratory flow rate; SSAB, single-strap abdominal binder; TSAB, triple-strap abdominal binder.

values by 28.2 % ($P < 0.001$). The largest increases in mean cough PEFR value using SSAB was seen in subjects with C8 level of injury, whereas with TSAB, this was seen in subjects with neurological level of C5.

There were no statistically significant differences in mean PEFR with SSAB and TSAB in the paraplegic subjects.

Regardless of the completeness of injury, this study demonstrated an increase of mean cough PEFR values using both types of abdominal binder compared with without binder. In subjects with complete injury, the SSAB increased the mean cough PEFR by 19.4% ($P < 0.005$) whereas the TSAB caused an increase of 23.4% ($P < 0.005$). In subjects with incomplete injury, significant difference was only observed with the use of TSAB.

The difference of mean cough PEFR between SSAB and no AB, TSAB and no AB and TSAB and SSAB were statistically significant in tetraplegic but not paraplegic subjects (Table 3).

Discussion

We evaluated the effects of elastic SSAB and TSAB on voluntary cough, measured as cough PEFR, among subjects with SCI (C5 to T4). We also examined the relationship

between the subjects' demographic characteristics and voluntary cough measurements. When TSAB and SSAB were compared, the values of cough PEFR were greater with TSAB, notably in subjects with tetraplegia and complete injury. Previous studies have found that the abdominal binder alone does not significantly improve the expiratory effort among SCI subjects.^{8-9,14} Our study, however, showed that the use of abdominal binder alone can improve voluntary cough with TSAB.

In neurologically intact individuals, the peak air flow during voluntary cough ranges from 300 and 700 l per min.²⁰ The mean cough PEFR without abdominal binder in our tetraplegic sample was 251 l per min. Thus, the PEFR has to increase by at least 20% to reach the normal lower limit of 300 l per min. We considered an increase of PEFR of at least 20% as clinically significant for tetraplegic subjects. Referring to the results in Table 2, comparing SSAB and TSAB, TSAB caused a clinically significant increase of cough PEFR in tetraplegic subjects (28.2%) and in subjects with incomplete and complete injuries (23.4 and 26.3%, respectively).

The SSAB used in this study is a narrow binder with firm lumbar support and straps at both sides. These properties do not only cause compressive effect on the abdomen but also support the lower part of the subject's back. Even though previous studies found that abdominal binders did not significantly improve cough ability, it was noted that there was an increment of PEFR reading by 2-7%.^{8,14} Our study showed SSAB alone improved PEFR by 19%, especially among the tetraplegic subjects.

Our findings show that TSAB significantly improved the mean cough PEFR compared with baseline especially in the tetraplegic subjects. The TSAB used in this study extends from the lower part of the rib cage to the symphysis pubis with graduated increase in tension inferiorly to superiorly. The elastic property of the binder provides compressive effect to the lower part of the ribs, which encompass the lower parts of the lungs. It also pushes the abdominal contents inward, moving the diaphragm upward and increasing its length during coughing, allowing the diaphragm to contract more effectively²¹ and the subject to generate higher intrathoracic pressure during forced expiration.¹³

In addition, the increased pressure over the abdomen would increase the fulcrum effect of the abdominal contents on the diaphragm and increase its efficiency. This would lead to an increase in inspiratory volume before coughing, thereby increasing the PEFR.

Therefore, in this study, TSAB has been used as a non-invasive technique to mimic the function of quad coughing, which helps to mobilize secretion from the lower portions of the lungs in subjects who are unable to cough effectively due to paralysis of the intercostal and abdominal muscles.^{8,20} Both types of abdominal binder used in this study showed more pronounced effects in tetraplegic subjects; comparing SSAB and TSAB, TSAB showed an additional increase of 9% compared with SSAB. We believe this is influenced by the compressive effects to the lower part of the chest when using TSAB, especially when sitting upright.

As in other studies,^{9-11,13} there were no reports of discomfort and no side-effects were observed, indicating

that the use of abdominal binders is safe, simple, inexpensive and well tolerated by patients.

As the small sample size may not be representative of the general SCI patients, our findings must be interpreted cautiously. Error in measurement would be expected even though all precautions were taken to reduce error. All measurements and binder applications were done by a single assessor.

In conclusion, we found that elastic abdominal binders have beneficial effects on the pulmonary function, specifically cough PEFR in subjects with tetraplegia with TSAB being superior to SSAB. As such, abdominal binders can be recommended for use as an effective method to improve cough ability and secretions management in SCI patients especially for tetraplegic subjects.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

This project was funded by the short-term project grant from University Malaya, Malaysia; IPPP/UPDiT/Geran(PJP)/F0169/2005A.

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