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# The active cycle of breathing techniques—to tip or not to tip?

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The active cycle of breathing techniques (ACBT) in gravity-assisted drainage positions is an effective airway clearance regimen for individuals who produce excess bronchial secretions. This study compared the ACBT in positions with and without a head-down tilt. Nineteen subjects (11 men), mean age 37·1 years (range 18–76 years), with bronchiectasis who produced more than 20g of sputum per day and had a mean forced expiratory volume in 1s ($FEV_1$) of 56·9 %predicted (range 23–90% pred.) were studied. There was no significant difference in the wet weight of sputum expectorated when using the ACBT in gravity-assisted drainage positions with or without a head-down tilt. Mean (SD) score for perception of breathlessness, measured on a visual analogue scale, increased significantly following treatment with a head-down tilt [2·3 (1·6) to 3·3 (2·0) cm, $P = 0{\cdot}02$]. There was no significant difference in oxygenation or lung function ($FEV_1$). Eighteen subjects preferred the ACBT without a head-down tilt. The ACBT in the horizontal position is a simple airway clearance regimen suitable for individuals who produce greater than 20 g of sputum per day. Subjects were less breathless and preferred the ACBT in the horizontal position, thus providing a treatment alternative that may improve adherence in individuals who are required to carry out daily airway clearance treatments.

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## Introduction

Daily use of airway clearance techniques is widely prescribed for individuals with chronic lung disease characterized by excess bronchial secretions. The aim of these techniques is to clear secretions and improve alveolar ventilation. Clearing secretions may also decrease the frequency of infection thereby preventing further airway damage and deterioration of lung function. Conventional chest physiotherapy, consisting of gravity-assisted drainage positions, percussion, vibrations and coughing, has been the traditional airway clearance technique for those individuals. Controlled studies of these techniques in this patient group found that mucociliary clearance was enhanced and/or sputum volume or weight increased (1–3). However this airway clearance technique is time-consuming and labour-intensive and adherence to daily treatment has been reported to be poor (4,5).

The active cycle of breathing techniques (ACBT) is a method of airway clearance that can be carried out either with an assistant or independently (6) and has been shown to be more effective than conventional chest physiotherapy for weight and rate of sputum expectorated (7). The ACBT can be used in a sitting position but is more effective when combined with gravity-assisted drainage positioning (8,9). These drainage positions are based on the anatomy of the bronchial tree and were first described by Nelson in 1934 (10). The recommended drainage positions for the middle and lower lobes require a 15° and 20° head-down tilt respectively (6). These head-down positions can aggravate gastro-oesophageal reflux, hypertension and breathlessness (6,11). Adherence to regular treatment may be low because of discomfort and lack of space and equipment (4,5). Consequently physiotherapists and individuals using these techniques sometimes carry out the ACBT in the horizontal position to avoid these side-effects.

The modification of the conventional head-down tilt to the horizontal position may provide a simpler, more comfortable regimen that would be easier to carry out in a variety of situations. The aim of this study was to compare the effects of the ACBT in gravity-assisted drainage positions with and without a head-down tilt on sputum expectoration, lung function, oxygen saturation ($SaO_2$) and breathlessness in subjects who produce a large amount of sputum.

## Methods

### SUBJECTS

Subjects were recruited from the Respiratory Medicine Department in a metropolitan teaching hospital. Inpatients

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and outpatients with bronchiectasis were included if they produced greater than 20 g of sputum per day, required treatment to clear secretions in the middle and lower lobes, were clinically stable and available for testing on 2 consecutive days. Subjects were judged to be clinically stable if they were afebrile, had no change in antibiotic therapy, had a forced expiratory volume in 1 s ($FEV_1$) which varied by less than 10% between study days and a 24 h sputum weight which varied by less than 10% during the 3 days leading up to the study. Subjects were excluded if they had a history of asthma, a 15% increase in $FEV_1$ after using an inhaled bronchodilator, a pneumothorax or a contraindication to a head-down position such as cardiac failure, uncontrolled hypertension, severe abdominal distension or gastro-oesophageal reflux (6).

Approval for the study was granted by the Committee for Human Rights of the University of Western Australia and the Human Research Ethics Committee of Curtin University of Technology. Subjects were given an information sheet outlining the procedures, purpose and significance of the study. They were told they would receive two treatments, one in a position with a head-down tilt and one in a horizontal position, and that the order of treatment would be determined by them choosing a card. The benefits and problems with each treatment were discussed and the need for a comparative study outlined. Written, informed consent was obtained from all subjects prior to the study.

## STUDY DESIGN

Subjects were assessed by a physiotherapist to determine the drainage positions to be used in the study. Lung segments to be drained, for which the recommended positions require a head-down tilt, were selected based on the most productive segments with the subject's usual airway clearance regimen, chest X-ray appearances and auscultatory findings. All subjects were familiar with the ACBT and were instructed in the cycle to be used in the study. The treatment regimens compared were the ACBT in two drainage positions with a head-down tilt and the ACBT in the same two positions without a head-down tilt, that is horizontal. A within subject cross-over design was used with a 24 h wash-out period. The order of treatment was randomized and each treatment was at the same time of day on 2 consecutive days. Subjects were positioned on a tilting bed and a goniometer used to ensure a head-down tilt of 20° (for lower lobes) was achieved (6).

Each treatment session consisted of a 30 min pre-treatment period, a 30 min ACBT treatment with 15 min in each position and a 30 min period following the treatment. If subjects routinely used inhaled bronchodilators prior to airway clearance treatments these were administered 30 min prior to the pre-treatment period.

The ACBT consisted of a sequence of breathing control, five thoracic expansion exercises, breathing control, five thoracic expansion exercises, breathing control and the forced expiration technique (FET) (6). Thoracic expansion exercises are deep breathing exercises that emphasize inspiration and breathing control is normal tidal breathing using the lower chest. The FET consisted of one or two mid-to low lung volume huffs combined with periods of breathing control. Subjects were allowed to cough as required, however, if at the end of two consecutive cycles the subject did not expectorate any sputum a high lung volume huff was used. The duration of the periods of breathing control varied among subjects depending on the time required for subjects to regain their normal breathing pattern and prevent bronchospasm and fatigue. However, the same cycle was repeated at both treatment sessions and the number of cycles controlled.

Two physiotherapists were involved in the study and the therapist that assessed the subject supervised both treatment sessions. Subjects carried out the treatment independently with the physiotherapist ensuring that the ACBT was the same at both treatment sessions. Other airway clearance treatments and exercise outside the study treatment sessions were the same on both days.

## MEASUREMENTS

Testing was carried out in an environment controlled for temperature and humidity. Instruments were calibrated according to the manufacturer's instructions prior to the testing of each subject and all measurements were taken by the principal researcher (NC).

Sputum expectorated during treatment and in the 30 min after treatment was collected and weighed using a Sartorius PT 310 weighing scale (Sartorius AG, Goettingen, Germany) accurate to 0·01 g. Sputum expectorated in the following 23 h was also collected and weighed. The number of productive coughs during treatment and in the 30 min after treatment was recorded.

Forced vital capacity (FVC) and $FEV_1$ were measured using a calibrated wedge bellows spirometer (Vitalograph, model S, Buckingham, U.K.). The highest values taken from three satisfactory attempts were recorded (12). Measurements were taken immediately prior to the pre-treatment period and at the end of the post-treatment period. Oxygen saturation was measured with a pulse oximeter with ear sensor attachment (Ohmeda Biox 3700e, Ohmeda, Boulder, Colorado, U.S.A) continuously during the treatment sessions. The slow response mode (average signal every 12 s) was used and the mean and standard deviation calculated for each 30 min time period (pre, during and post-treatment).

Immediately prior to treatment the subject received the same instructions in the use of a 10 cm horizontal visual analogue scale (VAS) with anchor descriptors of 'not at all breathless' and 'severely breathless'. The subject was then requested to rate the intensity of their breathlessness by marking a point on the line. This was repeated immediately following treatment without the subject viewing the initial recording.

At the end of the second treatment day subjects were asked which treatment they preferred, their reasons for this choice and which treatment they thought was more effective.

## STATISTICAL ANALYSIS

A difference of 15% in sputum weight was considered to be clinically significant and, allowing for a Type 1 error of 5% and a statistical power of 90%, a sample size of 20 subjects was required to detect this difference.

Sputum weight, number of productive coughs and lung function data were compared using a two-tailed paired *t*-test. Repeated measures analysis of variance (ANOVA) was used to analyse the $SaO_2$ data and the Wilcoxon signed-rank test to compare VAS scores before and after treatment. The level of significance was taken at $P<0{\cdot}05$. Data analysis was performed using SPSS for Windows software (Release 7·0, SPSS Inc., Chicago, U.S.A.) and the power calculation used the 'stplan' statistical package.

# Results

Twenty subjects were recruited and 19 subjects (11 male) completed the study. One female subject was withdrawn because $FEV_1$ varied by more than 10% between treatment days and a change in antibiotic therapy was required. Thirteen had cystic fibrosis, one immotile cilia syndrome and five had bronchiectasis of unknown cause (Table 1). There was no significant difference in $FEV_1$ (2·06 l *vs.* 2·08 l, $P = 0{\cdot}25$), $SaO_2$ (93·9% *vs.* 94·3%, $P = 0{\cdot}39$) and breathlessness score (2·3 *vs.* 2·02cm, $P = 0{\cdot}13$) before treatment on the 2 study days.

There were no significant differences between treatments for the number of productive coughs and weight of sputum expectorated during treatment or in the weight of sputum produced in 24 h (Table 2). The mean (SD) breathlessness score was increased following treatment with a head-down tilt from 2·3(1·6)cm to 3·3(2·0)cm and without a head-down tilt from 2·0(1·7)cm to 2·5(1·6)cm, the increase was only significant with a head-down tilt ($P = 0{\cdot}02$). There were no significant changes in $SaO_2$ during or after either regimen and no change in $FEV_1$ after either treatment.

Eighteen subjects preferred the regimen without a head-down tilt; however, five of the subjects felt that the regimen with a head-down tilt was more effective (Table 3). Four of these five subjects produced similar amounts of sputum with each treatment regimen, the remaining subject produced 24% more sputum when treatment involved a head-down tilt. Two subjects felt that percussion would have made the treatments more effective.

# Discussion

The results of this study show that for individuals with bronchiectasis who produce greater than 20 g of sputum per day the ACBT is as effective in terms of the weight of sputum expectorated in the horizontal position as in the head-down position. Subjects preferred the treatment in the horizontal position and were less breathless in this position. There are no published studies which have compared the ACBT in gravity-assisted drainage positions with and without a head-down tilt; however, it has been shown to be more effective in these positions than when sitting (8,9).

Gravity-assisted drainage positions use gravity to assist the flow of secretions from distal to proximal airways. The drainage positions are based on positioning the subject so

TABLE 1. Subject characteristics

| | |
|---|---|
| Subjects | 19 |
| Age (years) | 37·1 (18·2)* |
| Body mass index (kg m$^{-2}$) | 21·4 (3·5) |
| $FEV_1$ (l) | 2·1 (1·0) |
| $FEV_1$% predicted | 56·9 (19·7) |
| FEV1/FVC (%) | 62·0 (10·0) |
| $SaO_2$(%) | 93·9 (2·5) |
| Daily sputum weight (g) (average from 3 days prior to study) | 48·9 (33·3) |

*Mean (SD).

TABLE 2. Mean (SD) of sputum weight and number of productive coughs for the ACBT treatments

| | ACBT with HDT | ACBT without HDT | *P*-value |
|---|---|---|---|
| Treatment sputum weight (g)* | 15·17 (10·13) | 15·55 (7·86) | 0·71 |
| 24-h sputum weight (g)† | 47·89 (30·9) | 45·19 (26·9) | 0·06 |
| Productive coughs (n)* | 11·8 (6·6) | 11·5 (5·1) | 0·67 |

*During 30 min ACBT treatment +30 min after.
†Treatment sputum weight +23 h following. HDT, Head-down tilt.

TABLE 3. Response to questions at the end of the study. Values are numbers of subjects

| Question | ACBT with HDT | ACBT without HDT | No difference |
|---|---|---|---|
| Which treatment did you prefer? | 0 | 18 | 1 |
| Reasons for preference | | More comfortable (10)<br>Less headache or head fullness (5)<br>Treatment easier (4)<br>Less tiring (3)<br>Less breathless (3)<br>Less irritation in airways, not as tight (3)<br>More relaxing (2)<br>Easier to cough (2)<br>More convenient when away from home (1) | |
| Which treatment did you consider to be more effective? | 5 | 5 | 9 |
| Reasons for improved effectiveness | Produced more sputum (5) | Not as tight and so moved more sputum (2)<br>More productive (1)<br>Required less work to get sputum up (1)<br>Less breathless (1) | |

HDT, Head-down tilt.

that the segmental bronchi are as close to the vertical position as possible assuming that liquid flows fastest through a vertically inclined tube under the force of gravity (10). Factors influencing mucus flow may explain why this study did not find an increase in the weight of sputum expectorated when treatment included a head-down tilt. Wong *et al.* reported that gravity increased tracheal mucus clearance in some subjects with cystic fibrosis but that size of the airway should be considered (13). Mucus flows faster in large airways as less resistance is offered by the size of the lumen. In smaller or narrowed airways the mucus is in contact with a proportionately greater surface area of the airway creating a greater resistance to flow. If the mucus completely covers the cross-sectional area of an airway the pressure in the airspace distal to the obstruction is less than that in the proximal airspace (atmospheric) and a partial vacuum occurs stopping the flow of mucus (14). It is possible that an angle less than the vertical may be more effective for drainage of smaller airways, thereby avoiding complete obstruction of the airway. The horizontal position places the airways at an angle that allows gravity to assist with drainage of secretions. Furthermore, recommended drainage positions are based on a 'normal' bronchial tree and in individuals with chronic lung disease it is probable that recurrent infection causes scarring and distortion of the angles of the bronchi casting doubt on the accuracy of the recommended positions.

Aspects of study methodology which can influence the validity of the results of this study are the treatment protocol, control of cough which will influence airway clearance, the use of wet weight of sputum as an outcome measure and the power of the study to detect a difference between interventions. The study was designed to evaluate a simple, independent airway clearance regimen and a treatment time of 30 min was considered realistic and reflects clinical practice. Two positions were used in this study with the subjects changing position after 15 min. A minimum drainage time of 10 min for productive segments is recommended when using the ACBT (15). A set protocol for the ACBT was used with the periods of breathing control varying depending on the subject's recovery. The physiotherapist supervising the treatment ensured that the same number of cycles were repeated on each treatment day. Two subjects expressed a preference for adding percussion to the treatment regimen. These subjects expectorated over 90 g of sputum per day and would probably benefit from adding percussion to increase the rate of sputum expectorated (16). Percussion was not included in this study as it was considered to be another variable that may influence the outcome and only the head-down tilt was being studied. Cough improves radioaerosol clearance and sputum expectoration in subjects with hypersecretory disease (1,3). In this study the number of coughs in each treatment regimen were accounted for to ensure that any differences observed in the treatment regimens were not due to cough alone.

Wet weight of sputum is a simple, non-invasive short-term clinical outcome measure of the effectiveness of airway clearance techniques. It has been suggested that sputum weight or volume is misleading as unknown quantities of saliva may be included (3). Freeze-drying the sputum before weighing may better reflect tracheobronchial secretions only. In a study of airway clearance techniques by Sutton *et al.* the ratios of dry to wet weight of sputum were similar; however, the results appear to be based on observation of the data and no statistical analysis was reported (9). We conducted a pilot study to confirm these findings and establish whether wet weight of sputum was a good predictor for dry weight of sputum. Five sputum specimens were collected from three subjects with cystic fibrosis who produced a copious amount of sputum. The wet weights of the 15 specimens ranged from 0·54 to 17·88 g and the dry weights ranged from 0·01 to 1·19 g. Dry weight expressed as a percentage of wet weight ranged from 1·85 to 8·71%. For each subject there was a strong relationship between the wet and dry weight of sputum ($r = 0{\cdot}99$, 0·92, 0·98) and between subjects there was a strong linear relationship ($r^2 = 0{\cdot}98$). These findings indicate that wet weight of sputum is a good predictor of dry weight of sputum and thus it is unlikely that the salivary content of the wet weight influences the reliability of the measure.

It is further suggested that sputum weight is misleading as it may be swallowed or individuals may have difficulty expectorating (3). The subjects in this study were accustomed to expectorating sputum and treatment sessions were supervised by a physiotherapist who discouraged subjects from swallowing sputum. Sputum expectorated in the 23 h following the treatment session was a much less reliable measure as subjects were not supervised and may have swallowed secretions and not collected the sputum. The validity of sputum weight as an outcome measure is questioned in a study by Hansani *et al.* who reported that unproductive cough/FET improved mucociliary clearance (17). However, subjects in that study demonstrated airways obstruction and only five produced greater than 10 g of sputum per day. These factors may have contributed to the subject's failure to expectorate sputum. Our subjects regularly produced in excess of 20 g of sputum per day and their cough was productive.

A meta-analysis comparing airway clearance modalities in patients with cystic fibrosis recommended that future trials of chest physiotherapy have sufficient power to minimize random error and avoid type II error (18). The power of this study was 80%, thus allowing the researcher to be reasonably confident that there is no difference between the two treatments assuming a clinically significant difference of 15% or more of sputum weight.

Subjects were more breathless following treatment in the head-down position possibly due to an increased work of breathing resulting from a resistive loading on the diaphragm from the weight of the viscera (19). Sitting to huff or cough from the head-down position requires more effort than from the horizontal position and this added exertion may have contributed to the increased breathlessness. Ventilation/perfusion mismatching from placing subjects in a position that influences ventilation homogeneity (20) may have contributed to the increase in breathlessness; however, there was no significant desaturation to support this theory. Less breathlessness in the horizontal position allows a more comfortable treatment.

All of the subjects had previously been instructed on the importance of the head-down positioning for the ACBT and this may explain the choice by a third of the group of the head-down treatment being the most effective. The majority, however, preferred treatment in the horizontal position as it was more comfortable, caused less headache, was easier and less tiring. Time and effort required to perform regular airway clearance treatments are factors that contribute to poor adherence (21,22).

## Conclusion

The results of this study indicate that it is preferable to perform the ACBT in positions without a head-down tilt, as it is effective and better tolerated by subjects than in the same positions with a head-down tilt. In practice this means a simpler, more comfortable regimen which may improve adherence in individuals who are advised to carry out daily airway clearance treatments.

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