The effect of huffing and directed coughing on energy expenditure in young asymptomatic subjects

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Coughing and huffing have been shown to be effective airway clearance techniques and some authors have anecdotally reported that a huff requires less energy than a series of coughs commencing and finishing at the same lung volume. The aim of this study was to determine whether there is a difference in the energy expenditure between periods of huffing and directed voluntary coughing commencing from the same initial lung volume in young asymptomatic subjects. Energy expenditure was measured using open-circuit indirect calorimetry equipment. Twenty-four non-smoking asymptomatic subjects (12 male, 12 female, aged 18-24 years), without any form of disease and within 10% of their predicted pulmonary function, completed the study. Energy expenditure was measured over three 10min, randomly ordered sessions of huffing, directed coughing and rest. The forced expiratory sessions comprised a single huff or double-barrel cough (both starting at total lung capacity) at the end of every two minutes. Each session was separated by a 5min washout period. No significant difference in energy expenditure was found between the huffing and directed coughing periods (mean difference 0.003 mL/kg/min (95% CI -0.160 to 0.114) and both produced significantly greater energy expenditure than rest (rest and huff mean difference 0.309 mL/kg/min (95% CI 0.080 to 0.549) and rest and cough mean difference 0.306 mL/kg/min (95% CI 0.074 to 0.508)). The suggested benefits of huffing versus coughing in terms of energy conservation are yet to be shown. **[Pontifex E, Williams MT, Lunn R and Parsons D (2002): The effect of huffing and directed coughing on energy expenditure in young asymptomatic subjects. *Australian Journal of Physiotherapy* 48: 209-213]**

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Introduction

Both coughing and huffing are forced expiratory manoeuvres used for clearing airway secretions. In the clinical setting, huffing can be used in combination with breathing control to form the forced expiration technique. A number of studies have found no difference between the forced expiration technique and directed coughing in terms of sputum volume and isotopic clearance (Hasani et al 1991,1994a and 1994b, Sutton et al 1983). The forced expiratory manoeuvres reported in these studies differed in that the starting lung volumes with cough commenced at or near total lung capacity (TLC), while huffs commenced at or near mid-lung volume and ended close to residual volume (RV; Hasani et al 1991, 1994a and Hasani et al 1994b, Sutton et al 1983). Expiratory manouevres commencing from greater lung volumes might result in similar airways clearance but differ in the energy required to produce the manouevre. Hasani et al (1994b) reported that the peak expiratory airflow resulting from cough and huff differed significantly (359 ± 37 L/min vs 227 ± 34 L/min respectively) suggesting variation in the muscular work required to produce these airflows. Hasani et al (1994a) have claimed that the forced expiration technique required less energy to perform, and Pryor (1991) stated that a huff from a particular lung volume requires less energy than a series of coughs down to the same lung volume. To date, there is no evidence to support these anecdotal claims.

The energy cost of airway clearance techniques in patients with respiratory disease may be the relevant factor when selecting the appropriate therapy. Resting energy expenditure has been shown to be significantly increased in respiratory patients with chronic airflow limitation (CAL) and hypersecretion when compared with asymptomatic subjects (Baarends et al 1997, Bell et al 1996, Buchdahl et al 1988, Goldstein et al 1987, Lanigan et al 1990, Schols et al 1991). The aim of this study was to determine whether there is a difference in the energy expenditure between periods of huffing and directed coughing commencing from the same intial lung volume (TLC) in young asymptomatic subjects.

Methods

Ethical approval was gained from the Women's and Children's Hospital Research Ethics Committee and the University of South Australia's Human Research Ethics Committee.

Twenty-six subjects (13 male, 13 female) aged 18-24 years volunteered to participate in the study. Individual subjects were investigated using a repeated measures design. Data for each subject were collected during a single morning session of 90 minutes duration. Subjects were recruited from the University of South Australia and Adelaide University, and were required to be non-smokers with no history of respiratory or systemic disease. Pulmonary function was assessed in standing using an Erich Jaegar MasterLab (Version 4.0) computerised spirometer and performed as recommended in the American Thoracic Society criteria (American Thoracic Society 1995). Subjects were given clear instructions, and a demonstration of how to perform the forced expiratory manoeuvre. Of the three flow-volume curves performed by each subject, only that with the highest forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) was recorded. Where maximal values were not present within the one curve, a further flow volume curve was performed. Using height and weight measurements for each subject, predicted values were derived from the equations of Hibbert et al (1989) for subjects aged under 18 years, and those of Knudson et al (1976) for those 19 years and over. All subjects were required to be within 10% of their predicted pulmonary function to be included in the study.

Subjects fasted overnight and refrained from vigorous exercise prior to testing. Energy expenditure was measured continuously using open circuit indirect calorimetry. A low dead-space Hans Rudolph exercise mask (Series 7910) was secured on the subject's face, ensuring leak-free contact. The mask had two inspiratory ports and one expiratory port each equipped with one-way valves. One inspiratory port was fitted with a pneumotachometer (Fleisch Size 3, unheated) that measured inspiratory flow and the other with a gas-tight seal. Inspiratory flow was measured at 30 Hz with a Validyne MP-45 pressure transducer and signals were relayed into a Hewlett Packard amplifier (Model 77028) prior to digital integration and conversion to expiratory volume via a standard equation (Ruppel 1991). The expiratory port was connected to a 4L gas mixing box by a wide bore tube. The expired air was sampled from the box, dessicated and analysed throughout the testing period.

The expired oxygen and carbon dioxide concentrations were determined by an Ametek S-3A/1 and Bio Precision B1050-0001 gas analysis systems respectively. A Nelcor 200E oximeter was used to monitor pulse rate and oxygen saturation. Analogue signals were converted via an A-D board (Metrabyte DAS-8) to digital signals for real-time display as well as for analysis and storage. Cumulative values for minute ventilation (volume of air inspired per minute), mean expired oxygen and carbon dioxide concentrations, pulse rate and oxygen saturation were continuously recorded, calculated for each 10s interval and stored on computer using Labtech Notebook software. The inspiratory flow data was then mathematically integrated and corrected to expiratory volume using a standard correction calculation (Ruppel 1991). Energy expenditure (VO_2) and carbon dioxide output (VCO_2) data were corrected for ambient conditions (temperature, humidity, barometric pressure) and for gas transport time delays in the system using purpose-written macros in Microsoft Excel (Version 4). Oxygen consumption and carbon dioxide production were calculated via standard equations and expressed as mean values per minute, corrected for body weight (mean VO_2 mL/kg/min, VCO_2 mL/kg/min, Ruppel 1991).

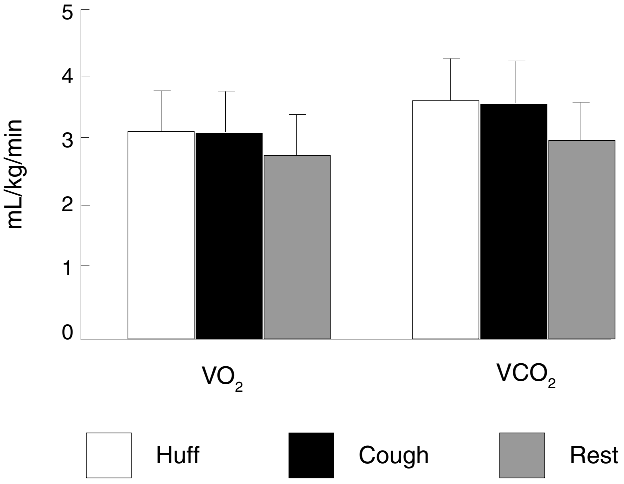

Figure 1. Energy expenditure and carbon dioxide output during the huffing, directed coughing and rest sessions (mean ± SD)

The calorimetry equipment components were calibrated daily against known standards. In adherence with the American Thoracic Society standards (Ruppel 1991), the flow and volume analysis was accurate to within 3% of known gold standards: a GEC-Elliot Rotameter (20-200L/min) for flow and a Hans Rudolph 3L calibration syringe for volume. Gas concentrations were calibrated against a β-standard gas mixture to within 0.5%.

Each subject was given the opportunity to practise the techniques of double-barrel coughing and huffing following demonstration by the investigator (at least 30 minutes before testing). The investigator provided feedback during this time to optimise performance during testing. Subjects were positioned in 45 degrees upright supported sitting on a plinth and maintained this position for the entire testing period. The facemask was fitted to the subject, connected to the gas analysis equipment and checked to ensure the absence of air leaks. A Nelcor 200E oximeter was attached to the subject's index finger and data for pulse rate and oxygen saturation were continuously recorded. The subject rested for 10-15 minutes to allow for stabilisation of the equipment and saturation of the mixing box with expired air. The data collection period took place over 40 minutes. This time was divided into three 10min measurement sessions: rest, directed cough and huff. The sessions were separated by 5min washout periods as empirical trials of the procedure showed this period allowed the subject's VO_2 to return to their baseline level, thereby reducing the possibility of carry-over effect. The order of the three measurement sessions was randomised using two mutually orthogonal Latin Squares.

Throughout the 10min rest session, the subject was advised to relax as much as possible and minimise body movement. Oxygen uptake, VCO_2, minute ventilation (V_EL/min), pulse rate (PR beats/min) and percutaneous oxygen saturation (SpO_2 %) were continuously recorded.

Table 1. Responses for test parameters during the huffing, directed coughing and rest sessions (mean ± SD)

	Huffing	Coughing	Rest
VO_2 mL/kg/min	3.04 ± 0.57	3.03 ± 0.62	2.72 ± 0.60
VCO_2 ml/kg/min	3.51 ± 0.64	3.48 ± 0.65	2.92 ± 0.57
V_E L/min	7.45 ± 1.61	7.29 ± 1.49	6.16 ± 1.43
PR beats/min	68.05 ± 11.26	68.06 ± 11.34	66.84 ± 10.72
SpO_2 %	97.69 ± 1.23	97.75 ± 1.16	97.30 ± 1.38

VO_2 ml/kg/min = oxygen consumption, VCO_2 mL/kg/min = carbon dioxide production, V_E L/min = minute ventilation, SpO_2 = oxygen saturation, PR = pulse rate.

Table 2. Mean differences (95% CI) for each of the test variables between the huffing, directed coughing and rest sessions.

	Cough vs Rest	Huff vs Rest	Cough vs Huff	LSD
VO_2 mL/kg/min	0.309* (0.080 to 0.549)	0.306* (0.074 to 0.508)	0.003 (-0.160 to 0.114)	0.178
VCO_2 mL/kg/min	0.547* (0.292 to 0.800)	0.560* (0.273 to 0.803)	-0.013 (-0.175 to 0.126)	0.215
V_E L/min	1.131* (0.650 to 1.614)	1.207* (0.600 to 1.737)	-0.076 (-0.416 to 0.265)	0.433
SpO_2 %	0.450* (0.132 to 0.675)	0.393* (0.102 to 0.590)	0.057 (-0.142 to 0.257)	0.204
PR beats/min	1.21 (-0.170 to 2.608)	1.20 (-0.070 to 2.490)	0.01 (-0.869 to 0.887)	1.212

* denotes a significant difference between the test session means ($p < 0.05$), LSD = least significant difference.

During the directed cough and huff sessions, subjects performed one double-barrel cough or one huff as appropriate from total lung capacity every two minutes for the 10min session. The double- barrel cough consisted of a deep inspiration followed by two cough manoeuvres without an second inspiration between each cough. Each huff was a single continuous forced expiration through an open mouth. The VO_2, VCO_2, V_E, PR, and SpO_2 were continually recorded. A stopwatch was used to maintain accurate timing and, when appropriate, the subject was verbally informed by the researcher to perform the cough. The subject rested quietly in between manoeuvres and interaction between the researcher and subject was minimised. The same investigator performed all studies on all subjects.

Once testing was completed, the mask and oximetry were removed from the subject. As bronchospasm is a possible complication of forced expiratory manoeuvres, subjects were then required to repeat the pulmonary function testing procedure as a safety measure to verify the patency of their airways.

Data analysis Three repeated measures analyses of variance (ANOVA) were performed using the statistical package Genstat (Payne et al 1993). In the first analysis, data were included for interventions and treatment-by-period interaction. The second analysis included data for interventions and carry-over effects with interventions being adjusted for carry-over. In the third analysis, data were again included for interventions and carry-over effects with carry-over adjusted for interventions. The calculations were then organised into an ANOVA table with *p*-values used to detect period-by-interaction effects, carry-over effects and treatment differences. Probabilities of < 0.05 were considered significant. The multiple comparison ANOVA procedure also detected a least significant difference (LSD) value for each test parameter. This represents the minimum difference between the means that would have been necessary for detection of a significant result. If the treatment session means for a particular parameter differed by more than the LSD, then this difference was judged to be statistically significant.

The desired sample size was based on an orthogonal statistical design. A sample size of 24 was calculated using VO_2 as an outcome variable with a Type I error of 0.05, Type II error of 0.20 (statistical power of 80%), an inherent variability in asymptomatic subjects of 15% (Williams 1997) and accepting a difference of 10% to be considered clinically significant (SigmaStat, Jandel Scientific; San Raphael California).

Results

Twenty-four subjects (12 male, 12 female) completed the study. Two additional subjects were excluded due to their pulmonary function results not being within 10% of their predicted values. The mean (± SD) age was 22.0 (1.5) years, height 174.2 (9.5) cm, and weight 71.9 (15.1) kg. No period-by-interaction or carry-over effects were identified ($p > 0.05$) for any of the test parameters indicating there was no apparent bias relating to the session number during which an intervention group was undertaken, nor was any intervention group observed to be significantly affected by participating in the preceding activity.

Figure 1 shows the mean (SD) values for the VO_2 and VCO_2 variables and Table 1 contains the mean (SD) values for all variables measured during the huffing, coughing and rest sessions. Table 2 contains the differences between each of the means for the three intervention sessions.

It can be seen from Figure 1 and Table 2 that the coughing and huffing sessions had significantly greater energy expenditure than rest ($p < 0.05$). Similar significant increases were seen for VCO_2, V_E and SpO_2 during the forced expiratory manoeuvre sessions when compared with rest. No significant differences were found between the directed coughing and huffing sessions for any of the test parameters ($p > 0.05$). Pulse rate showed no significant difference between any of the sessions.

In terms of pulmonary function, three subjects showed a reduction in their post-testing procedure FVC and FEV_1 values, with the largest drop being 0.09L for FVC and 0.12 L/sec for FEV. A paired two sample *t*-test demonstrated no significant difference between the pre-test and post-test mean FVC ($p = 0.70$) and mean FEV_1 ($p = 0.18$).

Discussion

Directed coughing sessions have been shown to significantly increase energy expenditure compared with rest in asymptomatic subjects (Holland et al 1998), however no previous study has compared the relative effects of both huffing and directed coughing on VO_2 in any population. Detrimental pulmonary effects have been reported for directed coughing in both asymptomatic and sympomatic populations. Using flow-volume loops, Holland et al (1998) showed that a 20min session of one double-barrel cough every two minutes increased airways obstruction in asymptomatic subjects. The effects of chest physiotherapy (including directed coughing) on airways obstruction was studied in a group of 24 patients with cystic fibrosis (Zapletal et al 1983). These authors demonstrated that while chest physiotherapy decreased airways resistance, presumably by removing secretions, it also resulted in compression and collapse of the central airways during the cough component of the treatment. While subjects symptomatic for respiratory disease would have provided more clinically relevant information, this initial study involved only asymptomatic subjects in order to provide normative data that would allow a comparison data set for further studies of subjects with chronic respiratory disease.

In comparison with rest, the energy expenditure of the asymptomatic subjects significantly increased during the sessions of directed coughing (11%) and huffing (12%) to approximately 3 mL/kg/min. This was an expected result as any exercise, including the increased respiratory muscle work produced during expiratory manoeuvres, elevates oxygen uptake above the resting level. While the mean value for resting oxygen consumption within this current study was lower ($VO_2 = 2.72$ (± 0.60) mL/kg/min) than the commonly reported value of 3.5 mL/kg/min, the standard deviations fall within the range of values reported by previous investigators such as Cropp and Rosenberg (1981) who found resting oxygen consumption in normal young subjects to be 3.16 mL/min/kg ± 0.20. Comparing these data with those reported by McArdle et al (1991), the VO_2 during a session of forced expiratory manoeuvres is less than half the energy expended during a light walk which is 6-15 mL/kg/min, and a fraction of the 20-30 mL/kg/min consumed during a heavy run. As resting oxygen consumption is increased in people with chronic respiratory disease (Baarends et al 1997, Bell et al 1996, Buchdahl et al 1988, Goldstein et al 1987, Lanigan et al 1990, Schols et al 1991) and since multi-modality respiratory physiotherapy including cough and huff, results in increases in energy expenditure compared with rest (Williams et al 2000, Williams et al 2001), it could be postulated that patients with respiratory dysfunction would experience a greater percentage increase in VO_2 than asymptomatic subjects when performing the forced expiratory manoeuvres in isolation, that is without periods of relaxed breathing.

This study found no significant difference in energy expenditure between the directed coughing and huffing sessions. This finding contradicts the anecdotal reports of Hasani et al (1994a) and Pryor (1991) who stated that huffing required less effort to perform than directed coughing. Since directed coughing produces higher transpulmonary pressure than huffing from the same lung volume, it could be hypothesised that coughing is likely to require greater force and tension to be produced by the expiratory musculature and would consume more energy than huffing. However, the results of this study suggest that this is not the case, at least in an asymptomatic population.

The anecdotal comments by Hasani et al (1994a) and Pryor (1991) that huffing required less effort than coughing were based on observations of patients with respiratory dysfunction. These patients are likely to be very familiar and well practised at the techniques of airway clearance and may be more efficient than asymptomatic subjects in terms of expiratory muscle recruitment for both forced expiratory manoeuvres, particularly huffing, and therefore require less concentration to carry them out effectively. Coughing can be a reflex process that proceeds according to a fixed pattern. However, huffing is not a reflex process and, for an asymptomatic individual, is more of a novel task than coughing. With any novel task, there is a strong initial influence of motor learning which can result in a variable performance of the new task initially. It is possible that the energy consumed by an asymptomatic subject performing a huff may be elevated due to inefficient muscle recruitment patterns. Therefore even though coughing is likely to demand greater muscle activity, huffing in asymptomatic subjects is likely to be a more demanding motor skill, which may account for the equal energy consumed during the periods of huffing and directed coughing in these subjects.

In conclusion, this study in asymptomatic subjects does not support the anecdotal reports that huffing requires less energy than directed coughing from the same lung volume. In order to fully address whether huffing requires less effort than directed coughing, comparison studies need to be repeated in a patient population. Such studies would also provide a better indication as to whether huffing can be recommended as a more energy efficient technique to directed coughing in respiratory patients with elevated resting energy consumption.

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