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ORIGINAL ARTICLE

Analysis of Clinicians' Perceptual Cough Evaluation

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Abstract This study examined the relationships between subjective descriptors and objective airflow measures of cough. We hypothesized that coughs with specific airflow characteristics would share common subjective perceptual descriptions. Thirty clinicians (speech-language pathologists, otolaryngologists, and neurologists) perceptually evaluated ten cough audio samples with specific airflow characteristics determined by peak expiratory flow rate, cough expired volume, cough duration, and number of coughs in the cough epoch. Participants rated coughs by strength, duration, quality, quantity, and overall potential effectiveness for airway protection. Perception of cough strength and effectiveness was determined by the combination of presence of pre-expulsive compression phase, short peak expiratory airflow rate rise time, high peak expiratory flow rates, and high cough volume acceleration. Perception of cough abnormality was defined predominantly by descriptors of breathiness and strain. Breathiness was characteristic for coughs with either absent compression phases and relatively high expiratory airflow rates or coughs with significantly low expired volumes and reduced peak flow rates. In contrast, excessive strain was associated with prolonged compression phases and low expiratory airflow rates or the absence of compression phase with high peak expiratory rates. The study participants reached greatest agreement in distinguishing between single and multiple coughs. Their assessment of cough strength and effectiveness was less consistent. Finally, the least agreement was shown in determining the quality categories. Modifications of cough airflow can influence perceptual cough evaluation outcomes. However, the inconsistency of cough ratings among our participants suggests that a uniform cough rating system is required.

Keywords Voluntary cough · Clinical/bedside assessment · Dysphagia · Cough perception · Cough airflow · Airway protection

Introduction

Cough is a protective mechanism generated to remove penetrant or aspirate material from the airways. A typical cough consists of three consecutive phases: inspiratory, compression, and expiratory phases. The inspiratory phase involves vocal fold abduction and contraction of inspiratory pump muscles to increase the volume of air in the lungs. The cough compression phase is marked by glottal closure accomplished by adduction of the true and the ventricular vocal folds. During this period, intrathoracic and subglottal pressure increase below the closed glottis. Finally, the expiratory phase includes rapid glottal opening and a burst of expiratory air reaching high flow rates through the opened airways. This is coincident with expiratory muscle contraction that occurs throughout the compression and expiratory phases. Therefore, sensory and/or motor dysfunction of the laryngeal or respiratory subsystems may cause impairment to the cough mechanism

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that decreases the effectiveness of cough to clear material from the airways [1, 2].

Objective measures of voluntary cough can be analyzed from cough airflow waveforms and cough acoustic signals (Fig. 1). Both methods of cough measurement have been studied for their sensitivity and specificity in identifying different aspects of airway dysfunction [1, 2]. For example, in the study of Smith-Hammond et al. [2], expiratory phase airflow parameters such as peak expiratory airflow rise time (PEFRT), cough volume acceleration (CVA), and peak expiratory airflow rate (PEFR) were found to be predictors of aspiration in stroke patients with sensitivities of 91, 91, and 82 %, and specificities of 81, 92, and 83 %, respectively. Abaza et al. [3] measured the acoustic and airflow properties of voluntary cough associated with normal and abnormal pulmonary function with the classification accuracy of 94 % for female and 97 % for male participants.

Studies have shown that the acoustic parameters of cough can reflect changes in airflow dynamics [4, 5]. Thus, analyzing both the acoustic and airflow characteristics of a voluntary cough have been found to help identify abnormal respiratory function associated with asthma or chronic obstructive pulmonary disease (COPD) [3, 6, 7]. Similarly, the examination of the acoustic properties of reflex cough has been used to detect excessive mucus in the airways or wheezing, but further validation of this acoustic analysis is needed [8]. Finally, voluntary cough airflow has been analyzed to predict the degree of airway compromise during swallowing in persons with Parkinson's disease (PD) [9]. In addition to specific cough airflow parameters which indicate risk of penetration-aspiration in this patient population, studies have shown differences between sequential voluntary cough patterns produced by PD participants with and without dysphagia [10]. Further, the airflow analysis of voluntary and reflexive cough in patients with PD showed reduced cough peak expiratory flow rate (PEFR) and cough expired volumes (CEV) in reflex cough [11]. Given that both swallowing and coughing are airway protective mechanisms that share components of the sensorimotor system [12], we can expect that reduced ability to detect and/or eject materials from the airways may indicate tandem impairments in airway protection during swallow. Therefore, developing a reliable method for reflex and voluntary cough assessment is particularly important for early identification of patients at risk of aspiration.

Despite the ongoing investigation of objective assessment tools, most clinicians still rely on auditory perception of voluntary or reflex cough to assess cough "strength,"

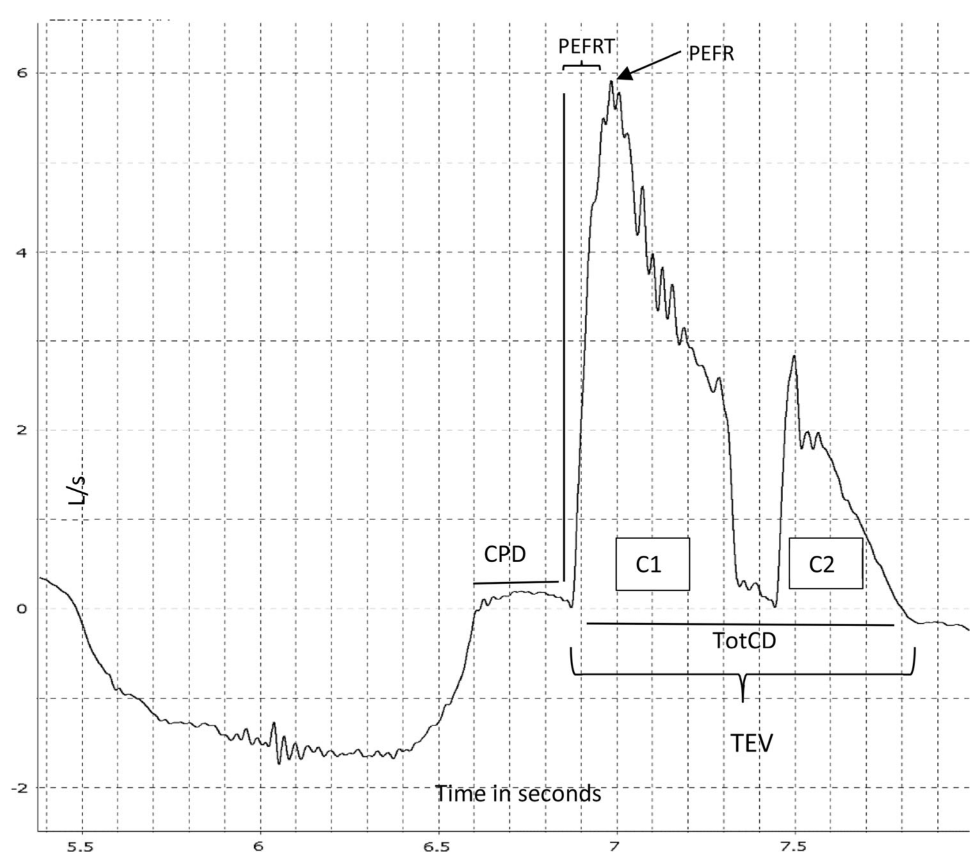

Fig. 1 Cough airflow measures. *CPD* compression phase duration (s); *PEFR* peak expiratory flow rate (L/s); *PEFRT* peak expiratory flow rise time (s); *TEV* total expired volume (L); *C1*, *C2* a first and a second cough in the epoch respectively; *TotCD* total cough duration (s)

and use variable, non-systematic terminology to describe and to report cough impairments. The evidence of disagreements in perceptual assessment of reflex cough has been recently reported in literature [13–16]. Nevertheless, subjective identification of a "weak" or "abnormal" cough is commonly used as a clinical indicator of an airway protection deficit, yet it remains unknown how perceptual descriptors of cough actually relate to objective measures of cough airflow and cough effectiveness.

The aim of this study was to examine the relationship between the subjective ratings of cough samples assigned by clinicians and the objective airflow dynamics of those cough samples. Our goal was to determine whether specific subjective descriptors of cough function reflected actual cough airflow characteristics, which commonly serve as indicators of cough effectiveness. We hypothesized that coughs with specific airflow characteristics would share common perceptual descriptions.

Methods

Data Collection and Equipment

The study was approved by the University of Florida Institutional Review board (IRB-02). Six members of the investigative team produced 10 voluntary expiratory maneuvers (nine coughs and one throat clear) according to specific criteria (Table 1). These criteria for cough samples were formulated to achieve particular cough airflow patterns emphasizing at least one specific cough airflow component that would differentiate a particular cough from the rest of the cough samples. For example, the investigators targeted high peak airflow for the "forceful cough" (number 3 in Table 1). Although a throat clearing is not a cough, it is an airway clearance maneuver that patients often produce, and thus, the airflow parameters of this maneuver are included in the study analysis.

Table 1 Pre-recording criteria for each cough audio sample

Cough number	Pre-recording criteria
1	A cough produced after maximum inhalation to total lung capacity (TLC)
2	A single cough produced after forced exhalation to residual volume (RV)
3	A forceful cough with a long compression phase
4	A cough with a long post-peak plateau phase
5	A single cough without a compression phase
6	Throat clearing maneuver
7	Multiple coughs after maximum inhalation to TLC
8	Multiple coughs after maximum exhalation to RV
9	Effortful expiratory maneuver
10	Discoordinated expiratory maneuver

A total of 60 samples (50 coughs and 10 throat clears) were collected. The audio samples of the expiratory maneuvers were recorded using a portable digital voice recorder (Olympus WS-6005) with a built-in microphone held at the mouth level with a mouth-microphone distance of one inch during cough airflow collection. Acrobat Audition software was used for audio sample formatting for presentation. Simultaneously, cough airflow was collected using a disposable facemask coupled to a filter, in line with a respiratory flow head (MLT1000; ADInstruments, Inc.) connected to a digital spirometer (FE141; ADInstruments, Inc). The airflow signal was digitized and then recorded (PowerLab 16/35 ADInstruments), and saved with LabChart 7 software to allow for offline airflow measurement. Samples were low-pass filtered at 60 Hz.

Cough Selection and Airflow Analysis

The investigators selected 10 out of the 60 cough samples (nine coughs and one throat clear) that varied in terms of number of coughs in the cough sequence (single versus multiple), the airflow rates, expired volumes, and durations of cough phases, and that were felt to best represent the airflow patterns targeted a priori. The airflow parameters were analyzed in order to determine the following variables: total number of coughs (CrTot), total expired volume (TEV) in the cough epoch in liters (L), total cough epoch duration (TotCD) in seconds (s) measured from the beginning of the expiratory phase of the first cough, peak expiratory flow rate (PEFR) in liters per second (L/s), peak expiratory flow rise time (PEFRT) in seconds (s), cough volume acceleration (CVA) calculated as a ratio of PEFR/PEFRT in liters per second per second (L/s/s), and compression phase duration (CPD) in seconds (s). In cases where more than one cough was produced, PEFR, PEFRT, CVA, and CPD were measured only in the first cough in the sequence (Fig. 1; Table 2).

Perceptual Cough Assessment by Clinicians

Thirty clinicians, who routinely assess cough function (typically during swallowing evaluations), were recruited for this study. The following clinicians' demographic information was collected: gender, profession, healthcare settings (outpatient, inpatient, or both), patient population they treat (adult, pediatric, or both), and number of years of clinical practice (Table 3). Cough audio samples were presented in random order using Microsoft 2010 Power Point Presentation on a laptop computer. No cough rating

Table 2 Airflow parameters of the cough samples

Cough number	1	2	3	4	5	6	7	8	9	10
CrTot	2.00	1.00	1.00	2.00	1.00	2.00	7.00	5.00	1.00	3.00
CPD (s)	0.27	0.11	0.29	0.34	0.00	0.27	0.22	0.38	0.00	0.63
PEFR (L/s)	5.91	4.20	4.71	5.99	5.77	4.81	7.60	3.78	6.78	2.45
PEFRT (s)	0.12	0.04	0.07	0.06	0.18	0.08	0.09	0.03	0.11	0.26
CVA (L/s/s)	49.24	105.03	72.38	99.91	32.07	60.15	84.41	126.15	61.6	9.43
TEV (L)	2.13	0.65	1.16	2.51	2.21	1.17	3.3	0.55	2.02	2.25
TotCD (s)	0.90	0.50	0.60	1.40	1.00	2.60	2.70	1.50	3.00	2.50

CrTot total number of coughs/expiratory events following a single inhalation; *CPD* compression phase duration (s); *PEFR* peak expiratory flow rate (L/s); *PEFRT* peak expiratory flow rise time (s); *CVA* cough volume acceleration (L/s/s); *TEV* total expired volume (L); *TotCD* total cough duration (s)

Table 3 Participants' demographic information

Demographics		*N* (%)
Gender	Female	21 (70)
	Male	9 (30)
Profession	Speech-language pathologist	23 (77)
	Otolaryngologist	4 (13)
	Neurologist	3 (10)
Patient population	Pediatric	2 (7)
	Adult	19 (63)
	Adult and pediatric	9 (30)
Practice settings	Inpatient	4 (13)
	Outpatient	14 (47)
	Inpatient and outpatient	12 (40)
Clinical experience (y)	Range	39.9
	Minimum	0.1
	Maximum	40
	Mean	10.5
	Median	7.5
	Mode	6

y years

training was provided for the participants. Each clinician listened to 10 cough audio samples via head phones. The volume for audio presentation was set to a comfortable loudness level for the participant and was not modified during the assessment session. Each clinician was allowed to listen to an audio sample no more than two times.

Clinician participants provided their responses on assessment forms containing cough descriptors grouped into five categories: overall effectiveness for airway protection (effective, ineffective), strength (weak, strong), cough duration (short, long), quantity (single, multiple), and quality (breathy, strained, effortful, discoordinated, normal, huffing, wet, throat clearing). One response was required for each category, except for "quality," when the participants were allowed to use more than one descriptor (Appendix). Regardless of the number of presentations (one or two) of one audio sample, the participants rated each cough sample only one time.

Statistical Analysis

A software statistical package (IBM SPSS Statistics 21.0) was used to generate descriptive statistics for both the subjective descriptors given to each cough sample and the airflow parameters of the coughs. The coughs were then classified according to common perceptual characteristics (i.e., effective, strong, breathy, etc.). These were then analyzed descriptively in order to identify which quantitative cough airflow measures aligned with the qualitative descriptors. Qualitative descriptors used with a frequency of less than 30 % in the cough perceptual assessment were excluded from the analysis.

Results

Thirty clinicians assigned specific perceptual descriptors to the audio presentations of ten cough samples. The cough ratings are presented in Table 4. The airflow parameters measured for each of the 10 coughs were grouped by shared perceptual characteristics (Table 5). A cough was classified as strong or weak, effective or ineffective based on perception of strength and effectiveness reported by 60 % or more of the raters. Following this criterion, four coughs were classified as strong and effective, five as weak and ineffective, and one cough was classified as undetermined. The most frequently used quality descriptors in cough assessment were those of breathiness, strain, effort, and normality. Qualitative descriptors of discoordination, huffing, wheezing, and wetness were used with a frequency of less than 30 % and subsequently excluded from further analysis.

The aerodynamic parameters distinctive for coughs with the highest perception of strength and effectiveness were CPD (0.22–0.34 s), PEFR (4.71–7.60 L/s), PEFRT

Table 4 Clinicians rating of cough audio samples

Cough number		1	2	3	4	5	6	7	8	9	10
Strength	Weak	46.7	83.3	6.7	26.7	90.0	10.0	10.0	66.7	66.7	73.3
	Strong	53.3	16.7	93.3	73.3	10.0	90.0	90.0	33.3	33.7	26.7
Effectiveness	Ineffective	46.7	76.7	20.0	33.3	93.3	20.0	26.7	76.7	90.0	80.0
	Effective	53.3	23.3	80.0	66.7	6.7	80.0	83.3	23.3	10.0	20.0
Duration	Short	76.7	100.0	66.7	23.3	76.7	43.3	26.7	56.7	36.7	13.3
	Long	23.3	0.0	30.0	76.6	23.3	56.7	73.3	40	63.3	86.7
Quality	Breathy	43.3	43.3	10.0	40.0	70.0	3.3	17.2	36.7	26.7	36.7
	Strained	6.7	3.3	30.0	40.0	6.7	20.0	20.0	13.3	53.3	66.7
	Effortful	20.0	6.7	20.0	26.7	3.3	3.3	6.7	10.0	30.0	10.0
	Throat clear	0.0	3.3	13.3	0.0	3.3	53.3	3.3	3.3	10.0	16.7
	Normal	26.7	30.0	33.3	6.7	0.0	26.7	53.3	23.3	3.3	3.3
Quantity	Single	53.3	93.3	80.0	20.0	90.0	0.0	3.3	3.3	16.7	10.0
	Multiple	46.7	6.7	20.0	80.0	10.0	100.0	96.7	96.7	83.3	90.0

The numeric values represent percentage (%) of clinicians assigning specific perceptual descriptors to each cough sample

Table 5 Airflow parameters of coughs grouped by perception of strength and effectiveness as determined by at least 60 % of raters

Strength/effectiveness	Strong and effective				Weak and ineffective					Undetermined
Quality (% raters)	N(33)	N(53.3)	B/S(40)	TC (53.3)	B(43.3)	B(36.7)	B(70)	S(53.3)	S(66.7)	B (43)
Cough number	3	7	4	6	2	8	5	9	10	1
CrTot	1	7	2	2	1	5	1	1	3	2
CPD (s)	0.29	0.22	0.34	0.27	0.11	0.38	0	0	0.63	0.27
PEFR (L/s)	4.71	7.6	5.99	4.81	4.2	3.78	5.77	6.78	2.45	5.91
PEFRT (s)	0.07	0.09	0.06	0.08	0.04	0.03	0.18	0.11	0.26	0.12
CVA (L/s/s)	72.38	84.41	99.91	60.15	105.03	126.15	32.07	61.6	9.43	49.24
TEV (L)	1.16	3.3	2.51	1.17	0.65	0.55	2.21	2.02	2.25	2.13
TotCD (s)	0.6	2.7	1.4	2.6	0.5	1.5	1	3	2.5	0.90

Coughs defined as *B* breathy, *N* normal, *S* strained, or *TC* throat clear based on the highest ratings provided by the study participants

*CrTot t*otal number of coughs/expiratory events following a single inhalation; *CPD* compression phase duration (s); *PEFR* peak expiratory flow rate (L/s); *PEFRT* peak expiratory flow rise time (s); *CVA* cough volume acceleration (L/s/s); *TEV* total expired volume (L); *TotCD* total cough duration (s)

(0.06–0.09 s), CVA (60.15–99.91 L/s/s), and TEV (1.16–3.3 L). A group of strong and effective coughs included a throat clear (Fig. 2; Table 5).

Coughs perceived as weak and ineffective represented a wide range of airflow characteristics (Table 5). However, three subsets of coughs were identified among coughs rated as week and ineffective based on their common aerodynamic characteristics. Subset 1 consisted of two coughs (number 2 and 8) characterized by relatively low values of PEFR (3.78–4.20 L/s) and the lowest values of TEV (0.55–0.56 L) among all the cough samples. In addition, both coughs received high ratings of breathiness (43.3 and 36.7 %, respectively). Subset 2 included two coughs (number 5 and 9) which shared a parameter of CPD = 0 and were produced with high values of TEV (2.13–2.51 L). Within this subset, cough number 5 received the highest ratings of breathiness among all cough samples (70 %), while cough 9 was perceived as both strain and breathy by 53 % raters. The third subset within the group of weak and ineffective coughs included only one cough (number 10) which received the highest ratings of strain among all the cough samples (66.7 %). This cough exhibited a highest CPD (0.63 s) and a lowest values of PEFR (2.45 L/s), and CVA (9.43 L/s/s) among all the cough samples, and was produced with a longest PEFRT (0.26 s) and a high TEVs (2.25 L) expelled within a relatively long TotCD (2.5 s) (Fig. 3; Table 5).

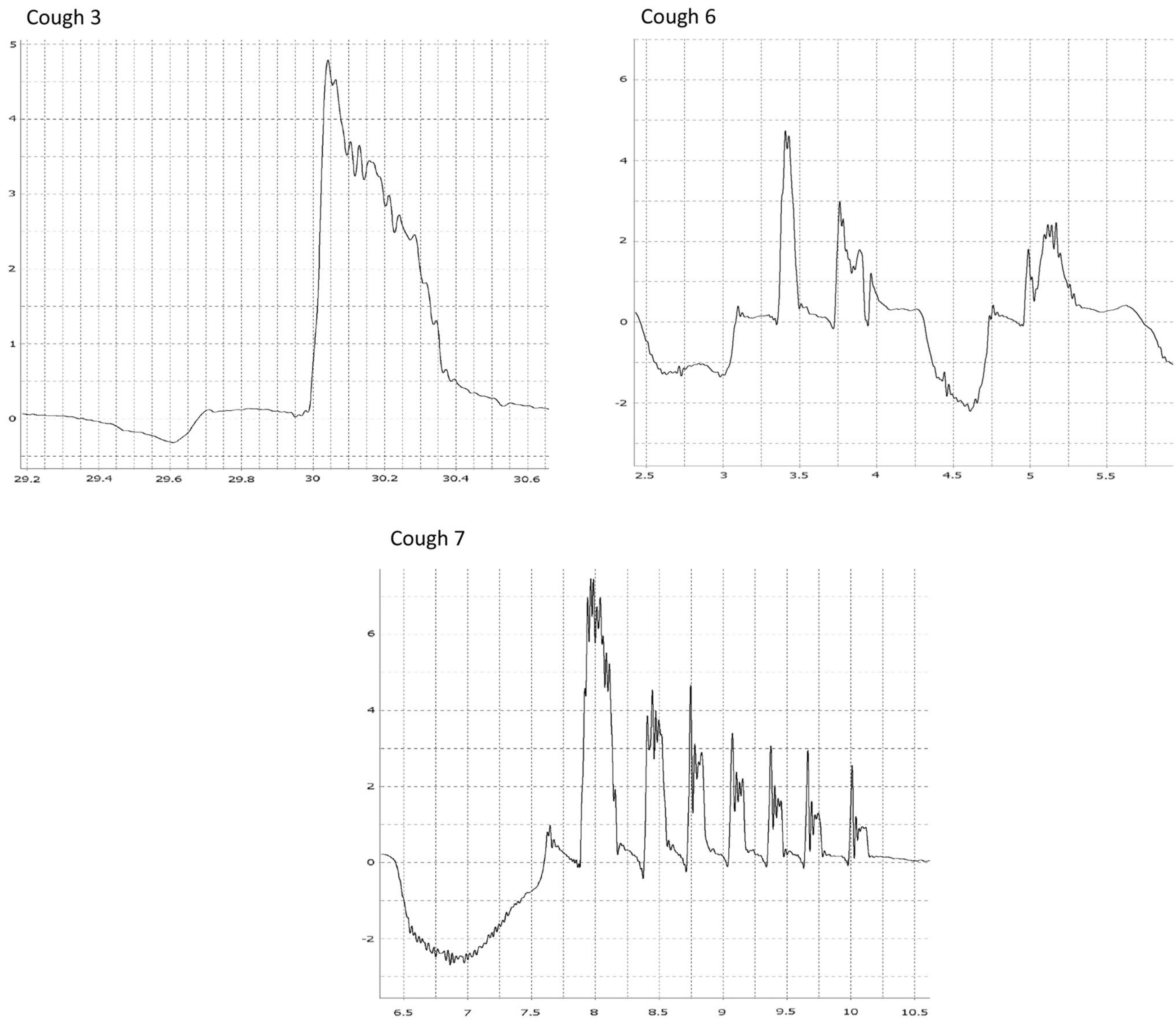

Fig. 2 Examples of cough airflow patterns with the highest frequency ratings of *strength* and *effectiveness*

Discussion

The purpose of this study was to examine the relationships between the perceptual classification of cough and objective cough airflow parameters. It was hypothesized that coughs with similar airflow parameters would share common perceptual characteristics as judged by health care professionals with experience subjectively rating either reflex or voluntary cough. In this study, perception of cough effectiveness reported by the clinicians was associated with perception of cough strength. According to the ratings provided by study participants, a combination of high values of peak expiratory airflow rate (PEFR), cough volume acceleration (CVA), and total expiratory volume (TEV) was characteristic of strong and effective coughs, when there was a compression phase. This constellation of airflow parameters is considered to be indicative of cough effectiveness. Thus, these data suggest that clinicians were adept at identifying coughs that are capable of clearing material from the airway.

One of the expiratory maneuvers perceived to be strong and effective by a majority of participants was a throat clear. A throat clear differs from cough in two aspects: it can be initiated without an inspiratory phase and does not require complete glottal closure [17]. However, a throat clear is often used successfully to remove residue or mucus remaining at the laryngeal level through a series of air expulsions through the partially

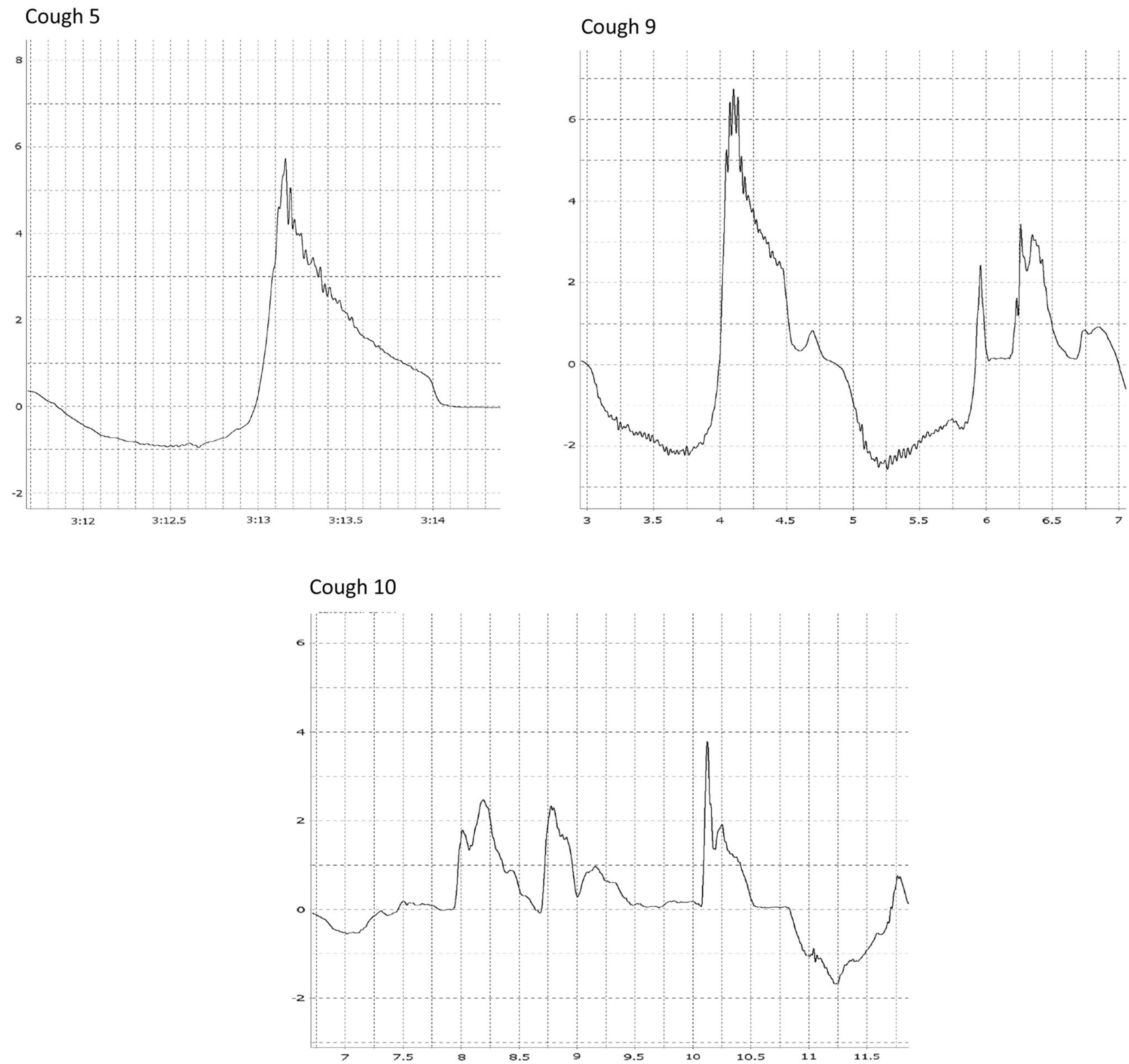

Fig. 3 Examples of cough airflow patterns with the highest frequency of ratings as *weak* and *ineffective*

adducted vocal folds. In fact, high airflow rates may be achieved without large inspiratory volumes if adequate narrowing of the glottis is achieved throughout the entire expiratory phase of a throat clear. It is uncertain whether a throat clear alone can be sufficient for clearing the lower airways from aspirants.

Coughs perceived as weak, ineffective, and breathy by the clinicians were characterized with low values of at least one of these parameters (PEFR, CVA, or TEV) and/or the absence of the compression phase compared to coughs with low ratings of breathiness. Production of coughs with a breathy quality may indicate impairments within respiratory and/or laryngeal subsystems. For example, dysfunction of the respiratory subsystem characterized by chest wall rigidity and/or reduced ability to recruit respiratory muscles may significantly reduce lung volumes and expiratory flow rates in cough. Coughs produced with low expired volume and/or low airflow rates may be inadequate for airway clearance [9]. Moreover, reduced values of PEFR may be an indicator of a risk of aspiration in patients with dysphagia. A study by Pitts et al. [9] showed that people with PD who aspirated during a videofluoroscopic swallow study (VFSS) demonstrated significantly reduced values of PEFR in voluntary cough compared to non-aspirators. Similarly, in the study by Smith-Hammond et al., [2], a combination of reduced PEFR (<2.9 L/s), increased PEFRT (>0.067 s), and subsequently reduced CVA (CVA $<$ 33 L/s/s) was indicative of aspiration during swallowing in a cohort of stroke patients. Neither of these two studies included laryngeal function assessment of the study participants, so it remains unclear whether the voluntary cough impairments were associated with respiratory or laryngeal dysfunction.

In our study, coughs produced without compression phases and with longer PEFRTs were most frequently rated as "breathy" or "strained," respectively. The compression phase and PEFRT are thought to reflect laryngeal function (or dysfunction), and studies suggest that the respiratory subsystem may compensate by producing higher expiratory airflow rates and expired volumes. For example, in the study of Fontana et al. [18], laryngectomized patients demonstrated significantly greater values of PEFRT and lower values of CVA in both voluntary and reflex coughs compared to healthy controls. Additionally, laryngectomized patients showed extended activation of the expiratory muscles during maximal voluntary and reflex coughs. Interestingly, the differences in voluntary cough PEFR between groups, although significant, were smaller than those in reflex cough [18]. This finding suggests that in the absence of laryngeal contribution, the prolonged abdominal muscle contractions play an important compensatory role in creating high PEFRs which potentially increases cough effectiveness. The attempt to achieve longer durations of the expulsive phase to maintain high cough flow rates may create a perception of cough strain. In our study, coughs with the highest ratings of strain were mostly produced with longer expiratory phase durations. However, it is not clear what other characteristics of cough samples influenced the participants' perception of strain.

The subjective nature of perceptual cough evaluation resulted in many inconsistent ratings of coughs in the current study. For example, only half of the raters accurately identified the throat clearing maneuver. It may suggest that there are clinicians who do not demonstrate full understanding of the differences between respiratory maneuvers. The participants reached greatest agreement in differentiating between single coughs and multiple coughs; however, some raters still demonstrated difficulties in this type of assessment, potentially due to confusion between a cough epoch and a single cough. Therefore, it is important to establish uniform terminology in assessment of cough quantity. The clinicians reached moderate agreement in assessing cough strength, effectiveness, and cough duration. It was observed that coughs with high ratings of strength received the same ratings of effectiveness. Disagreements in judging cough duration could be related to the lack of definition of short or a long cough. Finally, greatest inconsistencies were shown in determining the quality categories such as strain, breathiness, effort, and normality. The lack of strong agreement in perceptual assessment of cough strength and quality may be determined by the fact that the participants lacked a specific training in cough physiology prior to the assessment.

Miles and Huckabee [13] assessed the intra- and inter-reliability of perceptual assessment of coughs evoked by citric acid inhalation. Speech-language pathologists with different levels of experience in cough reflex testing reported cough presence or absence and cough strength after watching video clips of patients responding to the airway irritant. Raters demonstrated fair to moderate agreement in overall perceptual cough assessment. They showed more consistent judgement in reporting cough absence than in identifying cough strength. The inter-rater agreement was stronger in identifying strong coughs than weak coughs. However, the results showed fair agreement in identifying strong coughs and poor agreement in detecting weak coughs. According to the qualitative responses given by the participants, the difficulty with perceptual cough assessment was often associated with the lack of understanding cough definition or the differences between cough and throat clearing, and inadequate experience/practice in perceptual cough assessment. A second study conducted by Miles and colleagues [14] was testing a training effect on the intra/inter-rater agreement in cough assessment. According to the authors, the training factor did not result in significant improvement of the perceptual assessment of cough evoked by the airway irritant. Therefore, it was suggested that perception of cough presence and strength is not a reliable tool in assessing the degree of airway defensive abilities. Our study results, in agreement with the outcomes reported by Miles and colleagues, showed lack of agreement primarily in perceptual characteristics of impaired cough and poor understanding of the differences between cough and other respiratory events.

Similar discrepancies were reported in a study by Smith et al. [8] who analyzed healthcare professionals' perceptual descriptions of adult cough sounds in relation to associated acoustic properties of the coughs. Coughs were produced spontaneously by patients with common respiratory conditions such as COPD, asthma, idiopathic pulmonary fibrosis (IPF), laryngitis, and bronchiectasis. Clinicians used descriptors of cough sounds provided in a questionnaire and were asked to make diagnoses of respiratory conditions based on cough audio presentations. The authors suggested that health professionals were able to identify mucus in cough but were less successful at recognizing wheezes in cough sounds. Furthermore, the clinicians performed poorly in making diagnoses by using a wide range of cough descriptors which reflected the acoustic properties of the cough sounds rather than the diagnostic categories. The results of the study of Smith et al. [8] suggest that the clinicians' knowledge of cough features associated with specific respiratory disorders remains inadequate to make appropriate diagnoses based on perceptual cough assessment. Our study showed that perceptual assessment may not be sufficient to determine the ability of airway protection, and that clinicians require training in objective cough assessment to be able to relate their perception of cough impairment to a specific airway dysfunction.

Despite inconsistency of agreement among the clinicians in judgement of cough strength and qualities, this study has shown cough airflow parameters that influenced the perceptual characteristics of presented samples and consequently determined the cough ratings. Identifying the association of cough perceptual descriptors with specific cough airflow characteristic and understanding sensorimotor impairments of respiratory and/or laryngeal subsystem which impact cough objective and subjective measures will help improve the quality of clinical assessment of airway protective mechanism.

Conclusion

To our knowledge, this study is the first to examine the relationship between clinicians' perceptual ratings of cough and objective cough airflow parameters. These data showed that coughs with certain perceptual characteristics shared airflow characteristics. Future studies should contain a larger number of samples including disordered coughs grouped by those specific airflow parameters that influence cough perception. Future studies should also seek to determine whether these associations are maintained in the context of a typical clinical setting.

In the process of assessing airway protective ability, it is important to identify mechanisms of non-impaired and impaired cough, and to be able to distinguish between cough and other expiratory events. Therefore, it may be that accurately designed cough evaluation training would help clinicians understand physiological mechanisms which modify the cough waveform and what effect it may have on perceptual cough evaluation. Additionally, developing a uniform cough rating system may help facilitate more effective communication between clinicians and provide comprehensive evaluation of patients.

Appendix

APPENDIX A

ASSESSMENT FORM

Cough #:______

Strength:

- ❑ **Weak**
- ❑ **Strong**

Quality:

- ❑ **Breathy**
- ❑ **Huffing**
- ❑ **Strained**
- ❑ **Normal**
- ❑ **Wheezing**
- ❑ **Effortful**
- ❑ **Throat clearing**
- ❑ **Discoordinated**
- ❑ **Wet**

Duration:

- ❑ **Short**
- ❑ **Long**

Number of coughs:

- ❑ **Single**
- ❑ **Multiple**

Effectiveness:

- ❑ **Effective**
- ❑ **Ineffective**

Comments (optional):

References

1. Fontana GA, Widdicombe J. What is cough and what should be measured? Pulm Pharmacol Ther. 2007;20(4):307–12.

2. Smith Hammond CA. Predicting aspiration in patients with ischemic stroke: comparison of clinical signs and aerodynamic measures of voluntary cough. Chest. 2009;135(3):769–77.
3. Abaza A, et al. Classification of voluntary cough sound and airflow patterns for detecting abnormal pulmonary function. Cough. 2009;5(1):8.
4. Piirilä P, Sovijärvi AR. Differences in acoustic and dynamic characteristics of spontaneous cough in pulmonary diseases. Chest. 1989;96(1):46–53.
5. Thorpe W, et al. Acoustic analysis of cough. In: intelligent information systems conference, The Seventh Australian and New Zealand 2001. 2001.
6. Knocikova J, et al. Wavelet analysis of voluntary cough sound in patients with respiratory diseases. J Physiol Pharmacol. 2008;59(Suppl 6):331–40.
7. Korpáš J, Sadloňová J, Vrabec M. Analysis of the cough sound: an overview. Pulmonary Pharmacology. 1996;9(5–6):261–8.
8. Smith J, et al. The description of cough sounds by healthcare professionals. Cough. 2006;2(1):1.
9. Pitts T, et al. Voluntary cough production and swallow dysfunction in parkinson's disease. Dysphagia. 2008;23(3):297–301.
10. Hegland KW, Okun MS, Troche MS. Sequential voluntary cough and aspiration or aspiration risk in Parkinson's disease. Lung. 2014;192(4):601–8.
11. Hegland KW, et al. Comparison of voluntary and reflex cough effectiveness in Parkinson's disease. Parkinsonism Relat Disord. 2014;20(11):1226–30.
12. Troche MS, et al. A framework for understanding shared substrates of airway protection. J Appl Oral Sci. 2014;22(4):251–60.
13. Miles A, Huckabee ML. Intra- and inter-rater reliability for judgement of cough following citric acid inhalation. Int J Speech-Lang Pathol. 2013;15(2):209–15.
14. Miles A, McFarlane M, Huckabee M-L. Inter-rater reliability for judgment of cough following citric acid inhalation after training. Speech, Lang Hear. 2014;17(4):204–9.
15. Daniels SK, et al. Clinical assessment of swallowing and prediction of dysphagia severity. Am J Speech-Lang Pathol. 1997;6(4):17–24.
16. Mathers-Schmidt BA, Kurlinski M. Dysphagia evaluation practices: inconsistencies in clinical assessment and instrumental examination decision-making. Dysphagia. 2003;18(2):114–25.
17. Murty G, Lancaster P, Kelly P. Cough intensity in patients with a vocal cord palsy*. Clin Otolaryngol Allied Sci. 1991;16(3):248–51.
18. Fontana GA, et al. Coughing in Laryngectomized Patients. Am J Respir Crit Care Med. 1999;160(5):1578–84.

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