Respiratory Medicine (2014) 108, 1808–1815

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/rmed

How to count coughs? Counting by ear, the effect of visual data and the evaluation of an automated cough monitor

Richard D. Turner*, **Graham H. Bothamley**

Department of Respiratory Medicine, Homerton University Hospital NHS Foundation Trust, London E9 6SR, United Kingdom

Received 6 August 2014; accepted 6 October 2014
Available online 16 October 2014

KEYWORDS
Cough;
Cough counting;
Cough monitor

Summary
Background: Cough causes morbidity and transmits disease yet has been under-researched. The best method for recognising and counting coughs remains unclear. We tested the accuracy of the human ear and measured the influence of visual data on cough counting. We also evaluated PulmoTrack®, a potentially fully-automated cough monitor.
Methods: Consistency amongst listeners and the effect of visual data: Three 14–22-min sequences containing 45–79 coughs were played to 15 respiratory physicians on at least two occasions. Only sound was played on the first occasions but on the final occasion a simultaneous display of audio activity was included. Counts of cough sounds across methods and listeners were compared. Evaluation of PulmoTrack®: 20-h recordings were made from 10 patients with cough. Automated counts were compared with assessment by one investigator.
Results: Agreement among listeners was high. The intraclass correlation coefficient (ICC) for cough counts by ear alone was 0.89 (95% CI, 0.65–1.00). With a concurrent visual display of sound amplitude it was 0.94 (0.80–1.00). 4.8% (0.6–9.5) fewer coughs were counted using visual data than by listening alone (mean [SD] total coughs: 190.2 [3.4] *vs* 200.7 [14.6]; $p = 0.04$). Cough frequencies reported by PulmoTrack® and the researcher differed substantially (ICC 0.23, −0.51 to 0.34, $p = 0.87$); PulmoTrack® had a sensitivity of 26% for detecting coughs identified by ear.
Conclusion: Coughs are well recognised by different listeners. The method used to count coughs should be clearly described as visual information has a significant influence. Non-automated cough counting remains the gold standard method of quantifying cough.

* Corresponding author. Tel.: +44 (0) 208 8510 7814.
E-mail addresses: richard.turner@homerton.nhs.uk (R.D. Turner), graham.bothamley@homerton.nhs.uk (G.H. Bothamley).

http://dx.doi.org/10.1016/j.rmed.2014.10.003
0954-6111/

Introduction

Cough is one of the main symptoms of respiratory disease. Although a defensive mechanism for protecting the airways [1], cough is increased in a range of medical conditions and is a common cause of morbidity [2]. Cough is also important in the transmission of infectious diseases such as measles and tuberculosis [3,4].

The objective measurement of cough is complex but essential if we are to improve our understanding of cough. Fully-automated cough monitors are being developed [5], but counting coughs by ear remains the reference standard [6] against which automated systems should be compared. Individual cough sounds are the basic units of cough [7] but vary among patients and diseases [8]. Although it is assumed the human ear can distinguish coughs from other sounds [9] this has not been adequately tested. Experienced individuals in research groups show good agreement in cough counting within pairs [10—12] but a broader consistency among larger numbers of people naïve to counting coughs has not been examined. Audio editing software can be used to help identify and count coughs by visually representing sound activity at the same time as audio playback [13—16]. The effect of simultaneous visual feedback on cough measurements has not previously been reported.

Automated cough monitors would save time and might offer less variability than human counting yet few automated or semi-automated systems have been tested for clinical use [10,17,18]. PulmoTrack® (iSonea (formerly KarmelSonix), Haifa, Israel) is a fully-automated ambulatory device for measuring respiratory sounds [19]. For cough counting, its use has only been described in a small number of healthy volunteers over short recording times [20].

The aim of the current study was threefold: to investigate observer consistency in counting coughs, to measure the effect of visually representing audio data and to compare human cough counting with the PulmoTrack® cough monitor.

Methods

Patients

Patients with the symptom of cough were recruited as hospital inpatients and from a respiratory clinic after giving written consent. The study was approved by the London Riverside Research Ethics Committee (reference: 12/LO/1923).

Automated cough monitor

Cough monitoring with PulmoTrack® took place in hospital over 16—24 h. Clinic patients were admitted specifically for this purpose. The PulmoTrack® software (Version 6.5.0) uses an algorithm unknown to us to calculate cough counts expressed as *cough events* and *component coughs* per minute. These terms are not clearly defined in the product literature but we presume them to equate to bouts of coughing and individual cough sounds respectively. The system allows playback for non-automated cough counting. Recordings were analysed by the software twice to test repeatability.

Listeners

One of us (RT) counted cough sounds in a 4-h section from each of the recordings where PulmoTrack® indicated the greatest number of coughs. 15 respiratory physicians counted cough sounds in 3 sequences lasting from 14 to 22 min on 3 occasions in the same order at intervals of $\geq$4 weeks. The sequences were selected by the investigator for the high density of coughs and differing underlying pathologies. Listeners were asked about known hearing problems and, in order to estimate experience of listening to closely spaced sounds, frequency of playing a musical instrument and confidence in detecting fixed splitting of the second heart sound on auscultation of the praecordium (minimum duration 0.02 s [21]). No specific training of how to count coughs was given; listeners were instructed only to count cough sounds whether occurring in isolation or as part of a bout of prolonged coughing. Playback could be paused and repeated as desired. Participants were unaware of the cough counts of other auditors and the interpretation of the machine.

Visual data were not shown on the first two occasion, but on the final occasion a simultaneous visual representation of sound amplitude was provided using Audacity® open source audio editing software (version 2.0.2; see Fig. 1 and online supplementary audio file) [22]. The study protocol is summarised in Fig. 2.

Supplementary audio related to this article can be found at http://dx.doi.org/10.1016/j.rmed.2014.10.003.

Data analysis

Statistical analyses were performed using Stata (version 13.0) and PASW Statistics 18. Two-group comparisons were made with Student's *t*-tests for continuous variables and Fisher's exact test for categorical variables. Tests were two-sided unless stated otherwise. Intraclass correlation coefficients were used to describe agreement between observers and to evaluate PulmoTrack®. Mixed effects regression models and a likelihood ratio test were used to explore the variation associated with each non-automated counting method (using sound alone or sound with visual data). The two methods were also compared with a Bland—Altman plot. We aimed to enlist 15 observers. From initial data this number would give 80% power at a significance level of 0.05 to detect a difference in total cough counts of 7% when comparing listening alone to listening with the addition of visual data, or 50% power to detect a difference of 5%.

Results

We recruited 13 patients with sarcoidosis ($n = 1$), exacerbations of asthma ($n = 2$) and chronic obstructive pulmonary disease (COPD; $n = 2$), stable COPD ($n = 1$), tuberculosis ($n = 2$), non-tuberculous mycobacterial infection ($n = 1$), idiopathic pulmonary fibrosis (IPF;