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Data Article

Simulated obstructive respiratory disease dataset over increasing positive end-expiratory pressure

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ABSTRACT

The breathing dataset presented is collected from 20 healthy individuals at the University of Canterbury using a device to simulate the pressure and flow profiles of obstructive pulmonary disease. Specifically, the expiratory non-linear resistance, which generates the characteristic expiratory pressure-flow loop lobe seen in obstructive disease. Ethical consent for the trial was granted by the University of Canterbury Human Research Ethics Committee (Ref: HREC 2022/26/LR). Data was collected using an open-source data collection device connected to a Fisher and Paykel Healthcare SleepStyle SPSCAA CPAP. The trial was conducted at CPAP PEEP levels of 4 and 8 cmH_2O, as well as at ZEEP (0 cmH_2O) with no CPAP attached. The simulation device was a modular device connected to the expiratory pathway, consisting of a free volume diversion and fixed high resistance outlet. Three simulation levels were selected for testing, achieved by changing the size of the elastic free volume. The intended use of this dataset is for the initial validation and development of respiratory pulmonary mechanics models, using data collected from healthy people with simulated disease prior to clinical testing.

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Specifications Table

Subject	Biomedical Engineering
Specific subject area	Obstructive respiratory disease simulation data to inform the development and validation of pulmonary mechanics models.
Data format	Raw, Processed, Demographic (questionnaire)
Type of data	Raw data is .csv (pressures) format. Processed data is .csv format. Demographic data is .csv
Data collection	A modular device to simulate effects of obstructive disease, was connected in line with a data collection device [1,2]. Both are available open source and are easily modifiable [1]. The simulation and data collection devices were connected to a filter, mouthpiece and Fisher and Paykel Healthcare SleepStyle SPSCAA CPAP device. The test subject wore a nose clip to minimise leakage. The trial was conducted at 0 (ZEEP), 4, and 8 cmH_2O PEEP settings and using three different free volume sizes: 200ml; 250ml; and 300ml. Data was collected and processed in MATLAB. 20 healthy subjects were included in the trial with an even split of sex (10 females and 10 males).
Data source location	Low Risk Clinical Unit Mechanical Engineering Department University of Canterbury Christchurch New Zealand
Data accessibility	Repository name: PhysioNet Data identification number: https://doi.org/10.13026/xczc-3662 Direct URL to data: https://physionet.org/content/simulated-obstructive-disease/1.0.0/

1. Value of the Data

- The data can be used for the preliminary validation and development of respiratory mathematical models to diagnose or monitor lung disease and/or guide respiratory care without adding unnecessary patient burden in testing unhealthy people or using potentially invasive methods.
- Accurate model-based methods allow identification of patient specific biomarkers of respiratory dysfunction.
- Data collection is readily repeatable, as it was collected using predominantly open-source hardware and software, so the data can be readily augmented, or the overall approach can be adjusted to suit many applications.

2. Background

Chronic Obstructive Pulmonary Disease (COPD) is the 3rd leading cause of death worldwide [3]. COPD classified as an obstructive disease causing partial or full airflow blockage, typically during exhalation [4,5]. Blockage creates an increase in expiratory airflow resistance, which can lead to gas trapping [6–8]. The increase in resistance can be visually seen in a pressure flow (PQ) plot as a nonlinear lobe during expiration [9,10].

Respiratory model-based methods can be used to identify biomarkers of disease and disease progression, from structural and mechanical changes using pressure and flow profiles, even before dysfunction is readily apparent in PQ or PV (pressure-volume) data [11–14]. Thus, development and validation of these models requires data from people who have the disease, such as COPD. However, obtaining this data from this relatively fragile cohort can be highly burdensome.

This 20-person dataset uses a COPD simulation device to simulate the disease in a healthy cohort without ethical or clinical burden [1,2]. The device adds a non-linear expiratory resistance to generate pressure and flow profiles closely resembling those of COPD [2,9]. The resulting data

enables initial development and validation of the models and methods for diagnosis, monitoring, and potentially management of this disease.

3. Data Description

The data repository contains the files for each of the 20 healthy subjects in the trial including, demographic data, raw and processed data, example section of code with the corresponding figure, and README file. The raw data is in the folder 'PQ_RawData', and the processed data is in the folder 'PQ_ProcessedData'.

The demographic data is saved as the .csv spreadsheet 'COPD_Trial_Demographic.csv'. This spreadsheet contains the subject number, age [years], gender, height [cm], and any history of smoking, vaping, asthma, and/or heart condition.

The respiratory data (both raw and processed) are .csv files named using the subject number (1 through to 20), device size (0ml, 200ml, 250ml, and 300ml), and constant positive airway pressure (CPAP) positive end-expiratory pressure (PEEP) level used (0cmH_2O, 4cmH_2O, and 8cmH_2O). The processed data is in the units relevant to the data. The files include Time [s], Pressure [cmH2O], Flow [L/s], Tidal volume [L], Inspiratory indices, Weight [kg] for each 45sec trial. The raw data is the data both unprocessed and in the applicable units containing information for time, gauge pressure, inspiratory differential pressures, and expiratory differential pressures all sampled at 100Hz.

Within the folder the processed data has the prefix 'ProcessedCOPD_' and the raw data has the prefix 'COPDTrial2023_'. An example of a processed file name is 'ProcessedCOPD_Subject01_0cmH2O_0ml'. The raw data has the prefix 'COPDTrial2023_' with the raw files identified using the suffix '_raw'. For example, 'COPDTrial2023_Subject10_0cmH2O_0mL_raw.csv' and 'COPDTrial2023_Subject10_0cmH2O_0mL.csv'

4. Experimental Design, Materials and Methods

The trial collected respiratory data from 20 healthy people, 10 male and 10 female. It was approved by the Human Research Ethics Committee at the University of Canterbury (Ref: HREC 2022/26/LR) with amendments accepted on the 17th of February 2023. The 20 participants were given a written and verbal description of the trial, after which they were asked to fill out a consent form and de-identified demographic questionnaire asking for basic information including, age, gender, height, and any history of smoking, vaping, asthma, or heart condition. The devices used for the trial were an open-source data collection device and an open-source chronic obstructive pulmonary disease (COPD) simulation device [1,2].

A mouthpiece and filter were attached to the subject end of the data collection device and the participant given a nose clip to wear. The participants were seated for the trial and asked to hold the data collection device. The first test was conducted without the simulation device attached with no CPAP at zero end-expiratory pressure (ZEEP) and with the CPAP (SleepStyle SPSCAA, Fisher and Paykel Healthcare, East Tamaki, Auckland, NZ) attached and set to 4cmH_2O and 8cmH_2O PEEP, each test was 45s. This test with no device gave a base dataset for each person for comparison. The 200ml free volume size was then attached to the data collection device and the same PEEP trials carried out. This was then repeated for the 250ml and 300ml free volume device sizes. Between each test the subjects were given time (subject-determined) to take a break and catch their breath. The subjects were able to start the next test when they were ready and could stop at any time.

Limitations

Limitations to the data included system, and primarily mouthpiece, leakage common to CPAP devices, data collection and sensor errors, the additional resistance created by the filter used, and trial participant compliance.

System leakages had the most significant impact on the data. System leakages may have occurred within the device circuitry, due to modular connection points and 3D printing porosity. A significant potential area for leakage was at the mouthpiece if the participant didn't create a proper seal around the mouthpiece with their mouth. Additionally, if the nose clip wasn't used properly this could lead to uncaptured nasal breathing.

An example of data acquisition error is Subject 10 with the 250ml device at ZEEP. In this trial, the expiratory flow sensor captured a profile that appears to be pressure relative to atmospheric (gauge) at the expiratory flow (differential pressure) sensor Venturi constriction. This profile is thought to be due to a tube connection error which would leave a sensor port exposed to atmospheric pressure rather than capturing the pressure differential over the constriction.

In the analysis of this data, the additional resistance to inhalation and exhalation created by the bacterial-viral filter used, should be considered. Testing characterised this to be a 0.5 cmH2Os/L resistance [2]. This was important to use to ensure the device set up was sterile and to keep the trial participants healthy.

Another limitation to the data is that short trial times were used to minimise fatigue (45 sec), which allowed some subjects to hold their breath, rather than expiring through the simulation module. The simulation device made breathing out difficult, were breathing out is generally a passive process [5]. Due to the increased effort required, some participants inhaled more than they exhaled. However, this is a common effect of COPD and gas trapping [6]. As, both the leakages and the test subjects holding their breath resulted in deficits in the tidal volume calculations, it is difficult to differentiate leakage from gas trapping in this dataset.

Ethics Statement

Ethical consent was granted for this trial by the University of Canterbury Ethics Committee HREC (Ref: HREC 2022/26/LR) with amendments accepted on the 17th of February 2023. Subjects were given a written and verbal explanation of the trial and gave written consent.

Data Availability

Simulated Obstructive Disease Respiratory Pressure and Flow (Original data) (PhysioNet)

CRediT Author Statement

Jaimey A. Clifton: Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Writing – original draft, Visualization; **Ella F.S. Guy:** Conceptualization, Methodology, Software, Validation, Investigation, Resources, Writing – review & editing, Supervision; **Trudy Caljé-van der Klei:** Conceptualization, Investigation; **Jennifer L. Knopp:** Conceptualization, Methodology, Supervision; **J. Geoffrey Chase:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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