Data in Brief 52 (2024) 109874

Contents lists available at ScienceDirect

Data in Brief

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

Data Article

Respiratory monitoring dataset, with rapid expiratory occlusions, over increasing positive airway pressure ventilation

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A R T I C L E I N F O

Article history:
Received 10 November 2023
Revised 22 November 2023
Accepted 23 November 2023
Available online 1 December 2023

Dataset link: Respiratory dataset from PEEP study with expiratory occlusion (Original data)

Keywords:
Pulmonary mechanics
Venturi
Spirometry
Electrical impedance tomography
Vapers
Smokers
Asthmatics

A B S T R A C T

Resting breathing data was collected from 80 smokers, vapers, asthmatics, and otherwise healthy people in the low-risk clinical unit at the University of Canterbury. Subjects were asked to breathe normally through a full-face mask connected to a Fisher and Paykel Healthcare SleepStyle SP-SCAA CPAP device. PEEP (Positive End-Expiratory Pressure) support was increased from 4 to 12 cmH_2O in 0.5 cmH_2O increments. Data was also collected during resting breathing at ZEEP (0 cmH_2O) before and after the PEEP trial. The trial was conducted under University of Canterbury Human Research Ethics Committee consent (Ref: HREC 2023/04/LR-PS). Data was collected by and Dräeger PulmoVista 500 EIT machine and a custom Venturi-based pressure and flow sensor device connected in series with the CPAP and full-face mask. The outlined dataset includes pressure, flow, volume, dynamic circumference (thoracic and abdominal, and cross-sectional

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https://doi.org/10.1016/j.dib.2023.109874

aeration. Subject demographic data was self-reported using a questionnaire given prior to the trial.

Specifications Table

Subject	Biomedical Engineering
Specific subject area	Respiratory data collection to inform the development and validation of model-based assessments of respiratory mechanics
Data format	Raw, Processed, Demographic (questionnaire), Code
Type of data	P Raw data is in .csv (pressures and dynamic circumferences) and .bin (EIT) format. Processed data is in .csv format. Demographic data is in a .csv file. Example figures are in .png format. Code files are included in .mat format.
Data collection	Pressure, flow, and dynamic circumference data were collected using custom hardware and code that has been made open access [1,2]. This device was connected in series with a filter and a full-face mask, with the inspiratory inlet connected to a Fisher and Paykel Healthcare SleepStyle SPSCAA CPAP device, and the expiratory pathway rapidly occluded by a shutter system [1]. A Dräeger PulmoVista 500 EIT machine MATLAB was used to collect aeration data. The trial was conducted at increasing CPAP PEEP settings. Data was collected and processed in MATLAB. 80 subjects were included in the trial, with an even sex split, and evenly split by identification as smokers, vapers, asthmatics, and otherwise healthy [3].
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/d767-e709 Direct URL to data: https://physionet.org/content/respiratory-dataset/1.0.0/

1. Value of the Data

- These data are valuable in the development and validation of pulmonary mechanics models, as well as for understanding different mechanics across these subject groups.
- Researchers could use these data to develop patient-specific modelling software and predictive models for response to treatment.
- Increased model-enabled low-clinical input physiological assessments could then benefit the healthcare system and people who have limited access to testing and care currently.
- The majority of this data is collected using reproducible open-access hardware and software to increase the ability to understand, use, repeat, and augment these data.

2. Background

Respiratory datasets are critical in the development of models and technology to automate and better inform patient-specific care. An 80 subject trial was conducted to collect data from asthmatics, smokers, vapers, or otherwise healthy men and women [3]. This dataset was specifically collected to aid in the development of passive monitoring technology [3].

Passive mechanics can be difficult to elucidate from passive breathing modes [4–6]. A rapid expiratory occlusion (REO) device was used, based on the 'interrupter technique' principle which fits passive mechanics to 100ms occlusions [1,7-9]. The shorter REO instances were implemented to identify passive mechanics without the patient-effort dynamics in response to a perceptible occlusion [3].

Resting breathing is driven by diaphragmatic muscular recruitment [10,11]. However, apical breathing can be tiggered by increased load, disease, and dysfunction [12]. Hence, dynamic circumference digital tapes were utilised to assess the relative contributions of diaphragmatic and intercostal breathing modes [2,3].

Electrical impedance tomography (EIT) enables non-invasive assessment of regional cross-sectional aeration [3,13]. Thus, EIT provided an assessment of any regional abnormalities, correlating to subject demographic or applied PEEP [3]. Additionally, global aeration was assessed in comparison to flow based tidal volume computation as a validation metric [3].

3. Data Description

The pressure, flow, and dynamic circumference raw data is saved in a folder labelled *'PQ_rawData'*. The *'PQ_rawData'* folder contains both raw data (e.g. *'Subject1_raw.csv'*) and data processed into relevant units (e.g. *'Subject1.csv'*), saved by subject number [3]. Files contains the following data sampled at 100Hz:

- Gauge pressure
- Inspiratory differential pressure
- Expiratory differential pressure
- Chest circumference
- Abdominal circumference
- Initial chest cross-sectional depth
- Initial chest cross-sectional width

The EIT device raw data is saved in a folder labelled *'EIT_rawData'*, saved by subject number (e.g. *'S01_01_001_01.bin'* through to *'S80_01_001_01.bin'*) [3]. These files contain data as a matrix of pixel values representing regional aeration for a cross-sectional image (32 × 32 frame) over time, sampled at 50Hz sampling.

Processed data is saved the *'ProcessedDataset'* folder by subject number (e.g. *'Processed-Data_Subject01.csv'*) [3]. Procced data files contain:

- Time [s]
- Pressure [cmH2O]
- Flow [L/s]
- Tidal volume [L]
- Chest circumference[mm]
- Abdominal circumference [mm]
- Inspiratory indices
- Aeration data time array [s]
- Global aeration
- Aeration data inspiratory indices.

MATLAB code is saved in a folder labelled 'Code' [3]. Data collection code (*'Data-Collection_30MAR23.m'*) was included to collect pressure, flow, and dynamic circumference. Data processing code (*'DataProcessing_29AUG23.m')* and a function to read EIT device files (*'read_binData.m'*) is included to collate, align and process data [3]. Code to generate figures of the processed dataset is also included (*'FigureGenerationCode_29AUG23.m'*), alongside an example plot of the full processed dataset for Subject 1 ('figure-2.png') [3].

Subject demographic information for the 80 subjects was self-reported in a questionnaire. Demographic data is collated in a spreadsheet (*'subject-info.csv'*) [3]:

- Sex [M/F]
- Height[cm]
- Weight [kg]
- Age [years]
- History of asthma (including medication names/types and dosage frequency)
- History of smoking (including frequency, duration, and if a current smoker, or length of time since quitting smoking)
- History of vaping (including frequency, duration, and if a current vaper, or length of time since quitting vaping)

4. Experimental Design, Materials and Methods

A cohort of 80 people were included in the trial. 10 male and 10 female subjects were included in each of the following categories: asthmatics; smokers; vapers; and otherwise healthy. Subjects were classified in these categories based on their self-reported demographic information (Table 1).

Table 1
Inclusion Criteria.

Demographic Category	Criteria for Inclusion
Asthmatics	If has history of asthma, unless: 1) no longer ever uses inhaler; 2) smokes more than once daily; or 3) vapes more than 8 times daily, as 8 vapes are taken to approximate 1 cigarette (1S $\approx$ 8V).
Smokers	If has a history of smoking once monthly or more, unless: 1) is an asthmatic and smokes less than once daily; 2) is not a current smoker and is a current vaper; 3) is a current vaper and smoker and has a history of vaping for longer (duration) than smoking (if equal duration then vaped more than smoked where 1S $\approx$ 8V); or 4) is not a current vaper and smoker and has a history of vaping for longer (duration) than smoking (if equal duration then vaped more than smoked where 1S $\approx$ 8V).
Vapers	If has a history of vaping once weekly or more, unless: 1) is an asthmatic and vapes less than 8 times daily; or 2) has a history of smoking for longer (duration) than vaping (if equal duration then smoked more than vaped where 1S $\approx$ 8V).
Otherwise Healthy	If they are not an asthmatic, do/did not smoker once monthly or more, or do/did not vape once weekly or more.

Prior to the trial, the EIT device (Dräeger PulmoVista 500, Dräeger, Lübeck, Germany) was powered on and a system check was conducted while subjects filled out a demographic questionnaire. EIT electrodes were sprayed with conductive spray (Signaspray, Parker Laboratories, Fairfield, NJ, USA). Subjects then removed their shirt and bra straps and the EIT electrode belt was attached (Fig. 1), with spinal marker for alignment. Subjects were then seated for the trial.

The custom data collection system was powered on dynamic circumference bands attached (Fig. 1) [1]. The reference electrode was then attached to the abdomen using an adhesive electrode (Red Dot Electrodes, 3M, Saint Paul, MN, USA). The EIT belts electrode connections were checked and if any were low or fluctuating electrode conductive gel (Spectra 360 Electrode Gel, Parker Laboratories, Fairfield, NJ, USA) was applied to these electrodes.

A full-face mask (FreeMotion RT041, Fisher and Paykel Healthcare, New Zealand) was fit to the subject. A filter (Hudson Oxygen Bacterial Viral Filter, Teleflex, Wayne, PA, USA) attached to the mask port and then connected to the custom data collection system [1]. Finally, the EIT device was calibrated when setup was complete, and the patient was comfortably seated to minimise movement after calibration.

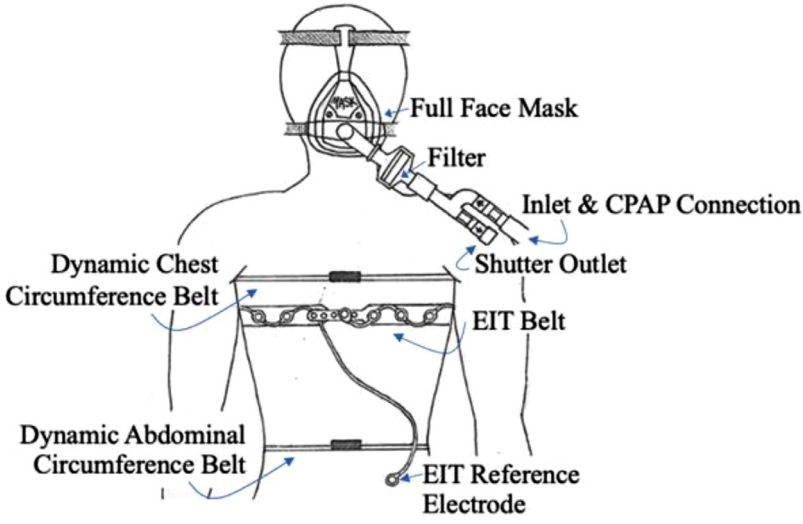

Fig. 1. Data collection system (EIT, dynamic circumference bands, and flowmeter) locations. Conceptual illustration by author E.F.S. Guy.

Recordings were started for both the EIT and custom recording device, and the cueing system timer started. The cueing system followed the protocol outlined in Table 2. During the trial a CPAP device (SleepStyle SPSCAA, Fisher and Paykel Healthcare, East Tamaki, Auckland, NZ) was connected and PEEP settings increased.

Table 2
Trial Recording Outline.

Time [min]	Duration	Settings	Time [min]	Duration	Settings
1:00	1 min	Resting breathing at ZEEP	8:50	20 seconds	Turn up to 8.5cmH2O
1:30	30 seconds	Plug in CPAP and turn on 4cmH2O	9:10	30 seconds	4cmH2O
2:00	30 seconds	4cmH2O	9:40	20 seconds	Turn up to 9cmH2O
2:20	20 seconds	Turn up to 4.5cmH2O	10:00	30 seconds	4cmH2O
2:50	30 seconds	4.5cmH2O	10:30	20 seconds	Turn up to 9.5cmH2O
3:10	20 seconds	Turn up to 5cmH2O	10:50	30 seconds	4cmH2O
3:40	30 seconds	4cmH2O	11:10	20 seconds	Turn up to 10cmH2O
4:00	20 seconds	Turn up to 5.5cmH2O	11:40	30 seconds	4cmH2O
4:30	30 seconds	4cmH2O	12:00	20 seconds	Turn up to 10.5cmH2O
4:50	20 seconds	Turn up to 6cmH2O	12:30	30 seconds	4cmH2O
5:10	30 seconds	4cmH2O	12:50	20 seconds	Turn up to 11cmH2O
5:40	20 seconds	Turn up to 6.5cmH2O	13:10	30 seconds	4cmH2O
6:00	30 seconds	4cmH2O	13:40	20 seconds	Turn up to 11.5cmH2O
6:30	20 seconds	Turn up to 7cmH2O	14:00	30 seconds	4cmH2O
6:50	30 seconds	4cmH2O	14:30	20 seconds	Turn up to 12cmH2O
7:10	20 seconds	Turn up to 7.5cmH2O	14:50	30 seconds	4cmH2O
7:40	30 seconds	4cmH2O	15:10	20 seconds	Turn off and unplug CPAP Hose
8:00	20 seconds	Turn up to 8cmH2O	16:10	1 min	Resting breathing at ZEEP
8:30	30 seconds	4cmH2O			

Limitations

System leakages have a significant effect on the collected data, especially at the mask interface. Mask leakage is a known issue in the delivery of CPAP therapy [14–16]. Mask leakage results in flow drift in 25% of subjects processed, combined inspiratory and expiratory, data (e.g., subject 62 and 64). Mask leakages also resulted in deficits in tidal volume calculations.

Known leakages, as well as unknown leakages, influenced the trial. The expiratory pathway, when un-occluded, was open to atmosphere with an equivalent tube diameter to the inspiratory pathway. Thus, the CPAP flow required to maintain the set PEEP was increased, resulting in a lower effective PEEP than CPAP set PEEP. This effect compounds at increasing PEEP. A higher resistance expiratory port could have maintained a higher PEEP, as in CPAP therapy. However, in this trial, the subjects would likely exhale actively in this case, limiting the applicability of this dataset to identify passive mechanics.

Another significant contributing factor to the dataset is the filter resistance. The bacterial-viral filter used, resulted in a large resistance (≈0.5 cmH2Os/L), as measured via the pressure drop measured across the filter alone. Entirely sterilisable or disposable respiratory circuitry is impractical with the expense of personal CPAP devices for trials of this size in healthy subjects, necessitating use of this filter, or similar. This pressure drop can be accounted for by using PEEP as measured by the gauge pressure sensor at the mask interface, rather than set PEEP, in modelling and computation.

The EIT device timed out during two of the subject recordings, resulting in no EIT aeration data for subject 69 and a truncated recording for subject 57. Remaining data for these subjects is still included as they have a complete pressure, flow, and dynamic circumference dataset.

Ethics Statement

Ethical consent for the trial was granted by the Human Research Ethics Committee at the University of Canterbury (Ref: HREC 2023/04/LR-PS), with amendments accepted on 24 March 2023. Subjects gave written consent prior to the trial after both written and verbal explanation of the procedure. Subjects consented to the publication of their de-identified data.

Data Availability

Respiratory dataset from PEEP study with expiratory occlusion (Original data) (PhysioNet)

CRediT Author Statement

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

Acknowledgements

This work was funded by a University of Canterbury Doctoral Scholarship and the EU H2020 R&I programme (MSCA-RISE-2019 call) under grant agreement #872488 — DCPM.

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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