Sep 29, 2025

Non-invasive investigation of the cardiodynamic response to breathing exercises in healthy individuals using impedance cardiography: a feasibility study

DOI
dx.doi.org/10.17504/protocols.io.q26g7nddqlwz/v1

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Protocol Citation: Viviane De Menezes Caceres, Anna Phillips, Elisio Pereira, Danielle Soares Rocha Vieira 2025. Non-invasive investigation of the cardiodynamic response to breathing exercises in healthy individuals using impedance cardiography: a feasibility study. **protocols.io https://dx.doi.org/10.17504/protocols.io.q26g7nddqlwz/v1**

Protocol status: In development
We are still developing and optimizing this protocol

Created: September 29, 2025

Last Modified: September 29, 2025

Protocol Integer ID: 228407

Keywords: cardiodynamic, impedance, breathing exercises, feasibility study respiratory exercise, incremental respiratory exercise session, controlled incremental respiratory exercises protocol, incremental respiratory exercises protocol, diaphragmatic breathing, respiratory exercise progression, respiratory muscle performance, respiratory exercise, breathing exercise, such as respiratory exercise progression, hemodynamic parameters such as heart rate, acute hemodynamic effect, systemic physiological load, positive expiratory pressure, affecting hemodynamic parameter, acute changes in hemodynamic variable, slow deep breathing, hemodynamic response, cardiodynamic response, lung volume, relationship with hemodynamic response, altering intrathoracic pressure, cardiac output, pulmonary benefit, using impedance cardiography, hemodynamic variable, exercises in healthy individual, including heart rate, impedance cardiography, cardiac index, physiotherapy, physiological monitoring, heart rate, airway clearance, symptom monitoring

Abstract

Respiratory exercises are widely prescribed in physiotherapy to improve lung volumes, facilitate airway clearance, and enhance respiratory muscle performance. Techniques such as, diaphragmatic breathing, slow deep breathing, huffing and positive expiratory pressure (PEP) aim to reduce dyspnoea, prevent atelectasis, and support secretion mobilisation, particularly in postoperative and bed-bound patients. Beyond their pulmonary benefits, respiratory exercises can impose a systemic physiological load. By increasing metabolic demand and altering intrathoracic pressure, they influence venous return, preload, and stroke volume, thereby affecting hemodynamic parameters such as heart rate (HR), cardiac output (CO), and cardiac index (CI). These acute hemodynamic effects are particularly relevant in frail, elderly, or acutely unwell populations, including patients with pre-existing cardiorespiratory conditions; however, they remain poorly characterised. This project aims to investigate the feasibility, safety and acceptability of implementing a study protocol with measurement of acute changes in hemodynamic variables, including heart rate (HR), stroke volume (SV), cardiac output (CO), and cardiac index (CI) in response to controlled incremental respiratory exercises protocol using impedance cardiography (ICG). It will also provide preliminary effect estimates, identify potential measurement challenges, and refine procedural elements, such as respiratory exercise progression, timing of data collection, and symptom monitoring for future clinical trial. Healthy adult participants will complete incremental respiratory exercise sessions, with measurements taken at baseline, during the intervention, and throughout the recovery period. Symptom assessment will accompany physiological monitoring to explore its relationship with hemodynamic responses.

Guidelines

National Statement on Ethical Conduct in Human Research (Australia)
PhysioFlow® Manufacturer Guidelines
ACSM Exercise Termination Guidelines

Materials

- Use of PhysioFlow® Enduro™ impedance cardiography system and associated consumables (electrodes, gel, leads).
- Devices for respiratory exercises.
- Pulse oximeter, BP monitor, and RPE scales.
- Access to laboratory space and equipment calibration/maintenance.
- Printingof participant information sheets, consent forms, and data collection sheets.
- Statistical software licences.

Troubleshooting

Safety warnings

This study involves incremental respiratory exercises that may temporarily alter cardiovascular and respiratory responses.
Continuous monitoring must be maintained throughout the session and pulse oximetry.
The protocol must only be conducted under the supervision of trained personnel experienced in cardiorespiratory assessment and emergency response.
Stop the test immediately if the participant experiences:
Oxygen saturation (SpO_2) drops of >5% from baseline.
Severe dizziness, discomfort, or pain.
Abnormal blood pressure responses or arrhythmias detected by the impedance device.
Emergency equipment (e.g., first aid kit, resuscitation equipment) must be readily available in the testing area.
Participants with unstable cardiovascular or respiratory conditions should not take part in this study.
All procedures must comply with approved ethics protocols and local institutional safety guidelines.

Ethics statement

Prior ethics approval will be obtained before performing data collection.

Before start

Confirmation of ethics approval from the relevant Human Research Ethics Committee (HREC).
Inclusion and exclusion criteria checklist to confirm participant eligibility.
Equipment preparation: Calibration and functionality check of key devices
Cleaning and infection control procedures for equipment.
Availability of consumables (electrodes, alcohol wipes, NuPrep gel, etc.).
Preparation of case report forms (CRFs) or digital templates for recording data.
Verification of participant ID coding and confidentiality procedures.
Backup and secure storage systems for data export from PhysioFlow
Safety and Emergency Readiness.

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1 The study's objectives and procedures will be explained to participants who meet the inclusion criteria, and written informed consent will be obtained prior to their participation.

2 The following demographic and baseline data will be collected:
Age, sex, height, weight, body mass index (BMI), and estimated lean body mass.
Relevant medical history, including respiratory and cardiovascular conditions, current medications, and smoking status.

3 Participants will be instructed to rest in a seated position for 10 minutes prior to commencing the breathing exercises to ensure stable baseline physiological parameters.
During this period, the following baseline measures will be recorded:
Heart rate (HR), stroke volume (SV), cardiac output (CO), and cardiac index (CI) using the PhysioFlow®.
Oxygen saturation (SpO_2) using a pulse oximeter.
Blood pressure (BP) using an automated BP monitor.

4 Skin impedance was reduced at electrode sites using NuPrep gel followed by cleaning with 70% isopropyl alcohol.

5 Pregelled Ag/AgCl electrodes (Skintact FS-TB wet-gel; Leonhard Lang GmbH, Austria) will be placed as follows (Figure 1):
Electrode 1: Left base of the neck, above the supraclavicular fossa.
Electrode 2: Sternal angle (manubriosternal joint).
Electrode 3: Standard ECG V6 position (left mid-axillary line, 5th intercostal space).
Electrode 4: Left paraspinal region at the xiphoid level.
Electrodes were connected to the PhysioFlow® device, which was secured in a belt pouch to maintain stability during breathing tasks.

6 Participants will perform a structured incremental protocol that will progressively incorporate respiratory techniques, including diaphragmatic breathing, slow deep breathing, huffing, and positive expiratory pressure.
The exercise will be divided into stages, each lasting 2 minutes, with participants instructed to maintain slow, deep, diaphragmatic breaths throughout each stage.
At the end of each stage, the rate of perceived exertion (RPE) for breathing effort will be recorded using the modified Borg scale (0–10).

7 Raw impedance data will be exported for analysis.
Heart rate (HR), stroke volume (SV), cardiac output (CO), and cardiac index (CI) will be averaged every 10 seconds to ensure data stability.
Data will be analysed at the following time points:
Resting baseline: Final 2 minutes of the initial seated rest.
During exercise: Values at 30-second intervals within each incremental stage.
Recovery period: Values at 30-second intervals during the first 10 minutes post-exercise.

8 Continuous monitoring will be conducted throughout the session.
The test will be immediately stopped if participants experience any of the following:
A drop in oxygen saturation greater than 5% from baseline.
Excessive dizziness, discomfort, or pain.
Abnormal blood pressure responses or arrhythmias detected by the PhysioFlow® device.

Protocol references

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