

Study protocol

Diaphragmatic and sternocleidomastoid muscle recruitment at various inspiratory loads with and without breathing instruction in healthy adults

Objectives

- (1) to investigate the relationship between sternocleidomastoid muscle recruitment and diaphragm thickness fraction during increasing inspiratory resistance in healthy adults.
- (2) to compare diaphragmatic and sternocleidomastoid muscle recruitment patterns with and without a standard diaphragmatic breathing instruction with increasing inspiratory resistance in healthy adults.

Method

Ethical committee approval

Ethical committee approval was granted by the Research Ethics Committee of Hong Kong Metropolitan University (ethics approval number: HE-OT2023/13).

Sample size calculation

Sample size will be determined by repeated-measures analysis of variance (ANOVA) using G*Power 3.1. Considering an effect size of 0.3, an alpha error probability of 0.05, a power of 0.80, the estimated sample size is 30 participants. An additional 20% of the cohort will be recruited to compensate for the predicted sample size attrition. The final estimated sample size will be at least 36 participants.

Participants

Participants ≥ 18 years of age with normal health will be recruited and screened for any of the following ‘exclusion’ criteria: (1) participants with known cardiovascular, pulmonary, musculoskeletal or psychiatric disorders; (2) pregnancy; (3) with respiratory symptoms (from flu or other respiratory infection during the 2 weeks prior to measurements).

Procedure

Upon arrival at the laboratory, eligible participants will first perform a standard spirometry lung function test. The maximum inspiratory pressure (MIP) will be determined with a pressure

threshold inspiratory loading device (POWERbreathe, K₂). Each participant will then be instructed to use the device to perform, in random order, 10 breaths at an inspiratory intensity of 30%, 40%, 50%, 60%, 70%, and 80% MIP. A rest period of 15 minutes will be allowed between each inspiratory pressure set of 10 breaths. Simultaneous surface electromyographic (sEMG) recording of the right sternocleidomastoid muscle and ultrasound of right diaphragmatic thickness will be conducted during each breath.

The entire recording procedure will be repeated on a separate day. During the repeat measurements, participants will be provided with specific breathing instruction to focus on the use of the diaphragm and to inhale air to the lower part of the chest. Practice trials will be conducted to ensure participant's understanding of diaphragmatic breathing.

Measurements

Spirometry respiratory function

Forced vital capacity, forced expiratory volume in 1 second, and MIP will be measured following the American Thoracic Society guideline protocol.

Diaphragmatic contraction

During each of the 60 breaths, thickness of the right diaphragm at the end of each tidal expiration and at the end of each forced inspiration will be measured using diaphragmatic ultrasonography (Mindray M9, Shenzhen, China). The recorded thickness over each set of 10 breaths will be averaged. The strength of diaphragmatic contraction will be reflected by the diaphragmatic thickening fraction (DTf), which is calculated as a ratio of [the difference between mean diaphragmatic thickness at the end of each inspiratory pressure and mean diaphragmatic thickness at the end of tidal expiration / the diaphragmatic thickness at the end of tidal expiration] x100%.

Recruitment of the sternocleidomastoid muscle

A Noraxon Ultium wireless sEMG system (Noraxon USA, Inc., Scottsdale, AZ, USA) will be used to detect the muscle recruitment activity of the right sternocleidomastoid muscle. On the 2 days of data collection, sEMG data over each set of 10 breaths will be averaged for data analysis.

Self-perceived exertion level

Self-perceived exertion level at the end of each 10-breath set at each inspiratory pressure, will be also recorded using the Borg's scale of Rate of Perceived Exertion.

Statistical analysis

All data will be analyzed using the IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp).

Changes in DTf, muscle activity of sternocleidomastoid and fatigue during each inspiratory protocol will be analyzed using repeated-measures ANOVA.