

Inspiratory Conductance does not vary with Height, Weight, Body Mass Index, Age, Sex or Spirometric Volumes in Healthy Adults

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ABSTRACT

Introduction and objective: We previously showed that inspiratory conductance (IC) can be calculated from early inspiratory pressure fall and initial acceleration of the inspiratory air column. To characterize IC further we conducted a study to determine whether its value varies with height, weight, BMI, age, sex and lung volumes.

Methods: We measured IC, height, weight, FEV1, FVC and PEFR in 147 healthy volunteers' age 18-50 years.

Results: During tidal breathing at rest the mean (SD) IC was 8.31 (3.15) L s⁻¹ kPa⁻¹. No significant correlation was found between IC and height (r=0.04), weight (r=0.142), BMI (r=0.058), FEV1 (r=0.275), FVC (r=0.019), PEFR (r=0.182) or age (r=0.017) and there was no significant difference between men and women. The same was found for IC measured during slow deep breathing and rapid breathing.

Conclusion: IC is independent of age, sex, height, weight, BMI and spirometric lung volumes so there is no imperative to correct for those factors in an individual. Within-subject directional changes in IC within the context of a short clinical timeframe might be the best potential for clinical application.

Keywords: Inspiratory conductance, Airflow resistance, Lung function, Spirometry

INTRODUCTION

In an earlier paper we published a proof-of-concept study that described a novel apparatus to measure the relationship between the initial drop in airway pressure and the acceleration of the inspired air at the start of inspiration. The derived index, referred to as inspiratory conductance (IC) has the units L.s⁻¹ kPa⁻¹ and can be posited as a potentially useful alternative to other measures of airways status because it can be measured with little or no co-operation from the subject [1]. It might therefore be of clinical value in patients who are unconscious, for example in an intensive care setting or unable to perform tests such as spirometry or whole-body plethysmography as is often the case in people with cognitive impairment, particularly those with overt dementia.

The full conceptual, physiological and technical background to IC is presented in depth in our previous papers [1,2]. In brief, IC is calculated from measurement of the maximum rate of pressure fall (dP/dt_{max}) during very brief occlusion by a spring-loaded valve at the onset of inspiration and the immediate maximum rate of acceleration of the air column after the valve opens (dF/dt_{max}), then expressing these as the ratio:

$$IC = dF/dt_{max} / dP/dt_{max}$$

$$= L s^{-2}/kPa s^{-1}$$

$$= L s^{-1} kPa^{-1} \text{ (the units of gas conductance in the airways)}$$

Where F = flow (L⁻¹), P = pressure (KPa), t = time (s)

We conducted a study that showed IC to be a stable, reproducible and consistent index in normal adult individuals and that it showed the expected directional changes in response to externally applied resistance to airflow [1].

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There was a clear imperative to explore the characteristics of IC further, particularly to establish whether it varied with age, sex and stature, as do lung volumes measured by spirometry, plethysmography or helium dilution. This was the logical next step because of a need to determine if work would be required to set normative ranges for between-subject comparative purposes in a population, and partly because we observed no apparent differences between IC values in men and women in the earlier small-scale study, which suggested the index does not vary with sex or stature.

METHODS

Apparatus

We used the same breathing apparatus described in the previous study, and the same calibration routines. The only component to be replaced was the 12 V DC supply to the pressure transducers to enable an even more stable pressure baseline and consistent frequency response time. The digitization and analysis of the analogue signals from the pressure transducers was also performed using the same sampling rate and software (BioPac Systems, Goleta, CA, USA).

Spirometry to measure peak expiratory flow rate (PEFR), forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC) was performed with a Vitalograph® Alpha 6000 spirometer (Vitalograph Ltd, Buckingham, UK) using standard procedures [3].

Participants

147 healthy volunteers (age range 18-50, 39 (26%) men) were recruited, all of whom were staff or students at Bournemouth University. A majority were either never-smokers or ex-trivial smokers (estimated total exposure <1 pack year) and 13 (9%) current light smokers (<10 pack years) were included. None had a history of diagnosed asthma or any other significant respiratory disease, though 53 (36%) reported occasional transient wheezing without dyspnea. All had otherwise negative answers to the standard European Respiratory Society screening questionnaire for respiratory disease [4]. The study was approved by the ethics subcommittee of Bournemouth University and all subjects provided written informed consent.

Procedures

After spirometry the volunteers had their IC measured using the same protocol as in the proof-of-concept study [1]. IC was recorded during tidal breathing at rest, deep breathing at a rate of 6 breaths per minute and voluntary rapid shallow breathing at a rate of 30 breaths/min.

Continuous data were tested 2-tailed for significant difference using the Kolmogorov-Smirnov method and for correlation using the Pearson method.

RESULTS

For the entire group of subjects (n=147), the mean (SD) height was 168.27 (9.04) cm, weight 66.51 (18.0) kg, body mass index (BMI) 22.90 (3.78) kg m⁻², FVC 4.24 (1.04) L, FEV1 3.51 (0.83) L, PEFR 449 (109) L min⁻¹. The mean (SD) IC values during tidal breathing at rest, slow deep breathing and rapid breathing were 8.31 (3.15), 9.55 (3.44) and 18.33 (5.34) L s⁻¹ kPa⁻¹, respectively. As found previously, IC during tidal breathing at rest and during slow deep breathing showed no significant difference, whereas IC values rose when the subject adopted rapid breathing. The most likely reason for this is the more pronounced drop in intrathoracic pressure in the inspiratory phase during rapid breathing which results in diffuse expansion of the airways and therefore a transient drop in airways resistance at the time dF/dt_{max} is being measured.

No correlation (Pearson) was found between height and IC during any pattern of breathing. The correlation coefficients (r) were: tidal breathing r=0.04, P=0.905 (**Figure 1**), slow deep breathing r=-0.07, P=0.369, rapid breathing r=0.004, P=0.961. There was also no significant correlation between IC and age (r=-0.017), weight (r=0.142), BMI (r=-0.058), FVC (r=0.019), FEV1 (r=0.275) or PEFR (r=0.182) during tidal breathing at rest and none in the other breathing patterns. There were no significant differences in the mean IC values for men and women. Men and women were found to have the expected differences in FVC and FEV1 which disappeared when expressed as a percentage of the predicted value adjusted for sex, age and height.

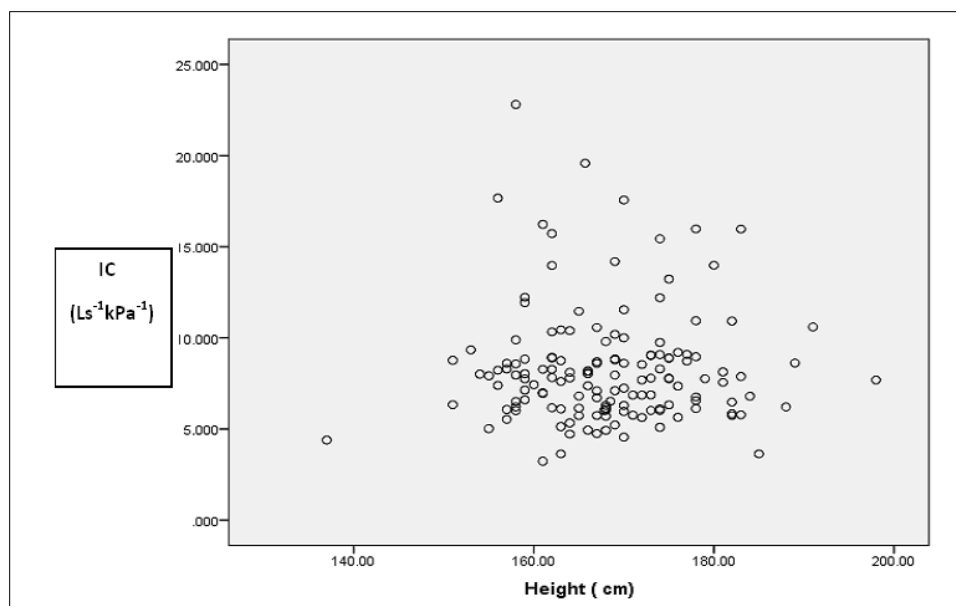


Figure 1. Relationship between height and inspiratory conductance (IC) during tidal breathing at rest. No correlation found, $r=0.04$, $P=0.905$.

DISCUSSION AND CONCLUSION

This study showed that IC was not related to sex, height, weight, BMI or lung volumes measured by spirometry in healthy adults. There was also no apparent relationship with age, though the age of the participants was not evenly distributed across the age range, so further work might be needed to confirm that finding. Therefore, unlike physiological indices that are clearly influenced by body size and age, such as spirometric lung volumes, IC appears not to need to be corrected for those factors. Potential clinical utility would therefore lie in directional change of IC in an individual in a manner similar to, for example, blood oxygen saturation. In the earlier study [1], we showed a relatively low within-subject variation in IC in any given breathing pattern, but considerable between-subject variation, as was the case in this study. This finding also indicates greater clinical potential for within-subject comparison use in short timeframe contexts. We now suggest that the behavior of IC as measured by our method should be studied in a range of clinical settings to position its usefulness as an indicator of changing respiratory physiological status in patients with, for example asthma, acute bronchitis, chronic obstructive pulmonary disease and pneumonia.

CONFLICTS OF INTEREST

None

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None

AUTHORSHIP

Stephen Allen: Proposed original hypothesis, suggested the study, interpreted data, wrote paper.

Debbie Gale: Collected data, interpreted data, approved final draft.

Ahmed Khattab: Suggested apparatus components, supervised data collection, approved final draft.

Ian Brown: Built apparatus and suggested improvements, interpreted data, approved final draft.

Jeff Bagust: Analysed and interpreted data, supervised analytical software, approved final draft.

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