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# Expiratory Muscle Weakness and Stress Urinary Incontinence Severity in Community-Dwelling Older Adults: A Cross-Sectional Study

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**ABSTRACT:** Continence during effort depends on coordinated control of intra-abdominal pressure by the diaphragm, abdominal wall and pelvic floor, and respiratory muscle strength declines with ageing. This analytical cross-sectional study examined whether respiratory muscle strength and pulmonary function are associated with stress urinary incontinence (SUI) severity in community-dwelling older adults. One hundred and four adults aged 60–82 years (95 women, 9 men) with stress or stress-predominant mixed urinary incontinence were recruited consecutively. SUI severity was measured with the ICIQ-UI Short Form, maximal expiratory (MEP) and inspiratory (MIP) pressures with a digital manometer, and pulmonary function by spirometry. MEP correlated negatively with ICIQ-UI SF score ($\rho = -0.37$, 95% CI −0.52 to −0.19; $p < 0.001$), and the association persisted after adjustment for age, sex, BMI, parity and chronic cough (partial $r = -0.36$). MIP showed a weaker association ($\rho = -0.25$; $p = 0.012$), whereas spirometric indices were unrelated to severity. In multiple regression, MEP remained an independent predictor ($\beta = -0.39$; $p < 0.001$), adding 9% explained variance; each 10 $cmH_2O$ lower MEP corresponded to a 0.8-point higher score. With MEP and MIP entered together, only MEP remained significant. Mean MEP declined from 81.7 $cmH_2O$ in slight to 46.2 $cmH_2O$ in very severe SUI (trend $p < 0.001$), and participants with MEP below the lower limit of normal (40%) had higher scores (12.2 vs 9.3; $p = 0.002$). Expiratory muscle weakness is an independent correlate of SUI severity in older adults, supporting respiratory muscle assessment in pelvic health evaluation.

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## 1. INTRODUCTION

Urinary incontinence affects a significant number of elderly individuals, and its incidence increases with age especially among women over the age of 60 (Hunskaar et al., 2003; Milsom and Gyhagen, 2019). Stress urinary incontinence (SUI) results from unintentional loss of urine during coughing, sneezing or effort (Haylen et al., 2010) and occurs when an increase in intra-abdominal pressure overcomes the pressure required to close the urethra. Risk factors for SUI include childbirth, number of births, obesity and chronic coughing (Rortveit et al., 2003; Hannestad et al., 2003; Subak et al., 2009). Pelvic floor muscle training is currently the initial conservative management option for SUI (Dumoulin et al., 2018).

Continence is not solely controlled by the pelvic floor. The diaphragm, abdominal muscles and pelvic floor muscles all constitute part of a single intra-abdominal pressure system. These muscles work in concert to allow management of intra-abdominal pressure during coughing, posture and breathing (Hodges and Gandevia, 2000; Sapsford and Hodges, 2001; Neumann and Gill, 2002). Respiration also modulates pelvic floor muscle activity (Hodges et al., 2007). Furthermore, dynamic imaging has demonstrated synchronous movement of the diaphragm and pelvic floor during coughing and breathing (Talasz et al., 2011). Modified postural engagement of the abdominal and pelvic floor musculature has been seen in people with urine incontinence. (Smith et al., 2007). There are also reported associations between breathing and continence abnormalities (Smith et al., 2006). It has been proposed that this may indicate that the ability of the respiratory muscles to generate and manipulate intra-abdominal pressure may play a role in the effort-related burden on the pelvic floor.

Expiratory muscle strength has been shown to decrease with age and lead to reduced performance in high pressure exercises (cough in the elderly) (Kim and Sapienza, 2005). Maximal inspiratory (MIP) and maximal expiratory (MEP) mouth pressures are non-invasive measures of respiratory muscle strength (Laveneziana et al., 2019) and have also been shown to decrease with age (Enright et al., 1994). Weak expiratory muscles could result in a poorly graded expiratory pressure and weak inspiratory muscles could result in less diaphragmatic contribution to inspiratory muscle strength. Both of these could place additional strain on weak pelvic floor muscles. A recent comparative study demonstrated reduced MIP and MEP in women between the ages of 35-65 years with UI compared to continent women (Abidi et al., 2022). Respiratory muscle strength has not been widely assessed in elderly women with SUI. It is also unknown if respiratory muscle strength is related to severity of SUI independent of age, sex, BMI, and parity. The present study aimed to assess the relationship between respiratory muscle strength, pulmonary function and severity of SUI in community living elderly women. It was hypothesized that there would be a correlation of −0.30 or greater between higher ICIQ-UI SF scores and lower MEP. Additionally, it was hypothesized that after adjustment for confounders, MEP would be an independent parameter.

## 2. MATERIALS AND METHODS

### 2.1. Study design, setting and ethics

This study is a cross-sectional analysis which was conducted following the STROBE statement (von Elm et al., 2007). Subjects were recruited from out-patient physiotherapy clinic, elderly clubs, community geriatric health centers consecutively among eligible volunteers. The study was done following Declaration of Helsinki, ICMR National Ethical Guidelines (Indian Council of Medical Research, 2017) and informed written consent was taken from all the participants. Patients with severe UI or abormal spirometry were referred to a physician.

### 2.2. Participants

Individuals aged 60 years or above, who self-report stress or stress-predominant mixed urinary incontinence (ICIQ-UI SF score ≥1), possess independent or little aided mobility, and achieve a Mini-Mental State Examination (MMSE) score of no less than 24 (Folstein et al., 1975) were deemed eligible. Exclusion criteria included neurological disorders impacting continence, such as stroke, Parkinson's disease, multiple sclerosis, or spinal cord damage, acute respiratory illness in the previous 4 weeks; pelvic, abdominal or thoracic surgery in the previous 6 months, or prostatectomy in men; active urinary tract infection; and contraindications to maximal pressure testing (recent myocardial infarction, uncontrolled hypertension, aneurysm, recent eye surgery or hernia).

### 2.3. Sample size

To detect a correlation of r = 0.30 with α = 0.05 (two-tailed) and 80% power, 84 participants were required (G*Power) (Faul et al., 2009). Allowing for 15% incomplete data, recruitment of 100 participants was planned; this also exceeded 10 participants per predictor for the regression model.

### 2.4. Procedure and measurements

Demographic and clinical information was first documented, including age, gender, stature, mass, parity (for females), persistent cough (≥8 weeks), smoking history, kind of urinary incontinence, and MMSE. Body mass index (BMI) was classified with Asian cut-offs (WHO Expert Consultation, 2004). Respiratory tests were performed in sitting after 10 min of rest in a fixed order (spirometry, MIP, MEP) with rest between tests. Questionnaires were administered by an assessor blinded to the respiratory results.

SUI severity was measured with the validated Tamil and English version of the ICIQ-UI Short Form, the sum of items on frequency (0–5), amount (0–6) and interference with daily life (0–10), giving a total of 0–21 (Avery et al., 2004); scores were categorized as slight (1–5), moderate (6–12), severe (13–18) or very severe (19–21) (Klovning et al., 2009). MIP was measured from residual volume and MEP from total lung capacity with a digital manometer, and the highest of three manoeuvres was recorded in $cmH_2O$ (Laveneziana et al., 2019); trials differing by more than 10% were flagged. Predicted values and lower limits of normal (LLN) were calculated with the age- and sex-specific equations summarized by Evans and Whitelaw (2009). Forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_1$) were measured with a portable spirometer according to the ATS/ERS 2019 standards (Graham et al., 2019) and expressed as % predicted, together with the $FEV_1$/FVC ratio; obstruction was defined as $FEV_1$/FVC below the LLN and a restrictive pattern as FVC below the LLN with a normal ratio.

### 2.5. Statistical analysis

All derived variables (ICIQ-UI SF total and category, best MIP and MEP, % predicted values and LLN status, BMI and spirometric indices) were computed from the recorded raw values, and all participants were retained; analyses used all available data for each variable. The assessment of normality was conducted by the Shapiro–Wilk test, and the results are reported as mean (SD) and median. (IQR) or n (%). Because ICIQ-UI SF scores were not normally distributed, associations with each respiratory variable were assessed with Spearman's correlation, with 95% confidence intervals (CI) from Fisher's z transformation; partial correlations adjusted for age, sex, BMI, parity (zero for men) and chronic cough were also calculated. Multiple linear regression was performed with ICIQ-UI SF score as the outcome and MEP, age, sex, BMI, parity and chronic cough as predictors. Unstandardized (B) and standardized (β) coefficients with 95% CI are reported, together with the change in $R^2$ when MEP was added to the covariates and Cohen's $f^2$. Collinearity was assessed with the variance inflation factor (VIF), and residual normality, homoscedasticity (Breusch–Pagan test) and influential observations (Cook's distance) were examined; robust (HC3) standard errors and 2,000 bootstrap replicates were used as checks. Equivalent models were fitted for MIP, for MEP and MIP together and, in sensitivity analyses, for MEP % predicted, women only, participants with reproducible manometry, additional adjustment for UI type and ordinal logistic regression of severity category. Respiratory variables were compared across severity categories with one-way ANOVA or the Kruskal–Wallis test, with Bonferroni-corrected pairwise comparisons and a Spearman test for trend. The threshold for statistical significance was determined to be $p < 0.05$.

## 3. RESULTS AND DISCUSSION

### 3.1. Participant characteristics

All 104 participants assessed were included (**Figure 1**); manometry was unavailable for one participant and spirometry for two. Participants were aged 60–82 years (mean 67.5 ± 4.7), 91.3% were women, 39.4% had stress-predominant mixed UI and 13.5% reported chronic cough, and 46.2% were obese by Asian criteria (Table 1). The mean ICIQ-UI SF score was 10.5 ± 4.2; most participants had moderate SUI (59.6%), with 13.5% slight, 22.1% severe and 4.8% very severe. Women had more severe SUI than men (10.8 ± 4.2 vs 7.2 ± 2.6; p = 0.013), and participants with chronic cough had higher scores than those without (14.1 ± 4.6 vs 9.9 ± 3.8; p = 0.001). Mean MEP was 65.0 ± 21.5 $cmH_2O$ (84.2% predicted), and 41 participants (39.8%) had MEP below their age- and sex-specific LLN, whereas mean MIP was 60.8 ± 21.2 $cmH_2O$ (87.7% predicted) and only 6 (5.8%) were below the MIP LLN; MEP was lower than MIP in 37 participants (36%). Spirometry was normal in 80.4%. The three

manometry trials agreed closely (intraclass correlation 0.94 for MIP and 0.95 for MEP), supporting the reliability of the strength measurements.

### 3.2. Respiratory muscle strength, pulmonary function and SUI severity

MEP was negatively correlated with ICIQ-UI SF score ($\varrho = -0.37$, 95% CI −0.52 to −0.19; $p < 0.001$) (Table 2; **Figure 2**). The point estimate exceeded the hypothesized threshold of −0.30, so the null hypothesis was rejected in favour of $H_1$, although the confidence interval also included weaker associations. Mean ICIQ-UI SF score decreased from 12.3 in the lowest tertile of MEP % predicted to 9.1 in the highest (trend $p = 0.002$). MIP showed a weaker association ($\varrho = -0.25$; $p = 0.012$), whereas FVC, $FEV_1$ and $FEV_1$/FVC were not associated with severity (all $|\varrho| \leq 0.03$; $p \geq 0.79$). Adjustment for age, sex, BMI, parity and chronic cough left the MEP correlation virtually unchanged (partial $r = -0.36$) and slightly attenuated the MIP correlation (partial $r = -0.22$; $p = 0.028$) (**Figure 3**). In women alone ($n = 94$), the MEP association persisted ($r = -0.32$; $p = 0.002$) but the MIP association did not ($r = -0.17$; $p = 0.10$). At item level, MEP was related similarly to frequency ($\varrho = -0.30$), amount ($\varrho = -0.34$) and interference with daily life ($\varrho = -0.33$), whereas spirometric indices were unrelated to any item (**Figure 4**).

These findings extend those of Abidi et al. (2022), who reported lower MIP and MEP in middle-aged women with UI than in continent controls, to an older community-dwelling population of both sexes and to a validated severity score with adjustment for the main obstetric, anthropometric and respiratory risk factors. The absence of any association with spirometric indices is informative: SUI severity was related to the force the respiratory muscles could generate, not to lung volume or airflow, which is consistent with a mechanism operating through pressure generation and control rather than through respiratory disease. The consistent relationship of MEP with all three ICIQ-UI SF items indicates that expiratory weakness relates to how often leakage occurs, how much is lost and how much it disturbs daily life, rather than to a single aspect of the symptom.

### 3.3. MEP as an independent predictor

In multiple linear regression (Table 3), MEP remained an independent predictor of ICIQ-UI SF score (B = -0.076 per $cmH_2O$, 95% CI -0.116 to -0.037; $\beta = -0.39$; $p < 0.001$), supporting $H_2$. Each 10 $cmH_2O$ lower MEP was associated with a 0.76-point higher score, and adding MEP to the covariates increased $R^2$ from 0.30 to 0.39 ($\Delta R^2 = 0.094$; $f^2 = 0.15$, a medium effect). Chronic cough (B = 3.64; $p < 0.001$), BMI ($\beta = 0.28$; $p = 0.001$) and parity (B = 0.39; $p = 0.047$) were also independent predictors, consistent with their established roles (Rortveit et al., 2003; Subak et al., 2009), whereas age and sex were not. Assumptions were satisfied (maximum VIF 1.87; residual normality $p = 0.34$; Breusch–Pagan $p = 0.26$; maximum Cook's distance 0.10), the relationship was linear (quadratic term $p = 0.37$; **Figure 5**), and the bootstrap 95% CI for MEP (-0.109 to -0.044) excluded zero.

The association was robust in sensitivity analyses: it was similar for MEP % predicted ($\beta = -0.32$), in women only ($\beta = -0.32$), in the 88 participants with reproducible manometry ($\beta = -0.37$) and after additional adjustment for UI type ($\beta = -0.41$), and did not differ by sex (interaction $p = 0.41$). In ordinal logistic regression, each 10 $cmH_2O$ higher MEP reduced the odds of a higher severity category (OR 0.62, 95% CI 0.47 to 0.80). MIP was a weaker independent predictor ($\beta = -0.21$; $p = 0.028$; $\Delta R^2 = 0.035$), and when both were entered together MEP remained significant ($p = 0.003$) whereas MIP did not ($p = 0.84$). Spirometric indices added nothing to the MEP model.

Several mechanisms may explain these associations. The expiratory and abdominal muscles generate the rises in intra-abdominal pressure during coughing and effort, and their co-activation with the pelvic floor is part of a feed-forward continence strategy (Sapsford and Hodges, 2001; Neumann and Gill, 2002). Weak expiratory muscles may require greater relative effort and less controlled pressure generation for a given task, while weakness of the diaphragm may reduce its contribution to pressure regulation (Hodges and Gandevia, 2000; Talasz et al., 2011); the dominance of MEP over MIP in the joint model suggests that the expiratory component matters most. Respiratory and pelvic floor muscle weakness may also share common determinants such as sarcopenia and physical inactivity in older adults (Enright et al., 1994). Because the design is cross-sectional, the direction of the association cannot be determined, and reduced physical activity due to SUI could itself contribute to respiratory muscle weakness.

### 3.4. Respiratory strength across SUI severity categories

MEP declined progressively across severity categories (Table 4; **Figure 6**), with means of 81.7, 65.8, 56.4 and 46.2 $cmH_2O$ in slight, moderate, severe and very severe SUI (Kruskal–Wallis $p = 0.003$; trend $p < 0.001$); MEP % predicted showed the same

gradient (94.8% to 64.1%; trend p = 0.002). After Bonferroni correction, MEP differed significantly between the moderate and very severe categories (p = 0.036), with a borderline slight–very severe difference (p = 0.050). MIP also differed across categories (p = 0.004) but not monotonically, being higher in very severe than in severe SUI. BMI increased across categories (p = 0.004), whereas age, parity and spirometry did not differ. Participants with MEP below the LLN had higher ICIQ-UI SF scores than those with normal MEP (12.2 ± 4.7 vs 9.3 ± 3.4; p = 0.002), whereas MIP weakness was too infrequent to show a difference (**Figure 7**). These results suggest that expiratory muscle testing may help identify older adults in whom respiratory muscle weakness contributes to SUI, and they provide a rationale for evaluating respiratory muscle training or combined diaphragmatic, abdominal and pelvic floor retraining (Hung et al., 2010) as adjuncts to pelvic floor muscle training (Bø, 2004; Dumoulin et al., 2018).

### 3.5. Strengths and limitations

Strengths include an adequately powered sample with no exclusions after enrolment, standardized respiratory testing with highly reproducible manometry, blinded questionnaire administration, a validated severity measure, adjustment for the principal confounders with verified model assumptions, and consistent results across correlation, regression, category and sensitivity analyses. Constraints include the cross-sectional framework, which inhibits causal conclusions; the limited male sample (n = 9) and the few individuals with extreme severity SUI (n = 5), which limits sex-specific and category-specific conclusions; manometry trials that did not all meet the 10% reproducibility criterion, although results were unchanged when these participants were excluded; the use of non-Indian reference equations for MIP and MEP; the lack of direct pelvic floor muscle strength and intra-abdominal pressure measurement; and the absence of UI-related quality of life and breathlessness data, which were planned secondary measures.

## 4. CONCLUSIONS

In community-dwelling older adults with SUI, lower expiratory muscle strength was associated with greater SUI severity independently of age, sex, BMI, parity and chronic cough, whereas inspiratory strength showed a weaker association that did not persist alongside MEP, and pulmonary function was unrelated. Two in five participants had expiratory muscle weakness, and they had more severe incontinence. Respiratory muscle strength testing is simple and inexpensive and could be added to pelvic health assessment in older adults. Longitudinal studies and randomized trials of expiratory muscle training combined with pelvic floor muscle training are needed to establish whether improving expiratory strength reduces SUI severity.

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**Author contributions:**

Dr C V Senthil Nathan : conceptualization, methodology, investigation, data curation, writing – original draft.

Dr Ajay Kumar: superision, data collection, writing – review and editing

Dr Praveen B M : supervision, methodology, writing – review and editing.

Dr. Vijayakumar Palaniswamy: Statistical analysis and visualization, review and editing.

Dr. Mohan Kumar G: Statistical analysis, data curation and visualization

Dr. Rajalaxmi V: Statistical analysis and visualization

Dr. S. Veenakirthika: writing – review and editing

Dr. S Jeyakumar: , data curation and visualization

All authors read and approved the final manuscript.

**Conflict of interest**

The authors declare that they have no potential financial interests

**Ethics statement**

The study was approved by the Institutional Review Board of Faculty of Physiotherapy (approval no – 0502/GIA/PHYSIO/IRB/2026) conducted in accordance with the ICMR

National Ethical Guidelines (2017) and the Declaration of Helsinki. Written informed consent was obtained from all participants.

**Data availability statement**

The dataset supporting the findings of this study is available from the corresponding author on reasonable request.

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**Table 1.** Characteristics of the participants (n = 104)

| Characteristic | Value |
|---|---|
| ***Demographic and clinical*** | |
| Age (years) | 67.5 ± 4.7 |
| Women, n (%) | 95 (91.3) |
| BMI (kg/m²) | 25.3 ± 4.3 |
| Obese (BMI ≥25 kg/m²), n (%) | 48 (46.2) |
| Parity (women, n = 95), median (IQR) | 3.0 (2.0–4.0) |
| MMSE (0–30), median (IQR) | 28.0 (27.0–28.2) |
| Chronic cough ≥8 weeks, n (%) | 14 (13.5) |
| Current or former smoker, n (%) | 8 (7.7) |
| ***Urinary incontinence*** | |
| Stress-predominant mixed UI, n (%) | 41 (39.4) |
| ICIQ-UI SF total (0–21) | 10.5 ± 4.2 |
| Slight (1–5), n (%) | 14 (13.5) |
| Moderate (6–12), n (%) | 62 (59.6) |
| Severe (13–18), n (%) | 23 (22.1) |
| Very severe (19–21), n (%) | 5 (4.8) |
| ***Respiratory muscle strength (n = 103)*** | |
| MIP ($cmH_2O$) | 60.8 ± 21.2 |
| MIP (% predicted) | 87.7 ± 26.5 |
| MIP below LLN, n (%) | 6 (5.8) |
| MEP ($cmH_2O$) | 65.0 ± 21.5 |
| MEP (% predicted) | 84.2 ± 21.1 |
| MEP below LLN, n (%) | 41 (39.8) |
| ***Pulmonary function (n = 102)*** | |
| FVC (% predicted) | 86.9 ± 9.6 |
| $FEV_1$ (% predicted) | 87.5 ± 10.9 |
| $FEV_1$/FVC | 0.780 ± 0.051 |
| Obstructive pattern, n (%) | 6 (5.9) |
| Restrictive pattern, n (%) | 14 (13.7) |

Values are mean ± SD unless otherwise stated. BMI categories follow WHO Asian cut-offs. MIP and MEP predicted values and lower limits of normal (LLN) from the sex-specific equations of Evans and Whitelaw (2009); spirometric patterns defined by the spirometer LLN. The term $FEV_1$ is used for forced expiratory volume in one second; FVC is the acronym for forced vital capacity; ICIQ-UI SF refers to the International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form; MEP means maximal expiratory pressure; MIP stands for maximal inspiratory pressure; MMSE is the Mini-Mental State Examination; UI represents urinary incontinence.

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**Table 2.** Correlations of respiratory muscle strength and pulmonary function with ICIQ-UI SF score

| Respiratory variable | Spearman ϱ (95% CI) | p value | Partial r (95% CI) | p value | Women only, r (p) |
|---|---|---|---|---|---|
| **MEP ($cmH_2O$)** | **−0.37 (−0.52 to −0.19)** | **<0.001** | **−0.36 (−0.52 to −0.18)** | **<0.001** | **−0.32 (0.002)** |
| MEP (% predicted) | −0.31 (−0.47 to −0.12) | 0.002 | −0.38 (−0.53 to −0.19) | <0.001 | −0.30 (0.003) |
| MIP ($cmH_2O$) | −0.25 (−0.42 to −0.06) | 0.012 | −0.22 (−0.40 to −0.02) | 0.028 | −0.17 (0.098) |
| MIP (% predicted) | −0.21 (−0.39 to −0.02) | 0.031 | −0.22 (−0.40 to −0.02) | 0.033 | −0.16 (0.136) |
| FVC (% predicted) | 0.01 (−0.18 to 0.21) | 0.912 | −0.00 (−0.20 to 0.20) | 0.995 | 0.05 (0.652) |
| $FEV_1$ (% predicted) | −0.01 (−0.21 to 0.18) | 0.891 | −0.03 (−0.23 to 0.17) | 0.757 | −0.02 (0.880) |
| $FEV_1$/FVC | −0.03 (−0.22 to 0.17) | 0.799 | −0.05 (−0.25 to 0.15) | 0.596 | −0.15 (0.137) |

n = 103 for manometry and n = 102 for spirometry. Partial correlations adjusted for age, sex, BMI, parity and chronic cough. Women-only correlations (n = 94 or 93) were Pearson or Spearman according to normality.

**Table 3.** Multiple linear regression of ICIQ-UI SF score on maximal expiratory pressure and covariates

| Predictor | B (95% CI) | β | p value | VIF |
|---|---|---|---|---|
| **MEP ($cmH_2O$)** | **-0.076 (-0.116 to -0.037)** | **−0.39** | **<0.001** | **1.65** |
| Age (years) | 0.104 (-0.048 to 0.255) | 0.12 | 0.177 | 1.13 |
| Female sex | -1.753 (-4.938 to 1.431) | — | 0.277 | 1.87 |
| BMI ($kg/m^2$) | 0.273 (0.112 to 0.434) | 0.28 | 0.001 | 1.08 |
| Parity | 0.390 (0.005 to 0.775) | 0.18 | 0.047 | 1.27 |
| Chronic cough (yes) | 3.635 (1.607 to 5.664) | — | <0.001 | 1.05 |
| ***Secondary and sensitivity models (MEP or MIP coefficient)*** | | | | |
| MIP ($cmH_2O$), adjusted for covariates | -0.041 (-0.078 to -0.004) | −0.21 | 0.028 | 1.26 |
| MEP, with MIP and covariates | -0.073 | — | 0.003 | 2.43 |
| MIP, with MEP and covariates | -0.004 | — | 0.841 | — |
| MEP (% predicted), adjusted for covariates | -0.063 (-0.095 to -0.032) | −0.32 | <0.001 | 1.02 |
| MEP, women only (n = 94) | -0.085 (-0.133 to -0.038) | −0.32 | <0.001 | 1.10 |
| MEP, reproducible manometry (n = 88) | -0.069 (-0.112 to -0.027) | −0.37 | 0.002 | 1.74 |
| MEP, additionally adjusted for UI type | -0.080 (-0.118 to -0.041) | −0.41 | <0.001 | 1.66 |

Primary model (n = 103): $R^2 = 0.389$, adjusted $R^2 = 0.351$, F-test $p < 0.001$; $R^2$ of covariates alone = 0.295; $\Delta R^2$ for MEP = 0.094 ($p < 0.001$); Cohen's $f^2 = 0.15$. $R^2$ of the model with MEP and MIP = 0.389. Ordinal logistic regression of severity category: OR per 10 $cmH_2O$ MEP = 0.62 (0.47 to 0.80). Results were unchanged with robust (HC3) standard errors and bootstrap resampling. Parity coded 0 for men. B, unstandardized coefficient; β, standardized coefficient (continuous predictors); VIF, variance inflation factor.

**Table 4.** Respiratory variables and covariates across ICIQ-UI SF severity categories

| Variable | Slight (n = 14) | Moderate (n = 62) | Severe (n = 23) | Very severe (n = 5) | p value | p trend |
|---|---|---|---|---|---|---|
| **MEP ($cmH_2O$)** | **81.7 ± 35.4** | **65.8 ± 17.4** | **56.4 ± 15.4** | **46.2 ± 6.0** | **0.003** | **<0.001** |
| MEP (% predicted) | 94.8 ± 25.9 | 85.9 ± 19.3 | 77.3 ± 20.4 | 64.1 ± 6.1 | 0.009 | 0.002 |
| MIP ($cmH_2O$) | 76.4 ± 32.6 | 60.9 ± 17.1 | 50.3 ± 18.9 | 62.4 ± 15.3 | 0.004 | 0.017 |
| MIP (% predicted) | 101.6 ± 31.2 | 88.4 ± 23.9 | 75.1 ± 27.3 | 94.3 ± 21.8 | 0.024 | 0.034 |
| FVC (% predicted) | 87.5 ± 12.4 | 86.7 ± 9.9 | 85.9 ± 7.1 | 93.6 ± 7.0 | 0.434 | 0.774 |
| $FEV_1$ (% predicted) | 87.7 ± 11.9 | 87.5 ± 11.9 | 87.0 ± 7.9 | 89.2 ± 10.9 | 0.980 | 0.992 |
| $FEV_1$/FVC | 0.785 ± 0.051 | 0.781 ± 0.050 | 0.785 ± 0.044 | 0.736 ± 0.085 | 0.260 | 0.881 |
| Age (years) | 65.7 ± 4.6 | 67.8 ± 4.4 | 67.3 ± 5.2 | 68.6 ± 5.6 | 0.255 | 0.381 |
| BMI ($kg/m^2$) | 22.3 ± 2.0 | 25.1 ± 4.3 | 27.2 ± 4.7 | 27.6 ± 3.6 | 0.004 | <0.001 |
| Parity (women) | 2.7 ± 1.9 | 2.9 ± 1.9 | 3.0 ± 1.7 | 4.0 ± 2.0 | 0.644 | 0.397 |

Values are mean ± SD. p values from one-way ANOVA or the Kruskal–Wallis test; p trend from Spearman correlation with category rank. Manometry missing for one participant in the severe category and spirometry for two. Bonferroni-corrected pairwise comparisons for MEP: moderate vs very severe p = 0.036; slight vs very severe p = 0.050; all others p ≥ 0.10.

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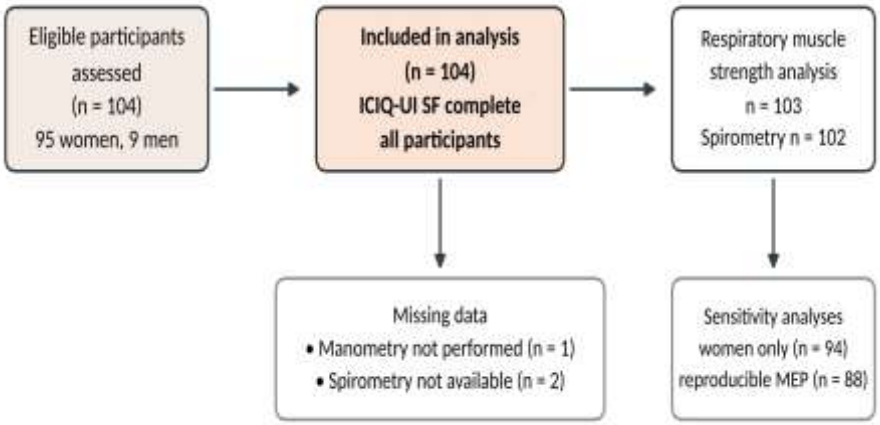



**Figure 1**

**Flow of participants through the study.** All 104 participants assessed were included; numbers available for manometry and spirometry, reasons for missing data and the samples for the women-only and reproducible-manometry sensitivity analyses are shown (STROBE).

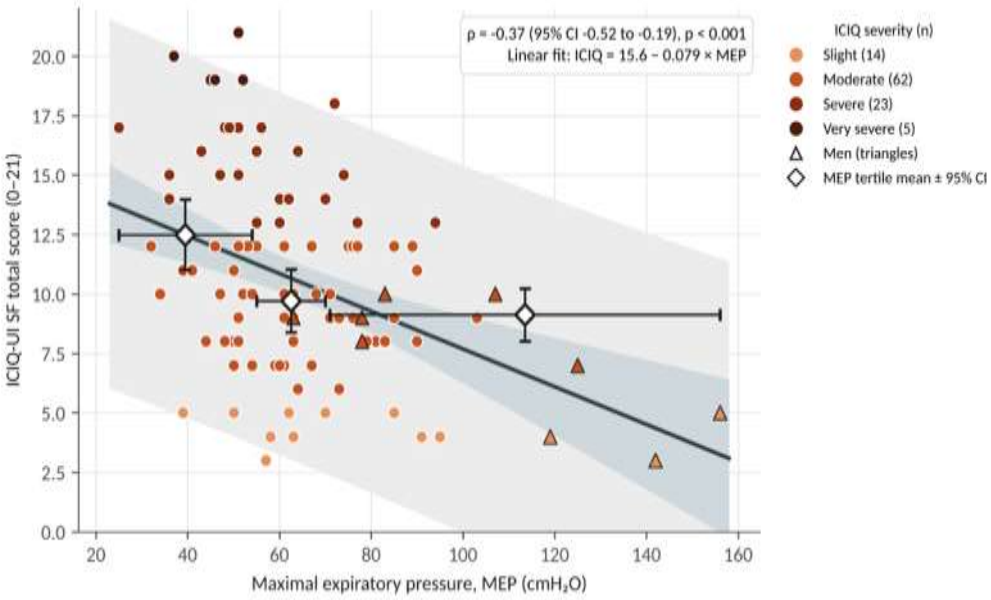



**Figure 2**

**Association between maximal expiratory pressure and ICIQ-UI SF score.** Points are participants (n = 103) coloured by SUI severity category; triangles are men. The line is the least-squares fit with its 95% confidence band (dark) and 95% prediction band (light). Diamonds are mean ICIQ-UI SF scores (± 95% CI) within MEP tertiles, plotted at the tertile midpoint with horizontal bars spanning the tertile Range.

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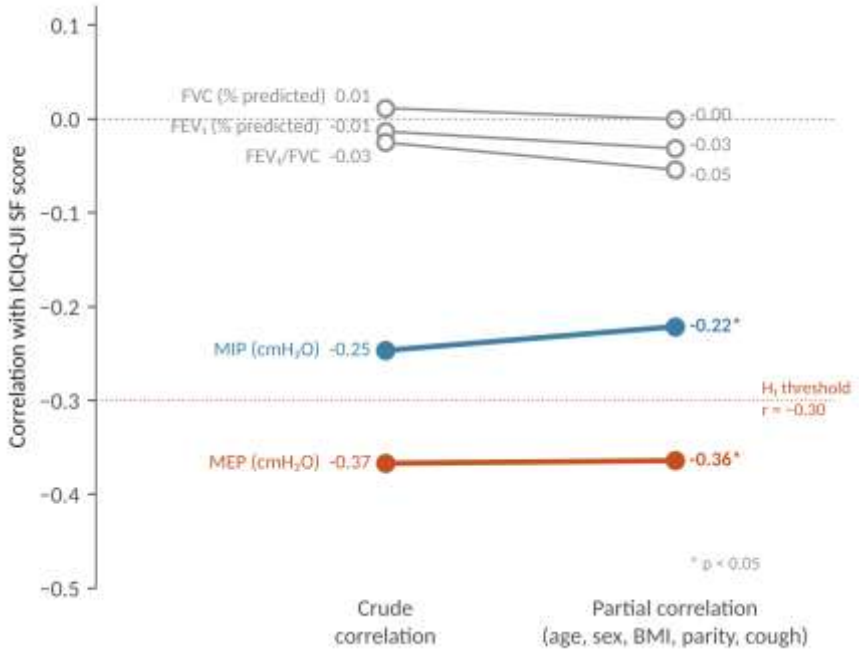



**Figure 3**

**Crude and adjusted correlations of respiratory variables with ICIQ-UI SF score.** Slopegraph showing the change from crude Spearman correlation to partial correlation adjusted for age, sex, BMI, parity and chronic cough. Filled markers indicate $p < 0.05$; the dotted line marks the hypothesized threshold of $r = -0.30$.

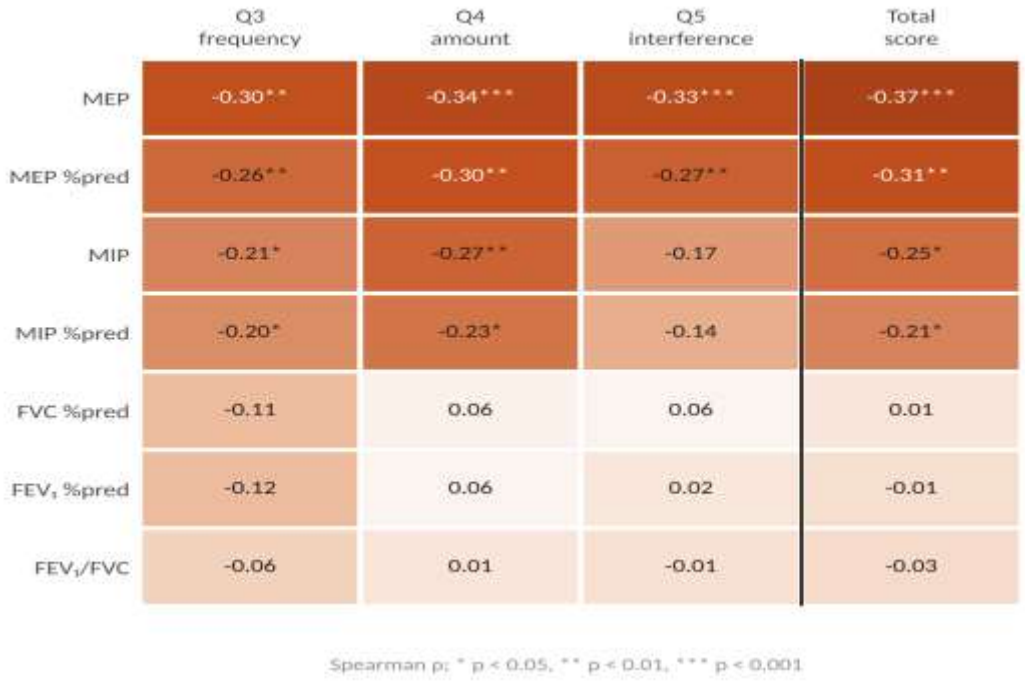



**Figure 4**

**Correlations of respiratory variables with ICIQ-UI SF items.** Heatmap of Spearman correlation coefficients between respiratory variables and the frequency (Q3), amount (Q4) and interference (Q5) items and total score; darker shading indicates stronger negative correlation. * $p < 0.05$, **$p < 0.01$,** * $p < 0.001$.

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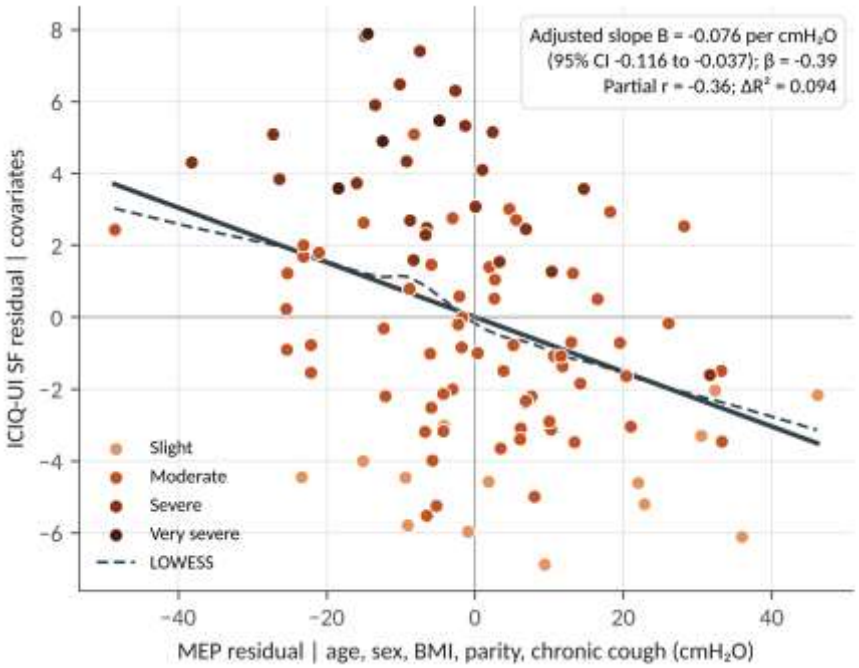



**Figure 5**

**Covariate-adjusted relationship between MEP and ICIQ-UI SF score.** Added-variable plot showing residuals of ICIQ-UI SF score against residuals of MEP, each after regression on age, sex, BMI, parity and chronic cough (n = 103). The solid line is the adjusted slope and the dashed line a LOWESS smoother; points are coloured by severity category.

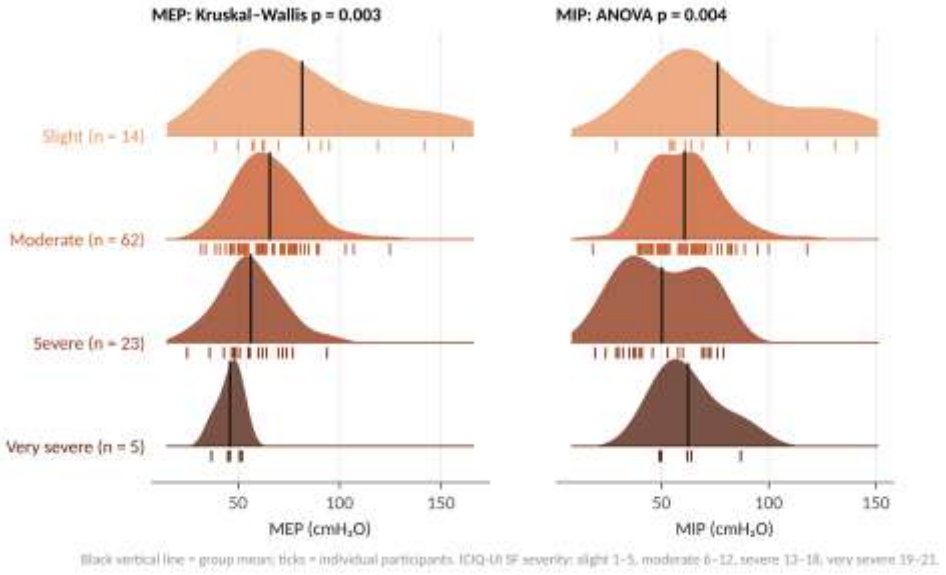



**Figure 6**

**Distribution of respiratory muscle strength by SUI severity category.** Ridgeline plots of MEP (left) and MIP (right) in participants with slight (n = 14), moderate (n = 62), severe (n = 22) and very severe (n = 5) SUI; vertical black lines are group means and ticks are individual participants.

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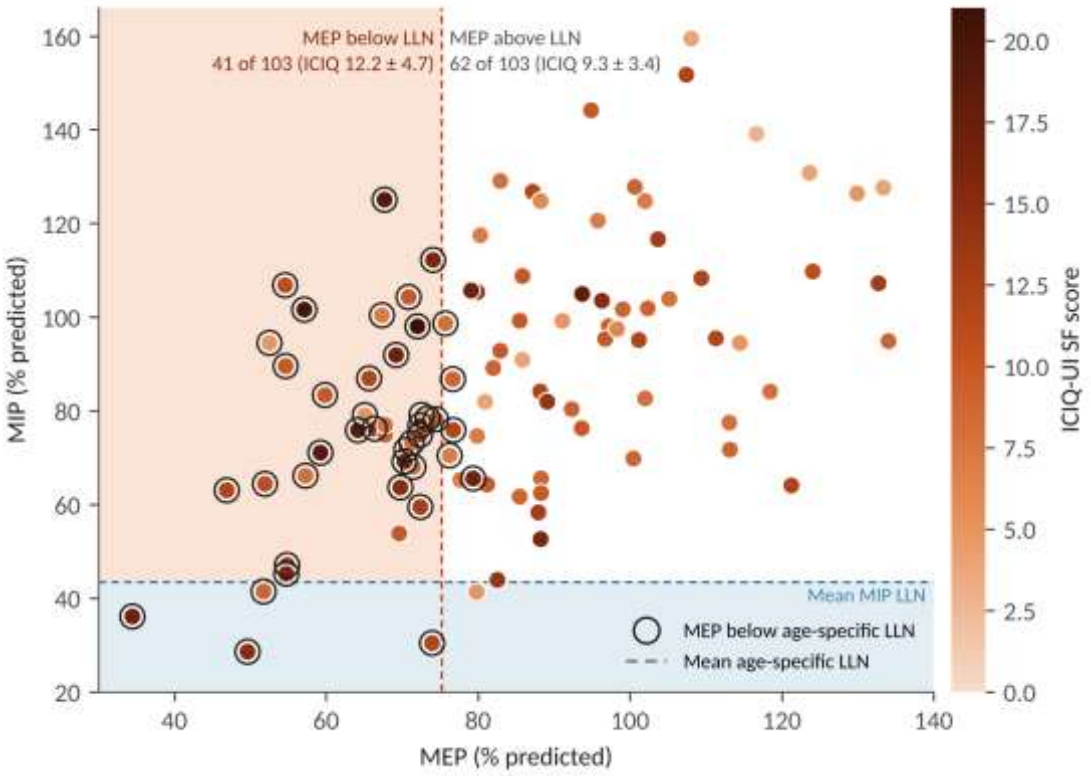



**Figure 7**

**Respiratory muscle strength profile and SUI severity.** Each point is one participant's MEP against MIP (% predicted), coloured by ICIQ-UI SF score. Dashed lines and shaded regions mark the mean age- and sex-specific lower limit of normal (LLN); circled points have MEP below their own LLN.