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RESEARCH ARTICLE

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Childhood respiratory risk profiles associate with lung function and COPD among the old population

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ABSTRACT

Background: Childhood, often characterized by multiple concurrent risk factors, holds significant influence over long-term respiratory outcomes, with the intricate interplay among these factors representing an intriguing but underexplored avenue for research. We aimed to determine if respiratory risk factors during childhood affect lung function and chronic obstructive pulmonary disease (COPD) in old age.

Methods: Participants were drawn from the Health and Retirement Study cohort. Latent class analysis (LCA) was applied with six variables used to develop the early-life respiratory risk profiles. Linear regressions and logistic regressions were used to assess the associations between childhood respiratory risk profiles and lung function, including peak expiratory flow (PEF) value, PEF value <80% of the predicted value and COPD.

Results: A total of 12,296 participants (5017 males and 7279 females) with an average age of 68 years were recruited. We identified six distinct childhood respiratory risk profiles: (1) 'Asthma and respiratory disorders in early childhood' (n = 241, 1.96%), (2) 'Unexposed or least exposed' (n = 3874, 31.51%), (3) 'Smokers at home' (n = 7609, 61.88%), (4) 'Ear problems and respiratory disorders in early childhood' (n = 162, 1.32%), (5) 'Allergic conditions and respiratory disorders in early childhood' (n = 220, 1.79%) and (6) 'Allergic conditions and respiratory disorders in later childhood' (n = 190, 1.55%). Profile 2 served as the reference. The highest reduction of PEF was seen for profile 1 (–30.07 L/min), followed by profile 6 (–22.24 L/min) and profile 5 (–18.47 L/min). Profile 6, profile 3 and profile 1 related to 1.98-, 1.52- and 1.66-fold increased risks of diminished PEF values, respectively. The highest risk of COPD was observed in profile 5 (aOR = 4.16, 95% CI: 3.75–4.57), followed by profile 6 (aOR = 4.10, 3.69–4.51), profile 4 (aOR = 3.70, 3.25–4.15), profile 1 (aOR = 3.46, 3.07–3.85) and profile 3 (aOR = 1.41, 1.25–1.57).

Conclusions: People exposed to early-life respiratory challenges experienced larger declines in lung function and increased risks of COPD later in life. Our findings underscore the importance of early-life respiratory health in shaping lung function trajectories.

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Respiratory risk; lung function; latent class analysis; peak expiratory flow; COPD; old people

Introduction

Respiratory health serves as a cornerstone of overall well-being [1]. Chronic obstructive pulmonary disease (COPD) is characterized by persistent airway and alveolar abnormalities, resulting in chronic respiratory symptoms such as dyspnoea, cough and sputum production, which is the eighth leading cause of poor health globally (measured in disability-adjusted life years) [2–4]. Despite its global prevalence, COPD is frequently under-recognized and inadequately diagnosed [5]. Projections from the World Health Organization on mortality and disease burden state that by 2030, COPD is projected to emerge as the third leading cause of mortality on a global scale [6]. The burden of COPD is disproportionately higher in the elderly, a demographic segment poised for amplification, underscoring the

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imperative for rigorous longitudinal studies to elucidate the implications of early-life exposures on subsequent pulmonary health outcomes [3,7]. Measures of limited lung function are recognized as pivotal physiological markers correlated with diminished physical capacity, poorer health status and reduced survival rates [8,9]. Peak expiratory flow (PEF) refers to the maximum instantaneous airflow achieved during forced expiration in a spirometry test and is widely acknowledged as an indicator of airflow through the bronchi, providing insight into obstructive ventilatory defects in the airways [10]. Traditional metrics like forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) are commonly used as the gold standard to measure lung function status [10]. However, in the context of the elderly and large-scale epidemiological surveys, the ease of operation and convenience of PEF seem to make it an alternative indicator to reflect lung function to some extent [9,11].

COPD is a progressively developing condition over time, often resulting from the combined effects of multiple risk factors. Researches have shown that tobacco exposure (either active smoking or passive exposure to second-hand smoke) and air pollution are the most common causes, while other contributing factors include occupational exposures (such as dust, smoke, or chemicals), early-life events that hinder maximal lung development (e.g. intrauterine growth restriction, preterm birth and frequent or severe respiratory infections during childhood), childhood asthma and poor mental health (e.g. anxiety and depression) [4]. Additionally, a rare genetic disorder, alpha-1 antitrypsin deficiency, can lead to COPD at a young age [12]. A mounting body of evidence underscored the pivotal role played by early-life respiratory risk factors in shaping the trajectory of COPD later in life [13–15]. Childhood often serves as the crucible for a myriad of concurrent risk factors, the intricate interplay among which may wield a profound influence on long-term respiratory outcomes [1,16–21]. While prior investigations have delved into isolated or simplistic combinations of childhood factors, the intricate web of interactions among coexisting factors remains largely uncharted territory [1,16–21]. For instance, a plethora of childhood adversities, including respiratory infections, asthma, allergies, pneumonia, passive smoking exposure and an expanding array of other risk factors, have all been implicated in the erosion of adult lung function and the heightened susceptibility to COPD [1,16–21]. However, the synergistic impact of these factors remains an avenue yet to be fully explored. A comprehensive understanding of the trajectories that link early respiratory risk factors to the attenuation of adult lung function assumes paramount importance in both the prophylaxis and management of COPD.

In this study, we endeavour to elucidate the longitudinal trajectories of lung function across different childhood risk profiles identified through latent class analysis (LCA) and to investigate the associations between childhood respiratory risk profiles and pulmonary function outcomes in later life via a sizable cohort of elderly individuals. We hypothesize that early childhood respiratory issues may be significantly associated with a decline in lung function and an increased risk of COPD in older adults. Through a multidimensional approach, our study contributes to a deeper understanding of the early-life origins of respiratory disease.

Methods

Data source and participants

Participants were drawn from the Health and Retirement Study (HRS), a nationally representative longitudinal study of Americans aged 50 and older, providing de-identified data updates every 2 years since 1992 [22,23]. It covers a wide range of structured variables including demographics, childhood experiences, medical health and physical measurements [22,23]. Physical measurements were taken for one-half of the full survey sample in 2006, and the other half in 2008 [9]. To reduce recall bias, trained interviewers segmented the recall into different life cycle stages (e.g. 0–12 years, 12–16 years, etc.), allowing participants to recall each stage more specifically and clearly, thereby minimizing bias. At the same time, consistency check questions (e.g. asking about other events or health details consistent with the participant's recall) were used to verify the accuracy. The inclusion and exclusion criteria of this study are shown in the flowchart (Figure 1). The HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.

Childhood respiratory risk condition

Respondents were queried about their childhood health, including whether they experienced asthma, respiratory disorders (such as bronchitis, wheezing, hay fever, shortness of breath, or sinus infection), allergic conditions, or ear problems (chronic ear problems or infections) before the age of 16. Additionally, information on the age of first diagnosis for these conditions was collected for classification purposes. Participants were also asked about parental smoking habits and their smoking history during adolescence. Ultimately,

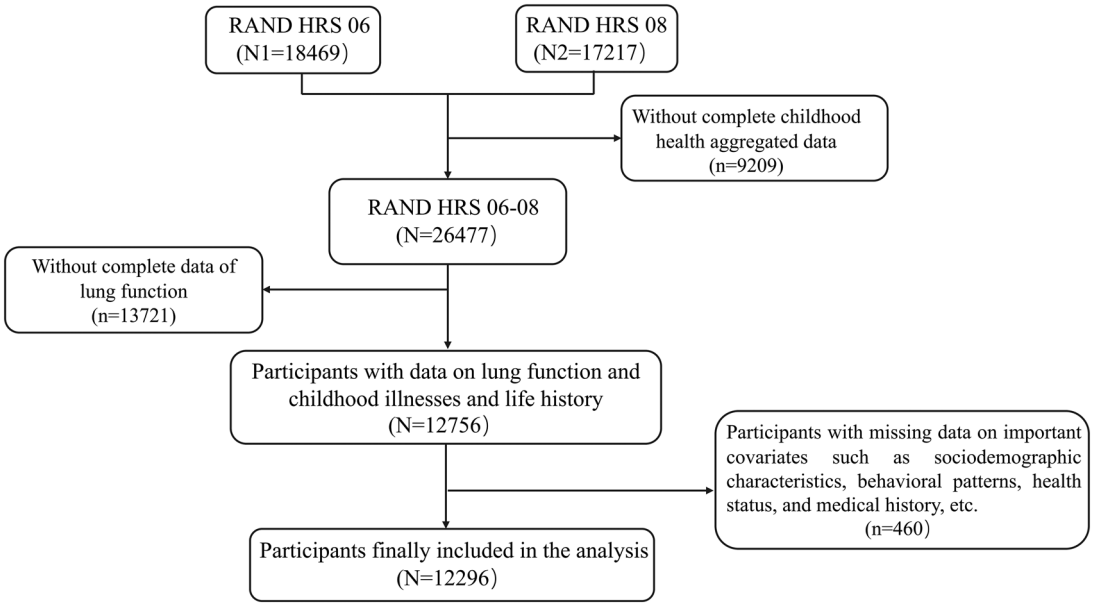

Figure 1. Flowchart of analysis based on the Health and Retirement Study (HRS).

six childhood respiratory risk factors were included in the analysis: parental smoking (yes/no), childhood smoking (yes/no), respiratory disorders (<12 years old, ≥12 years old, or none), asthma (<12 years old, ≥12 years old, or none), allergic conditions (<12 years old, ≥12 years old, or none) and ear problems (<12 years old, ≥12 years old, or none).

PEF, PEF < 80% of the predicted value and COPD

In assessing lung function, we focused on three key indicators: PEF value, prevalence of PEF < 80% of the predicted value and COPD diagnosis, which allowed for a thorough evaluation of lung function and respiratory health status among study participants. The PEF test procedure involved taking three measurements at 30-s intervals using a Mini-Wright peak flow meter (Clement Clarke International Ltd., Harlow, United Kingdom) by trained interviewers [11]. The highest value from the three measurements was recorded as the respondent's PEF value. Consistent with previous research, we examined the clinical threshold for PEF < 80% of the predicted value [9,11]. For both men and women, the predicted PEF was calculated using the equation unified in previous studies [11]. The measured PEF was subsequently divided by the predicted PEF to yield the percentage of the predicted PEF, with values <80% indicating diminished lung function. Physician-diagnosed COPD was ascertained through responses to the question: 'Has a physician ever informed you that you have chronic lung disease such as chronic bronchitis or emphysema? Yes, or no?'

Covariates

The demographic covariates comprised age, gender, educational level (in years), race, ethnicity and total wealth income (quartiles). Mother's education (in years) served as a robust indicator reflecting the socioeconomic status (SES) of childhood [24]. Additionally, height (cm), moderate physical activity, current and past cigarette smoking and body mass index (BMI; kg/m^2) were also considered. Physician-diagnosed chronic diseases included stroke, heart disease, hypertension, diabetes, cancer, arthritis and psychiatric disorders, based on which the total number of chronic diseases was computed. Depressive symptoms were assessed using the eight-item Centers for Epidemiologic Research Depression (CES-D) scale, which measured the frequency of feelings on eight dichotomous items in the past week [24,25]. The total scores ranged from 0 to 8, with higher scores indicating more severe depressive symptoms [24,25].

Statistical analysis

We applied descriptive statistics, presenting means (standard deviation, SD) for continuous variables and frequencies (proportions) for categorical ones. Normality was tested through the distribution of residuals examined by histograms and Q–Q plots. Between-group differences were tested using one-way ANOVA/independent *t*-tests for continuous data and chi-square tests for categorical variables. Charting the landscape of early-life respiratory risk factors was achieved through the sophisticated application of LCA [26].

Within this statistical framework, we honed in on two essential probabilities: the conditional, which portrays the chance of exhibiting specific indicators within identified classes, and the posterior, offering insights into each participant's likelihood of class membership. To achieve optimal model fit, we tested models with an increasing number of classes based on the Akaike Information Criterion and the substantive relevance of the classifications.

We examined the association between childhood respiratory risk factor profiles and lung function in old age using linear regression with PEF value as the outcome and logistic regressions with the presence of PEF < 80% of the predicted value and COPD as the outcomes. Model 1 adjusted for age, gender, education, race, ethnicity and height; Model 2 additionally added the SES both in childhood and adulthood; Model 3 then included smoking status, moderate physical activity and BMI based on Model 2; Model 4 further integrated CES-D score and the number of chronic diseases as the full-adjusted model. Given that the presence of PEF < 80% of the predicted value was derived from gender, age, height, race and ethnicity, those variables were not included as covariates in the corresponding logistic regression models. We also examined interactions between the independent variables and covariates and then conducted stratified analyses. All analyses were conducted using R statistical software (version 4.3.2). Significance was set at $p < 0.05$ (two-tailed).

Results

Characteristics of study participants

Only 12,296 individuals were ultimately included in the analysis (Figure 1). The average age of all participants was 68.25 (9.79) years old, with 40.8% being male, 13.56% identified as Black/African American and 8.29% as Hispanic. Nearly three-fifths of participants were afflicted by two or more chronic diseases. The average PEF value for all participants was 330.83 (80.03) L/min, and about 18.16% had a low PEF < 80% of the predicted value. Moreover, 1042 (8.5%) participants reported a physician-diagnosed COPD, showing lower lung function, current or former smoking, older age, White/Caucasian ethnicity, non-Hispanic background, lower education, lower SES (both in childhood and adulthood), reduced physical activity, higher BMI and more concurrent chronic diseases compared to those without a COPD diagnosis (Table S1).

Childhood respiratory risk factor profiles identified by LCA

Figure 2 illustrates the best-fit LCA model, which identified six latent classes, each reflecting a distinct childhood respiratory risk factor profile. These profiles were characterized by their elevated likelihood of specific risk factors and categorized as follows: 'Asthma and respiratory disorders in early childhood' profile ($n = 241$, 1.96%), 'Unexposed or least exposed' profile ($n = 3874$, 31.51%), 'Smokers at home' profile ($n = 7609$, 61.88%), 'Ear problems and respiratory disorders in early childhood' profile ($n = 162$, 1.32%), 'Allergic conditions and respiratory disorders in early childhood' profile ($n = 220$, 1.79%) and 'Allergic conditions and respiratory disorders in later childhood' profile ($n = 190$, 1.55%). The 'Unexposed or least exposed' profile served as the reference for all analyses. Detailed characteristics of each risk profiles are provided in Table S2.

Lung function characterized by LCA profiles and basic features

Notable variations were observed in PEF values, the prevalence of PEF < 80% of the predicted value and the presence of COPD across six distinct childhood risk factor profiles, as outlined in Table 1. Specifically, PEF values exhibited a gradient across profiles, with the highest noted in the 'Smokers at home' profile (365.84 L/min), followed by the 'Allergic conditions and respiratory disorders in early childhood' profile (359.82 L/min), the 'Asthma and respiratory disorders in early childhood' profile (347.44 L/min), the 'Unexposed or least exposed' profile (343.93 L/min), the 'Ear problems and respiratory disorders in early childhood' profile (343.64 L/min) and the 'Allergic conditions and respiratory disorders in later childhood' profile (326.73 L/min) in Table 1. Elderly individuals diagnosed with COPD exhibited a substantially lower PEF of only 268.67 L/min compared to 365.8 L/min in the non-diseased group (Table 1). Among those participants with COPD, their PEF values exhibited significant reductions, ranging from 253.54 L/min in the 'Unexposed or least exposed' profile to 279.49 L/min in the 'Allergic conditions and respiratory disorders in early childhood' profile (Table S3–S4).

Regarding the prevalence of PEF < 80% of the predicted value in the total sample in Table 1, the top three profiles with the highest prevalence were the 'Ear problems and respiratory disorders in early childhood' profile (24.07%), the 'Asthma and respiratory disorders in early childhood' profile (26.97%)

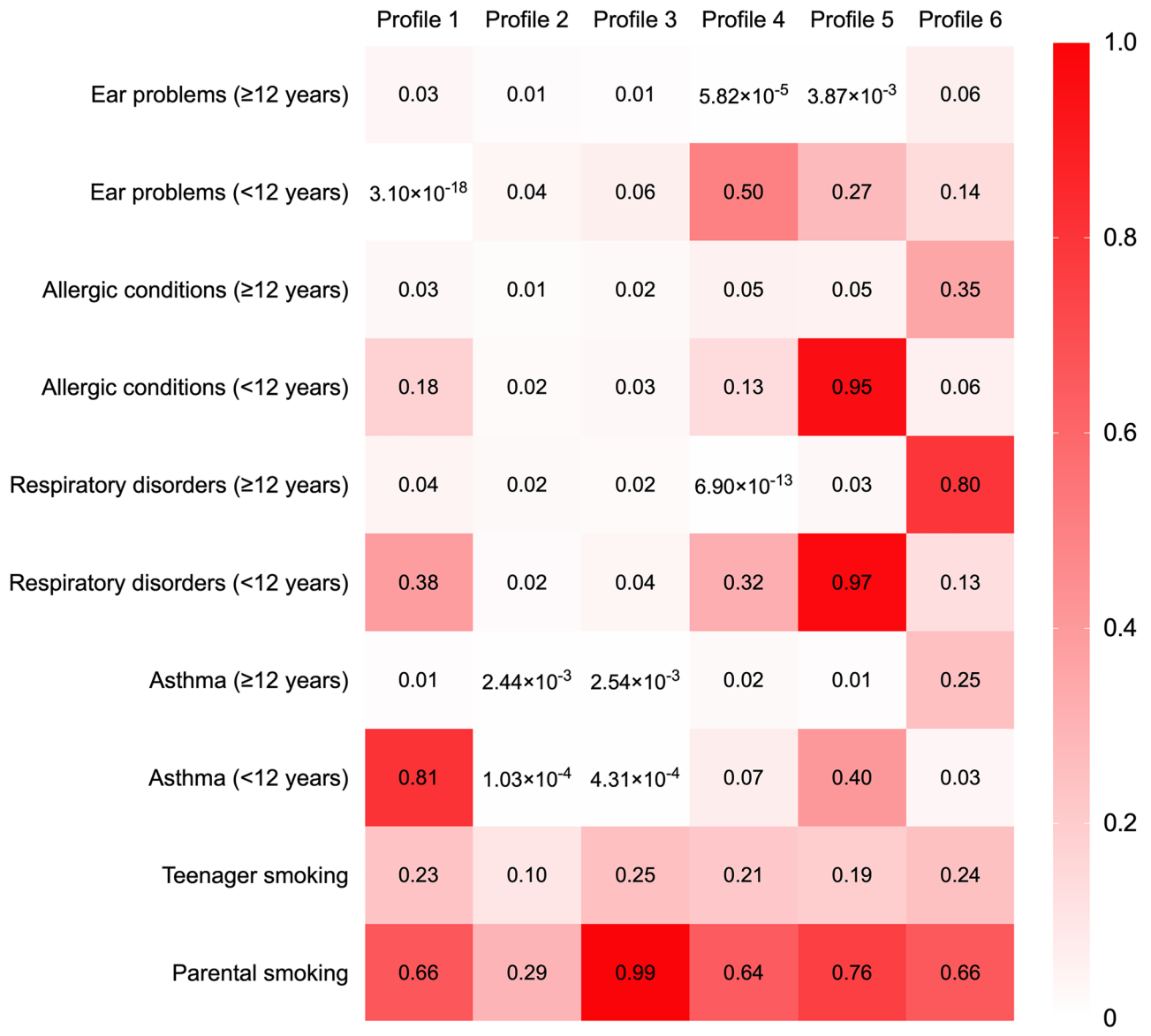

Figure 2. The probability of having each risk factor among six risk factor profiles based on the latent class analysis (LCA).
Notes: Profile 1 = Asthma and respiratory disorders in early childhood; Profile 2 = Unexposed or least exposed; Profile 3 = Smokers at home; Profile 4 = Ear problems and respiratory disorders in early childhood; Profile 5 = Allergic conditions and respiratory disorders in early childhood; Profile 6 = Allergic conditions and respiratory disorders in later childhood.

and the 'Allergic conditions and respiratory disorders in later childhood' profile (27.89%). In addition, the prevalence of PEF < 80% of the predicted value of the COPD sample was three times higher than the non-COPD group (Table 1). Among participants with COPD, the 'Allergic conditions and respiratory disorders in later childhood' profile, 'Asthma and respiratory disorders in early childhood' profile and 'Smokers at home' profile had the highest prevalence of PEF < 80% of predicted values, at 60.53%, 53.66% and 49.85%, respectively (Table S3). Conversely, in the non-COPD group, the three profiles with the highest prevalence rates of PEF < 80% of predicted values remained consistent with the overall population, albeit with a different ranking of the top two (Table S4).

As for the presence of COPD, the prevalence of other populations affected by childhood respiratory risk factors was significantly higher compared to the 'Unexposed or least exposed' profile (Table 1). The top three groups with the highest COPD prevalence were the 'Ear problems and respiratory disorders in early childhood' (21.60%), the 'Allergic conditions and respiratory disorders in later childhood' profile (20.00%) and the 'Allergic conditions and respiratory disorders in early childhood' profile (17.73%), closely followed by the 'Asthma and respiratory disorders in early childhood' profile (17.01%) (Table 1).

Table 1. Lung function characterized by features of the overall study participants ($n = 12,296$).

	PEF (L/min)			PEF < 80%			COPD		
Characteristics	Mean	SD	*p*-value	*N*	Percentage (%)	*p*-value	*N*	Percentage (%)	*p*-value
Total	357.57	132.35		2233	18.16		1042	8.47%	
Age groups (years)			<0.01**			<0.01**			<0.01**
<60	414.57	126.45		407	14.45		156	5.54	
60–64	385.70	124.89		257	15.04		117	6.85	
65–69	366.47	130.04		425	17.92		221	9.32	
70–74	338.44	124.56		438	20.65		234	11.03	
≥75	299.85	121.45		706	21.54		314	9.58	
Gender			<0.01**			<0.05*			0.334
Male	441.18	137.87		857	17.08		410	8.17	
Female	299.94	91.38		1376	18.9		632	8.68	
Race			<0.01**			<0.01**			<0.01**
White/Caucasian	362.95	132.71		1816	17.99		901	8.93	
Black/African American	327.27	128.07		366	21.96		109	6.54	
Other	350.60	125.7		51	9.50		32	5.96	
Ethnicity			<0.01**			<0.05*			<0.01**
Non-Hispanic	359.47	132.64		2074	18.39		1004	8.90	
Hispanic	336.57	127.3		159	15.60		38	3.73	
Education			<0.01**			<0.01**			<0.01**
<9 years	291.47	120.34		340	30.14		106	9.40	
9–12 years	337.41	126.97		1219	21.56		588	10.40	
13–16 years	383.16	129.50		529	13.09		266	6.58	
≥17 years	415.44	131.26		145	9.86		82	5.57	
Height (cm)			<0.01**			<0.01**			0.365
<1.65	297.57	95.57		1176	19.44		527	8.71	
≥1.65	415.65	137.02		1057	16.92		515	8.24	
Mother's education			<0.01**			<0.01**			<0.01**
<9 years	326.51	126.76		1308	21.77		562	9.35	
9–12 years	384.73	130.88		758	15.67		389	8.04	
13–16 years	393.03	129.26		153	11.86		84	6.51	
≥17 years	417.08	134.92		14	8.70		7	4.35	
Total wealth income			<0.01**			<0.01**			<0.01**
Lowest	290.02	117.59		912	29.32		387	12.44	
Quartile 2	339.78	119.96		590	19.14		279	9.05	
Quartile 3	382.56	126.23		447	14.56		244	7.95	
Highest	419.64	128.86		284	9.36		132	4.35	
BMI (kg/m^2)			<0.01**			<0.01**			<0.01**
Underweight	244.51	108.17		41	39.81		22	21.36	
Normal	326.02	126.4		676	23.85		273	9.63	
Overweight	370.12	137.11		772	16.96		326	7.16	
Obesity	366.71	127.47		744	15.48		421	8.76	
Physical activity			<0.01**			<0.01**			<0.01**
Every day	372.42	131.27		197	14.41		96	7.02	
>1 per week	379.95	129.34		781	14.09		349	6.30	
1 per week	361.36	131.53		345	17.96		141	7.34	
l–3 per month	347.90	127.93		226	20.68		98	8.97	
Never	298.13	123.96		684	28.82		358	15.09	
Smoking			<0.01**			<0.01**			<0.01**
Never	353.07	128.00		733	13.70		190	3.55	
Ever smoked	371.72	134.91		926	17.43		568	10.69	
Current smoking	326.29	131.63		574	35.13		284	17.38	
Depression			<0.01**			<0.01**			<0.01**
Low	367.58	132.05		1582	16.08		693	7.05	
Moderate	317.64	128.19		446	26.22		219	12.87	
High	317.36	120.51		205	27.01		130	17.13	
Chronic diseases[a]			<0.01**			<0.01**			<0.01**
0	397.24	133.69		246	13.64		46	2.55	
1	374.78	136.02		503	15.45		180	5.53	
2	352.91	127.36		592	17.37		268	7.86	
3	338.59	127.32		474	20.20		268	11.42	
≥4	312.3	121.55		418	28.19		280	18.88	
LCA[b]			<0.01**			<0.01**			<0.01**
Profile 1	347.44	133.94		65	26.97		41	17.01	
Profile 2	343.93	132.74		716	18.48		235	6.07	
Profile 3	365.84	131.99		1319	17.33		654	8.60	
Profile 4	343.64	124.68		39	24.07		35	21.60	
Profile 5	359.82	124.29		41	18.64		39	17.73	
Profile 6	326.73	124.15		53	27.89		38	20.00	
COPD			<0.01**			<0.01**			/
No	365.80	130.88		1715	15.24		/	/	
Yes	268.67	114.30		518	49.71		/	/	

Notes: BMI, body mass index; COPD, chronic obstructive pulmonary disease; LCA, latent class analysis; PEF, peak expiratory flow; SD, standard deviation.

[a]Chronic diseases include stroke, heart disease, hypertension, diabetes, cancer, arthritis, and psychiatric disorders.

[b]Profile 1 = Asthma and respiratory disorders in early childhood; Profile 2 = Unexposed or least exposed; Profile 3 = Smokers at home; Profile 4 = Ear problems and respiratory disorders in early childhood; Profile 5 = Allergic conditions and respiratory disorders in early childhood; Profile 6 = Allergic conditions and respiratory disorders in later childhood.

*$p < 0.05$.

**$p < 0.01$.

Childhood respiratory risk condition associates with PEF and PEF < 80% of the predicted value in the elderly

Compared with the 'Unexposed or least exposed' reference profile, with all covariates controlled in Model 4, the highest reduction was seen for the 'Asthma and respiratory disorders in early childhood' profile (−30.07 L/min; 95% CI: −42.32 to −17.82), followed by the 'Allergic conditions and respiratory disorders in later childhood' profile (−22.24 L/min; 95% CI: −35.94 to −8.54) and the 'Allergic conditions and respiratory disorders in early childhood' profile (−18.47 L/min; 95% CI: −31.33 to −5.61) (Table 2). Minimal heterogeneity was found across nearly all subgroups (all *p*-values for interaction >0.05), except for individuals stratified by race (Table S5). Within the Black/African American subgroup, childhood respiratory conditions exhibited a more pronounced impact on the decline in PEF during old age, especially the 'Allergic conditions and respiratory disorders in early childhood' profile (Table S5).

Regarding the association between childhood risk factor profiles and the prevalence of PEF < 80% of the predicted value, the 'Allergic conditions and respiratory disorders in later childhood' profile demonstrated a risk 2.05 times higher than the reference group in Model 1 (Table 2). Both the 'Asthma and respiratory disorders in early childhood' profile (aOR = 1.70, 95% CI: 1.41–1.99) and the 'Ear problems and respiratory disorders in early childhood' profile (aOR = 1.63, 95% CI: 1.26–2.00) were significant risk factors for diminished lung function (PEF <80% of the predicted value) in older participants. Model 2, sequentially adding total wealth income and the mother's education as covariates while retaining the original covariates in Model 1, reported similar results (Table 2). With smoking status, moderate physical activity and BMI further controlled in Model 3, compared with the 'Unexposed or least exposed' reference profile, all other profiles (except for the 'Smokers at home' profile) were positively associated with the prevalence of PEF < 80% of the predicted value. In full-adjusted Model 4, the 'Allergic conditions and respiratory disorders in later childhood', 'Ear problems and respiratory disorders in early childhood' and 'Asthma and respiratory disorders in early childhood' profiles were significantly associated with 1.98-, 1.52- and 1.66-fold increased risks of diminished lung function, respectively (Table 2). Our findings remained robust across all subgroups in Table S6, with no evidence of covariate modification on the results (all *p*-values for interaction >0.05).

Childhood respiratory risk condition associates with COPD in the elderly

As is shown in Table 3, all other profiles were positively associated with the risk of COPD compared with the 'Unexposed or least exposed' reference profile, with similar patterns among different models. In Model 4, which comprehensively adjusts for all socio-demographic characteristics, SES, lifestyle behaviours and health status, the highest risk was observed for the 'Allergic conditions and respiratory disorders in early childhood' profile (aOR = 4.16, 95% CI: 3.75–4.57), followed by the 'Allergic conditions and respiratory disorders in later childhood' profile (aOR = 4.10, 95% CI: 3.69–4.51), the 'Ear problems and respiratory disorders in early childhood' profile (aOR = 3.70, 95% CI: 3.25–4.15), the 'Asthma and respiratory disorders in early childhood' profile (aOR = 3.46, 95% CI: 3.07–3.85) and the 'Smokers at home' profile (aOR = 1.41, 95% CI: 1.25–1.57). Subgroup analyses were exhibited in Table S7, and no modification was found in most subgroups (all *p* for interaction >0.05), except for people stratified by race and smoking habitat. Those above-mentioned associations were more significant among Black/African Americans than those among White/Caucasian participants, especially for the 'Asthma and respiratory disorders in early childhood' profile and the 'Allergic conditions and respiratory disorders in early childhood' profile. Furthermore, the impact of childhood respiratory conditions on COPD was more pronounced in the current smoking subgroup.

Discussion

This study explored the long-term trajectories of lung function across various childhood risk profiles and examine their associations with pulmonary outcomes in later life. Specifically, asthma and respiratory disorders in early childhood, ear problems and respiratory disorders in early childhood, or allergic conditions and respiratory disorders in both early and later childhood all have varying degrees of impact on lung function during old age. Furthermore, all other childhood respiratory risk profiles showed a positive association with the risk of COPD compared to the 'Unexposed or least exposed' reference profile. The data from 12,296 participants highlights how early-life exposures relate to later-life respiratory health, emphasizing the importance of early interventions to reduce respiratory disease burden in the elderly.

A recent meta-analysis found that, globally, COPD prevalence among individuals aged ≥40 was 12.64%, with the highest prevalence in the Americas at 22.93%

Table 2. Associations between childhood risk factor profiles and lung function in older adults.

	PEF (L/min)				PEF < 80%			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Profiles	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Asthma and respiratory disorders in early childhood	−35.36 (−48.16, −22.56)**	−35.41 (−48.09, −22.73)**	−31.16 (−43.45, −18.87)**	−30.07 (−42.32, −17.82)**	1.70 (1.41, 1.99)**	1.82 (1.51, 2.13)**	1.68 (1.37, 1.99)**	1.66 (1.35, 1.97)**
Unexposed or least exposed	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
Smokers at home	−1.02 (−4.88, 2.84)	−2.27 (−6.09, 1.55)	0.23 (−3.49, 3.95)	0.62 (−3.1, 4.34)	0.96 (0.86, 1.06)	1.04 (0.94, 1.14)	0.98 (0.88, 1.08)	0.97 (0.87, 1.07)
Ear problems and respiratory disorders in early childhood	−15.1 (−30.58, 0.38)	−16.52 (−31.85, −1.19)*	−12.69 (−27.55, 2.17)	−9.03 (−23.85, 5.79)	1.63 (1.26, 2.00)*	1.8 (1.43, 2.17)**	1.65 (1.26, 2.04)*	1.52 (1.11, 1.93)*
Allergic conditions and respiratory disorders in early childhood	−20.26 (−33.69, −6.83)**	−20.16 (−33.45, −6.87)**	−21.77 (− 34.67, −8.87)**	−18.47 (−31.33, −5.61)**	1.29 (0.94, 1.64)	1.39 (1.04, 1.74)	1.48 (1.11, 1.85)*	1.38 (1.01, 1.75)
Allergic conditions and respiratory disorders in later childhood	−28.42 (−42.75, −14.09)**	−25.69 (−39.88, −11.5)**	−25.45 (−39.21, −11.69)**	−22.24 (−35.94, −8.54)**	2.05 (1.72, 2.38)**	2.02 (1.69, 2.35)**	2.08 (1.73, 2.43)**	1.98 (1.63, 2.33)**

Notes: aOR, adjusted odds ratio; CI, confidence interval; PEF, peak expiratory flow.
Model 1 adjusted for age, gender, education, race, ethnicity and height; Model 2 includes Model 1 covariates, total wealth income and mother's education; Model 3 includes Model 2 covariates, smoking status, moderate physical activity and BMI; Model 4 includes Model 3 covariates, CES-D score and the number of chronic diseases (stroke, heart disease, hypertension, diabetes, cancer, arthritis and psychiatric disorders). Given that PEF < 80% of the predicted value was derived from gender, age, height, race and ethnicity, those variables were not included as covariates in the analyses predicting PEF < 80%.
*$p < 0.05$.
**$p < 0.01$.

Table 3. Associations between childhood risk factor profiles and COPD in older adults.

	Model 1	Model 2	Model 3	Model 4
Profiles	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Asthma and respiratory disorders in early childhood	3.65 (3.28, 4.02)**	3.71 (3.34, 4.08)**	3.42 (3.03, 3.81)**	3.46 (3.07, 3.85)**
Unexposed or least exposed	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
Smokers at home	1.52 (1.36, 1.68)**	1.57 (1.41, 1.73)**	1.41 (1.25, 1.57)**	1.41 (1.25, 1.57)**
Ear problems and respiratory disorders in early childhood	4.75 (4.34, 5.16)**	4.97 (4.56, 5.38)**	4.38 (3.95, 4.81)**	3.70 (3.25, 4.15)**
Allergic conditions and respiratory disorders in early childhood	4.23 (3.86, 4.6)**	4.35 (3.96, 4.74)**	4.87 (4.48, 5.26)**	4.16 (3.75, 4.57)**
Allergic conditions and respiratory disorders in later childhood	4.43 (4.04, 4.82)**	4.26 (3.87, 4.65)**	4.5 (4.09, 4.91)**	4.10 (3.69, 4.51)**

Notes: aOR, adjusted odds ratio; CI, confidence interval; PEF, peak expiratory flow.
Model 1 adjusted for age, gender, education, race, ethnicity and height; Model 2 includes Model 1 covariates, total wealth income and mother's education; Model 3 includes Model 2 covariates, smoking status, moderate physical activity and BMI; Model 4 includes Model 3 covariates, CES-D score and the number of chronic diseases (stroke, heart disease, hypertension, diabetes, cancer, arthritis and psychiatric disorders).
**$p < 0.01$.

based on the fixed ratio criteria [3]. In our study, we found that the prevalence of PEF values <80% of the predicted value in the general population was 18.16%, while COPD prevalence was 8.47%. These findings partially confirm the often-underdiagnosed nature of COPD and imply a potential underestimation of its prevalence, while it is likely influenced by testing methodologies. PEF values below 80% of the predicted norm are significant indicators of airway obstruction often associated with COPD [27,28]. While conventional metrics like FEV1 and FVC are standard for assessing health status, PEF emerges as a crucial tool,

particularly in elderly populations and large-scale epidemiological surveys [9,11]. Numerous studies have explored the link between diminished PEF rates and the development or presence of COPD, highlighting PEF's clinical utility in both screening and managing COPD [27,29]. Our findings underscore that individuals with various respiratory risk factors in childhood identified through LCA exhibit a markedly increased prevalence of COPD in old age, particularly those with a history of asthma, allergies, ear diseases and respiratory infections [1,18, 26,30–32]. This emphasizes the imperative of early intervention and targeted screening to identify high-risk individuals and avert disease progression. Interestingly, the group with the highest PEF value was observed in the 'Smokers at home' profile, contrary to common beliefs about the long-term deleterious effects of tobacco smoke [33]. But in our subsequent multivariable association analyses, after adjusting for confounders, the 'Smokers at home' profile was not statistically significantly associated with PEF or PEF < 80%, but it was positively associated with COPD.

Impaired lung function in the elderly significantly heightens morbidity and detracts from overall quality of life [34]. The intricate interplay of various concurrent respiratory risk factors likely serves as a key determinant of long-term lung health. Those individuals characterized by 'Asthma and respiratory disorders in early childhood', 'Allergic conditions and respiratory disorders in early childhood' and 'Allergic conditions and respiratory disorders in later childhood' profiles exhibit decreased PEF values in old age. Notably, these profiles maintain an increased risk of developing PEF values below 80% of the predicted value even after adjusting for several covariates. Prior research has demonstrated a persistent decline in lung function from childhood to adolescence in individuals with childhood asthma accompanied by eczema and hay fever [35]. Certain lung function deficits associated with childhood asthma and allergies seem to manifest prominently during childhood and persist into adulthood [26]. Additionally, the impact of childhood allergies and respiratory disruptions (such as bronchitis, wheezing, hay fever, shortness of breath, or sinus infection) on declining lung function in old age has been corroborated by another large prospective cohort study with 8352 participants [26].

Additionally, we observed significant associations between all childhood respiratory risk factor profiles, except for the 'Unexposed or least exposed' group, and an elevated risk of COPD later in life, even after adjusting for several crucial confounders consistent with prior research [36]. A recent systematic review revealed that asthmatic children were three times more likely to develop COPD in adulthood compared to non-asthmatic children [3]. Moreover, the risk of COPD increases with a younger age at asthma diagnosis [31]. Previous studies indicated a complex interplay between asthma and other respiratory conditions such as bronchitis, sinusitis and wheezing episodes [37–40]. Longitudinal studies have shown that children with severe asthma or persistent bronchitis symptoms were more prone to develop airflow limitation and decreased lung function in middle and old age [16]. According to our results, childhood allergies and respiratory issues, particularly in early childhood (aORs >4), showed the strongest association with COPD in old age, followed by ear problems and respiratory disorders in early childhood (aOR = 3.70). Existing literature suggests a positive correlation between childhood allergies and the incidence of respiratory diseases [41].

Systemic inflammation and lung development abnormalities in early life may increase the risk of COPD through several mechanisms [14,16,18,19,41]. Abnormal activation of the immune system can lead to chronic inflammation in the airways and lung tissue, as well as airway remodelling. Impaired lung development, especially during childhood, may result in permanent declines in lung function and increased susceptibility to COPD. Early-life infections and environmental factors may exacerbate these mechanisms, further promoting the onset of COPD. These early-life allergic and respiratory conditions may contribute to an increased risk of developing more severe respiratory diseases in adulthood, thus exacerbating the chronic burden of respiratory illnesses [14,16,41].

Environmental factors, such as exposure to tobacco smoke, also play a significant role in linking childhood lung function impairment to the development of COPD in adulthood [26]. For instance, parental smoking increases children's exposure to second-hand smoke, thereby exacerbating the risk. Furthermore, we found that the effects of childhood respiratory conditions on reduced PEF and heightened COPD risk were more pronounced among Black/African Americans and current smokers, aligning with documented racial disparities in respiratory health and the detrimental impact of smoking on accelerating lung function decline, respectively [42,43].

By delineating distinct subgroups of individuals with similar patterns of childhood respiratory risk factors, LCA enables us to scrutinize the cumulative effects of multiple exposures on respiratory health across the life course. These findings underscore the importance of early diagnosis and management of childhood respiratory conditions to prevent long-term

respiratory impairments. Based on the high-risk populations identified through LCA analysis, individuals with a history of different childhood respiratory risk profiles, including childhood asthma, allergies, respiratory disorders, allergic conditions and ear disorders, can be considered potential candidates for screening. Identifying these high-risk groups can drive personalized early intervention and monitoring strategies. In particular, conducting lung function assessments at an early stage in these individuals can significantly increase the chances of early diagnosis and allow for intervention before disease progression. Early diagnosis and management help to slow the development of COPD, reduce the severity of symptoms, and, ultimately, improve the quality of life and extend the lifespan of patients.

However, limitations of our research include: retrospective acquisition of childhood respiratory risk factors hindering causal establishment, reliance on self-reported data introducing recall bias/measurement error, lack of data on birth weight/gestational age potentially impacting findings and variations in sample sizes among identified risk profiles limiting association detection. Despite these, significant effects of certain childhood factors on later-life outcomes were observed. We caution, however, that our discussion remains preliminary, as the detailed scrutiny of the mechanisms through which each of these childhood factors influences lung health in old age is beyond our current scope and is still scarce.

Conclusions

In conclusion, our findings underscore the importance of early-life respiratory health in shaping pulmonary function trajectories and highlight the need for comprehensive strategies to promote respiratory health across the lifespan. Targeted interventions aimed at reducing childhood respiratory insults and addressing social determinants of health may help mitigate the long-term burden of respiratory diseases in older age.

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Author contributions

Conceptualization: C.Q., J.G. and J.L.; methodology and analysis, visualization and writing – original draft preparation: C.Q.; review and editing, and supervision: M.L. and J.L. Moreover, C.Q., M.L., X.S. and J.L. have directly accessed and verified the underlying data reported in the article. All authors have read and agreed to the published version of the article.

Ethics approval

The institutional review board of the Peking University, Beijing, China determined that the study did not need approval because it used publicly available data.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

All data in the study are available at https://hrsdata.isr.umich.edu/data-products/public-survey-data, which can also be obtained from the corresponding author upon reasonable request.

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