The impact of child and adolescent health on adult respiratory health: the evidence, gaps and priorities

Anne B. Chang [1,2,3], Diane M. Gray [4], Wicharn Boonjindasup[5], Richard S. Irwin[6], Weijing Feng[7], Edgar Beltetón[8], Rebecca Fortescue[9], Zena Powell[10], Seif O. Shaheen[11,12], Shyamali C. Dharmage[12,14] and Keith Grimwood[3,13,14]

[1]Australian Centre for Health Services Innovation and School of Medicine, Queensland University of Technology, Brisbane, Australia. [2]Department of Respiratory and Sleep Medicine, Queensland Children's Hospital, Brisbane, Australia. [3]NHMRC Centre for Research Excellence in Paediatric Bronchiectasis (AusBREATHE), Child and Maternal Health Division, Menzies School of Health Research, Darwin, Australia. [4]Department of Paediatrics and Child Health, University of Cape Town Faculty of Health Sciences, Paediatrics and Child Health, Cape Town, South Africa. [5]Department of Pediatrics, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. [6]Division of Pulmonary, Allergy, and Critical Care Medicine, Department of Medicine, UMass Memorial Medical Center, and UMass Chan Medical School, Worcester, MA, USA. [7]Department of Cardiology, State Key Laboratory of Organ Failure Research, Guangdong Provincial Key Lab of Shock and Microcirculation, Nanfang Hospital, Southern Medical University, Guangzhou, China. [8]Centro Pediátrico de Guatemala, Guatemala City, Guatemala. [9]Population Health Research Institute, School of Health and Medical Sciences, City St George's University of London, London, UK. [10]Child-BEAR-Net Parent Representative, European Lung Foundation, Sheffield, UK. [11]Wolfson Institute of Population Health, Barts and The London School of Medicine and Dentistry, Queen Mary University of London, London, UK. [12]Allergy and Lung Health Unit, Melbourne School of Population and Global Health, The University of Melbourne, Melbourne, Australia. [13]School of Medicine and Dentistry, Griffith University, Gold Coast, Australia. [14]Co-senior authors.

Corresponding author: Anne B. Chang (Anne.Chang@menzies.edu.au)

Shareable abstract (@ERSpublications)
Child respiratory health and lung function trajectories are inextricably linked to adult respiratory health and cardiovascular events, as well as all-cause mortality. We need interventions that are equitable and integrated through a whole-society approach. https://bit.ly/447uO9h

Cite this article as: Chang AB, Gray DM, Boonjindasup W, *et al*. The impact of child and adolescent health on adult respiratory health: the evidence, gaps and priorities. *Eur Respir Rev* 2025; 34: 250044 [DOI: 10.1183/16000617.0044-2025].

Received: 4 March 2025
Accepted: 1 June 2025

Abstract

Chronic respiratory diseases impart a huge global disease burden. Many cases of adult chronic respiratory disorders are recognised to originate early in life during critical phases of lung growth and development. We therefore reviewed the longitudinal evolution of common childhood respiratory diseases across the lifespan. We included studies relating childhood respiratory health (preterm birth, asthma, low lung function or bronchiectasis) to respiratory health in adolescents and adults, including COPD.

The negative impact of preterm birth (with or without bronchopulmonary dysplasia) on future respiratory health has now been quantified, with many having increasing deviation of lung function from the norm over their life course. While previous studies report children with asthma frequently "outgrow their disease" by adolescence or early adulthood, recent data describe asthma trajectories that include relapse, early-onset adult-remitting, and early-onset persistent childhood asthma. Evidence is emerging in adults of the negative impact of chronic productive cough, breathlessness and lower lung function on future respiratory and cardiovascular health and all-cause mortality. In addition, we found that in general, childhood respiratory health and adverse lung function trajectories are inextricably linked to adult respiratory health and cardiovascular events, as well as cardiovascular and all-cause mortality. Thus, we highlight the importance of pulmonary assessments in high-risk groups during childhood (*e.g.* preterm birth, parental smokers, early life hospitalisation for acute lower respiratory infections). Our review emphasises the importance of childhood respiratory health and the need for interventions to reduce or manage disease burden, which require a whole-of-society approach across the life course.

Introduction

Most chronic respiratory diseases (CRDs) are potentially preventable [1], and despite their global impact they receive substantially less funding than other chronic disorders [2]. In 2019 there were 454.6 million

(95% uncertainty interval 417.4–499.1 million) prevalent cases [3], with a higher burden among Indigenous peoples [4] and those living in low- and middle-income countries (LMICs) [5]. The Global Impact of Respiratory Disease report [1] highlighted that respiratory diseases account for the top three causes of death globally and "childhood respiratory disease has long-term negative consequences on adult health" [6]. A focus on children is now recognised as important, since abnormal lifetime lung function trajectories [7–9] and many adult CRDs have their origins in childhood, stemming from adverse exposures during pre-conception [10], pregnancy and childhood [11, 12]. The goal of this review is to evaluate studies relating childhood respiratory health to adolescent/adult respiratory health and recommend intervention and research priorities spanning the whole life course.

Lung growth and development and lung function trajectories

Underpinning the life-course paradigm of respiratory health is lung growth and development, beginning *in utero* and continuing throughout childhood and adolescence. Although airway development starts in the first 16 weeks of gestation, alveolar development occurs later in pregnancy with most growth occurring post-natally [13]. Lifelong respiratory health is characterised by normal lung function at birth, throughout childhood and adolescence, reaching peak lung function in early adulthood (20–25 years) and declining gradually thereafter [12]. Negative deviation from this trajectory affects not only future adult lung function trajectories and respiratory health [7–9], but also subsequent cardiovascular disease and all-cause mortality in a dose-dependent manner [14, 15]. Identifying children with either established or risk of impaired respiratory health and undertaking optimisation strategies for improving lung function is critically important (figures 1 and 2).

Origins of adult lung disease and impaired lung function

The early origins of some lung diseases in adults are multifactorial in nature [12, 17–19]. Risk factors for future CRD or impaired lung function include: genetic susceptibility, adverse social determinants and environmental exposures [20], continuation of childhood diseases, existence of pre-clinical disease beginning in childhood or exposure to early-life risk factors (*e.g.* preterm birth, tobacco and vapes, acute lower respiratory infections (ALRIs), suboptimal nutrition/growth and indoor/outdoor air pollution) [21–24]. However, there is no published comprehensive review of the longitudinal evolution of childhood lung diseases across the lifespan. Moreover, the impact of common childhood lung diseases on adult respiratory morbidity across the lifespan is underappreciated.

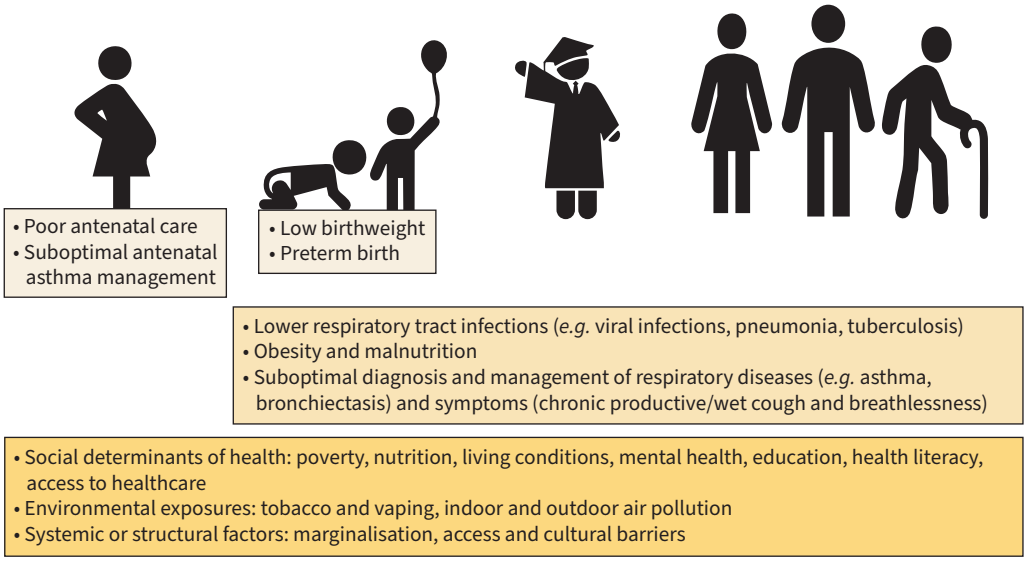

FIGURE 1 Key factors on the pathway to chronic respiratory disease in adults. Contributing factors have their effects from pre-conception (*e.g.* nutrition status and tobacco and vaping) and during pregnancy, and are particularly important in early life, when the initial lung function trajectory is generally set. However, exposures and events (including optimal treatment) throughout the life course can influence the lung function trajectory and respiratory health outcomes. Some factors are age-specific, whereas others are relevant to childhood, adolescence and adulthood or have an impact over the lifespan. Reproduced and modified with permission from [4].

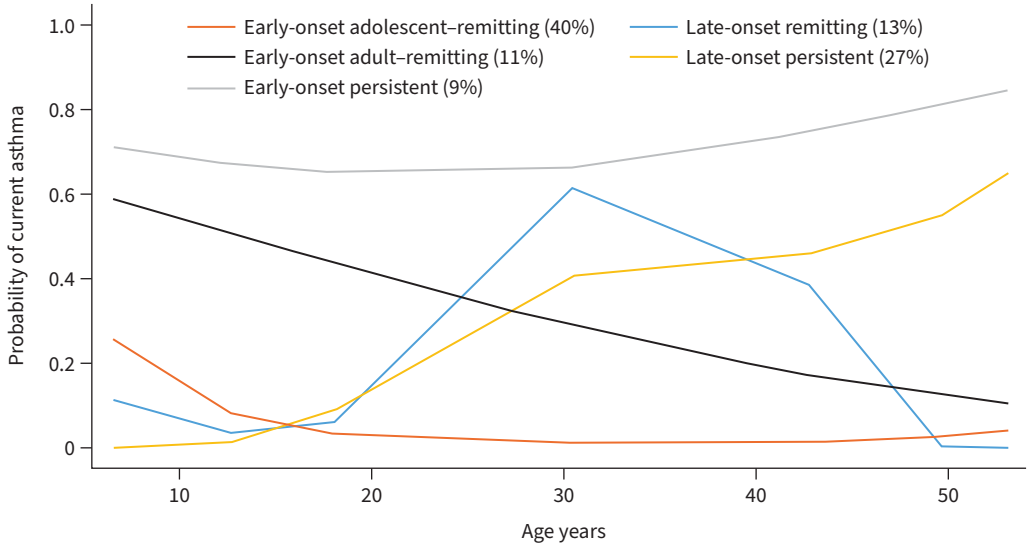

FIGURE 2 Probability of current asthma at each time point. Trajectories up to the sixth decade of life identified by the Tasmanian Longitudinal Health Study, the longest study globally of asthma patterns. Among those who reported asthma by age 53 years, five longitudinal asthma patterns were identified, with three related to childhood asthma: 1) early-onset adolescent-remitting, 2) early-onset adult-remitting, and 3) early-onset persistent phenotypes. Reproduced with permission from [16].

Here, we focus on the consequences of preterm infant lungs, specific childhood diseases (asthma, COPD, bronchiectasis) and undifferentiated respiratory symptoms. The latter is because evidence of undifferentiated respiratory symptoms impacting upon future respiratory health is emerging. Reviews of monogenic disorders (*e.g.* cystic fibrosis), generic adverse environmental factors (*e.g.* pollution [25], tobacco smoke exposure [26]), lifestyle factors (*e.g.* nutrition, obesity [24, 27, 28], pre-natal [29] and social determinants [20]) have been published before [20, 25, 26, 27, 29, 30] and therefore out of the scope of our review. However, given their importance, they are included among potential interventions to assist policymakers and healthcare workers to develop strategies for optimising respiratory health spanning the whole life course before identifying a series of research needs and questions to help address important knowledge gaps.

Literature search methods

References relating childhood respiratory health to adolescent (age 10–19 years) and adult respiratory health in those 1) born preterm, 2) with specific diseases (asthma, COPD, bronchiectasis) or 3) undifferentiated respiratory symptoms across the lifespan, were identified by systematic searches in PubMed for articles published in English (supplementary file S1) from inception until January 2025. Additional articles were identified from the authors' own collections and from references cited in the selected articles. The final reference list was generated based on relevance to the scope of this review. Conditions are defined in supplementary file S1.

Preterm infants and bronchopulmonary dysplasia

The negative effect of preterm (<37 weeks' gestation) birth, either with or without bronchopulmonary dysplasia (BPD), on future respiratory health is well documented [31], but its impact has only been well quantified recently (supplementary file S2). A systematic review unrestricted by age at follow-up (range 6–28 years), found that those born preterm (*versus* those born at term) had lower spirometry values (forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), FEV_1/FVC and forced expiratory flow at 25–75% of FVC ($FEF_{25–75\%}$)) [32]. Furthermore, those with BPD had the greatest lung function deficits [32]. Meta-regression showed that the FEV_1/FVC deviated −0.04 SD away from term controls with each increased year in age in those with BPD, but not for those without BPD, or for other spirometry variables [32]. Despite future lung function data on those born preterm after introducing surfactant and antenatal corticosteroids being better than pre-adoption of these interventions, no additional improvements have occurred subsequently [33]. A univariate meta-regression analysis of 42 preterm cohorts found that the

risk factors associated with abnormal future lung function were gestational age, birthweight, BPD and invasive mechanical ventilation, while year of birth did not influence future FEV_1 [33].

In an individual participant data meta-analysis of very preterm (<32 weeks gestation) or very low birthweight (⩽1500 g) individuals aged 16–33 years, the mean differences in their lung function (*versus* those born at term (⩾37 weeks gestation) or with normal birthweight (⩾2500 g)) were $zFEV_1$ −0.78 (95% CI −0.96–−0.61), zFVC −0.25 (95% CI −0.40–−0.10) and $zFEV_1$/FVC −0.74 (95% CI −0.85–−0.64) [34]. If antenatal steroids were administered, $zFEV_1$ and zFVC were increased, but they had no effect upon $zFEV_1$/FVC and $zFEF_{25–75\%}$ values. In contrast, all these spirometric variables were decreased in those with BPD, while age of lung function assessment did not influence results [34].

Oscillometry is a useful measure when spirometry is not possible in young children [35]. While no longitudinal studies of oscillometry exist in children undergoing additional testing during adolescence/adulthood, cross-sectional data show that preterm-born children have increased resistance and decreased reactance (reflecting lung stiffness) when oscillometry is performed in adolescents/adults [35–37]. Additional abnormalities on extended lung function testing of adolescents/young adults born preterm included impaired diffusion capacity, higher residual volume and ventilation inhomogeneity [38, 39]. Furthermore, structural lung abnormalities (*e.g.* linear, subpleural and parenchymal opacities) were detected on chest computed tomography (CT) scans in 88% of adolescents born very preterm [38, 40]. These radiographic abnormalities decreased with increasing gestation [38].

Data on lung function trajectories in adolescents aged 10–19 years with BPD are variable: five studies reported worsening spirometry variables; one reported no difference; and one reported improvement [40]. In a study with multiple assessments, participants born extremely preterm (<28 weeks gestation) or weighing <1000 g had lower $zFEV_1$/FVC than contemporaneously born controls weighing ⩾2500 g at ages 8–18 years, but not at ages 18–25 years [41].

Preterm-born adolescents with BPD are up to four times more likely to have respiratory symptoms (*e.g.* wheeze, need for medications, respiratory exacerbations, hospitalisations for respiratory infections) than those without BPD [40]. As young adults, 15–35% reported needing asthma medications, wheezing during exercise, or shortness of breath [31, 38, 39]. Respiratory symptoms (*e.g.* cough and/or "rattly breathing") are more marked in those with BPD (25–50%) having two to three times the prevalence of those born preterm without BPD [31, 38, 39].

Widespread surfactant use has not reduced BPD rates, which may be increasing in extremely preterm infants [34]. Strategies are needed to prevent poor respiratory health outcomes associated with extreme preterm birth or BPD in adult survivors [42]. As these adults are at high risk of future COPD (OR 8.17, 95% CI 5.15–12.93 compared to those born at term [43] with the OR reported to be as high as 30 [42]), they should be monitored closely and encouraged to follow healthy behaviours and choices (table 1).

Asthma

Asthma in children can persist into adulthood [47, 48], which contributes to ∼50% of the asthma burden in middle-age. Contribution of childhood asthma to adult asthma burden is likely to be even higher, as many patients do not remember childhood symptoms and some asthma that is considered as adult-onset can be related to relapsed asthma originating in childhood [49]. Severity of asthma, along with associated risk factors, *e.g.* parental smoking [47] and childhood atopy or allergies [50], may enhance this progression. Understanding the natural history of asthma evolved as birth and child cohort studies matured globally, leading to the natural history of childhood asthma being studied into adult life (supplementary file S2). However, the absence of a gold standard definition for measuring wheeze [51] and asthma in population-based studies has led to varying epidemiological definitions, ranging from symptom-based to doctor-diagnosed asthma [52]. Nevertheless, and despite differences in focus, studies used their respective definitions consistently, allowing direct comparisons and tracking asthma status longitudinally. Thus, overall findings are usually consistent across studies.

Most studies report that children with asthma frequently "outgrow their disease" and achieve symptomatic remission by adolescence or early adulthood [47, 48, 53]. Two birth cohort studies found that infant lung function predicted asthma persisting into early adulthood [19, 54]. Those with persistent asthma develop severe symptoms by adulthood [50, 55]. In the Tasmanian Longitudinal Health Study (TAHS) and the British National Child Development Study (NCDS), >70% of children with asthma at the age of 7 years were in remission by 29–32 years [50, 55]. TAHS showed 65% of those with childhood asthma remained in remission by the age of 45 years [47]. The lower percentage of remission in middle-age in TAHS was

TABLE 1 Potential interventions for high-risk populations[#]

Regular follow-up from birth to at least adolescence	Nutritional screening: avoid all forms of malnutrition, including being underweight during infancy, micronutrient deficiency (*e.g.* vitamin D) and obesity; early referral to nutrition programmes with follow-up
	Lung function and symptom screening: start early to assess respiratory health and lung function growth trajectory to identify problems promptly [13]
	Multidisciplinary care [4, 44]
	Planned transition of care from neonatal to paediatric services and in those with CRD from paediatric to adolescent/adult services [45]
Prevention of ALRI	Vaccinations: accessible and affordable maternal and infant vaccine/immunoprophylaxis programmes for prevention of respiratory disease
	Post-exposure prophylaxis: tuberculosis preventive therapy
Avoidance of chronic disease exacerbations	Access to disease specific treatments: inhaled corticosteroids for asthma, antiretroviral therapy for children living with HIV infection
	Antibiotic prophylaxis: Bronchiectasis: ⩾3 exacerbations per year [44] Children and adolescents living with HIV [46]
General	Tobacco and vaping avoidance: education, cessation support programmes, legislation
	Healthy environments: clean air, well-ventilated public spaces
	Healthy nutrition: optimisation of maternal nutrition, also in optimising nutrition in children and adults, including preventing malnutrition and obesity
	Strengthen support structures: access to care grants, social uplift programmes, referral to disease-specific support groups and dedicated nongovernmental agencies
	Promotion of exercise [9]

ALRI: acute lower respiratory infection; CRD: chronic respiratory disease. [#]: social deprivation, preterm birth (especially those born <28 weeks gestation or with bronchopulmonary dysplasia [33]), air pollution exposure including tobacco and vaping, severe or recurrent ALRI/wheeze, maternal illness, HIV, previous pulmonary tuberculosis, disadvantaged Indigenous people.

attributed to relapses of childhood asthma in young adults, possibly from interactions between childhood asthma and subsequent adverse exposures. Supporting this hypothesis, adult smoking increases the risk of childhood asthma persisting into adulthood, independent of childhood risk factors (*e.g.* allergies, passive smoke exposure) [47].

While the NCDS first described temporal asthma patterns [55], the Dunedin Multidisciplinary Health and Development Study (DMHDS) birth cohort's manual classification of repeated assessments (questionnaires, lung function, bronchial challenge and allergy testing) collected at seven time points between the ages of 9 and 26 years [48] was reported in a seminal paper. It found wheeze at age 9 years evolved into four "wheeze patterns": persistent wheeze, remission, relapse and intermittent wheeze across the 17-year study period [47]. Female sex, dust mite sensitisation, bronchial hyperreactivity and parental smoking predicted asthma persistence [48].

Recent studies employing innovative data-driven techniques (*e.g.* latent class analysis, group-based trajectory modelling and Partition Around Medoids) [52, 56–58] to investigate asthma trajectories have provided novel insights into childhood asthma evolution. A recent systematic review identified 13 cohorts using these methodologies [59]. Of these, only three (BAMSE [52], Pelotas [58], and the STELAR consortium of five United Kingdom-based birth cohorts [56, 57]) followed participants beyond the age of 18 years (supplementary file S3). Despite differences between cohorts, especially in number of data points and follow-up duration, all described similar childhood asthma-wheeze trajectories. These included an early-onset transient phenotype with symptoms in early childhood remitting by adolescence; a late-onset phenotype where symptoms either begin or peak during adolescence; and a persistent phenotype where symptoms persist over the entire follow-up period (supplementary file S4) [52, 56–58]. The studies showed stronger associations of the early-onset persistent phenotype with parental asthma and allergic comorbidities, including aeroallergen sensitisation [52, 56–58]. Since this systematic review [59], TAHS published the longest study involving a trajectory analysis to the sixth decade of life [16] Among those reporting asthma by the age of 53 years, five longitudinal asthma patterns were identified (figure 2) with three involving childhood asthma: 1) early-onset, adolescent-remitting; 2) early-onset, adult-remitting; and

3) early-onset, persistent phenotypes. Combining asthma–allergy trajectories across the first six decades of life, highlighted childhood allergies can enhance persistent childhood asthma [60]. Two studies [16, 60] demonstrated that childhood asthma, regardless of its persistence to middle-age, is also associated with adult multimorbidity, including COPD. Interestingly, childhood-onset adult asthma has a stronger adverse impact on adult lung function decline and COPD than late-onset adult asthma [16]. Lung function deficits in those with childhood-onset adult asthma may result from both the tracking of reduced lung function from childhood and additional loss from a greater rate of decline in adulthood.

COPD

COPD, although a diagnostic entity confined to adults, is included as it is increasingly appreciated that a substantial proportion of COPD has its origins in childhood [8, 61, 62]. This link is evident by low lung function trajectories starting in early life (referred to as pre-COPD [63]) and recognised by their inclusion in the two newly proposed COPD classifications (Lancet Commission (as subtypes) [64] and Global Initiative for Chronic Obstructive Lung Disease (GOLD) (as aetiotypes) [65]). Early COPD (early phase of COPD), especially in young COPD (COPD diagnosed before age 50 years), is very likely to start in early life and continue into adulthood [8, 61, 62]. Genetics also play a complex role [66, 67].

Broadly, current longitudinal data show two groups of children at risk of developing future COPD, defined epidemiologically by spirometric fixed airflow obstruction (FEV_1/FVC ratio below the lower limit of normal (LLN)) (supplementary file S2). Firstly, evidence showing that children with asthma are at risk of developing COPD comes from five studies [8, 16, 61, 68, 69]. The United States based Childhood Asthma Management Program study reported that children with persistent asthma and reduced lung function trajectories were at increased risk of fixed airflow obstruction in early adulthood [61]. A Melbourne study highlighted children with severe, but not milder asthma were more likely to have COPD at that age of 50 years [68]. The DMHDS found that childhood asthma and airway hyperresponsiveness were associated with persistently low FEV_1/FVC trajectories from the age of 9 years, which contributed most to COPD at the age of 45 years [8]. The TAHS confirmed that four of five asthma patterns, regardless of whether they were persistent or remitted, were associated with COPD at 53 years of age [16], as was frequent asthma at the age of 7 years, mediated by persistently low lung function trajectories and adult asthma [7]. Finally, an Aberdeen child asthma cohort described that participants were more likely to develop COPD from the fourth decade onwards following reduced FEV_1 trajectories from childhood, not an increased rate of FEV_1 decline after reaching their plateau in early adulthood [69]. These studies suggest that optimising asthma control could improve lung function development and reduce the risk of COPD. However, such an intervention may have limited impact, as the association between asthma and worse lung function is probably bidirectional, with later lung function deficits unlikely to be wholly a consequence of asthma, since a birth cohort study revealed that children with subsequent asthma may already have reduced lung function at birth [70].

The second group at risk of COPD are those without asthma, but who fail to attain optimal lung function as young adults. Risk factors for not attaining optimal lung growth include preterm delivery and low birthweight [34], ALRIs [22], preschool wheeze [69], poor nutrition [24, 28] and adverse maternal and childhood socioeconomic determinants and environmental exposures (*e.g.* tobacco smoke/vapes and other air pollutants) [20]. However, many of these early-life risk factors are also strongly associated with restrictive, rather than obstructive, adult lung function impairment [71]. A form of COPD may arise from dysanapsis, whereby a structural mismatch between airway lumen calibre and parenchymal lung volume arises from nonproportional growth between the two, leading to reduced FEV_1/FVC ratios. Dysanapsis, measured by CT scan, and its association with airflow obstruction, is described in nonsmokers during early to mid-adulthood [72], and associated with spirometrically defined COPD in older adults [73]. It explains COPD developing from failure to attain maximal lung function potential as a young adult, rather than from accelerated decline later in life, especially in never-smokers [74].

The TAHS observed that children in the lowest quartile of pre-bronchodilator FEV_1/FVC ratios at 7 years of age were at increased risk of COPD and asthma–COPD overlap syndrome at that age of 45 years [62]. Additionally, it found that the prevalence of COPD at 53 years was highest in individuals with an obstructive-only lifetime pattern (low FEV_1/FVC ratio only) and especially a mixed obstructive/restrictive pattern (low FEV_1/FVC ratio and low FVC) [75]. The DMHDS showed that lung function trajectories leading to COPD in mid-adult life are largely established before adolescence, confirming the childhood origins of COPD [8]. This suggests it might be possible to intervene in childhood to improve lung function development and trajectories (in particular, to optimise FEV_1 in proportion to FVC), thereby maximising lung function attainment and reducing COPD risk. If so, screening and monitoring childhood lung function to identify those at risk should be considered [13]. This, with other lung function trajectory studies,

resulted in the pre-COPD paradigm, defined as having symptoms and/or lung structural abnormalities and/or lung function deficits, but not reaching the diagnostic COPD threshold (FEV_1/FVC <LLN). This framework needs evaluating, although initial studies look promising [76].

While "catch-up" in some children with low lung function that normalises the lung function trajectory is reported in some population-based cohorts, the proportion varies greatly across studies and depends on the methodology used to define trajectories [7, 77]. Unfortunately, we know little about promoting catch-up in lung function. However, even in the challenging settings of outback Australia, Indigenous children with CRD receiving multidisciplinary paediatric respiratory care demonstrated significantly improved lung function after 12 months of care (mean change in $zFEV_1$ 0.35, 95% CI 0.22–0.28, zFVC 0.36, 95% CI 0.23–0.50) [78].

Bronchiectasis

There are no prospective long-term studies of childhood bronchiectasis diagnosed by CT scans (supplementary file S2). The sole prospective short-term study from childhood to adolescence [79] was conducted in Indigenous people from Alaska, Australia and New Zealand. It found that, with mostly optimal healthcare, adolescent lung function was stable and within the normal range with current treatment regimens (median FEV_1 90% predicted, FVC 98% predicted). However, 43 (39%) out of 111 reported intermittent chronic (>4 weeks) cough [79]. In contrast, an Alaskan chart-review study [80] of 31 adults aged 20–40 years with bronchiectasis identified that four had died, four had severe respiratory impairment and 11 experienced persistent respiratory symptoms. Of the 29 surviving to adulthood, 18 failed to receive transition planning when moving from child to adult care services.

Two cross-sectional studies in adults with bronchiectasis reported that 40–59% of their cohort had bronchiectasis symptoms commencing either before the age of 10 or 16 years [81, 82]. Importantly, the larger study (n=182) found that those adults with symptom onset before 16 years had more severe bronchiectasis (worse lung function, worse CT scores, more respiratory exacerbations) than those whose symptoms began in adulthood [82]. Moreover, their lung function values (FEV_1 % predicted) were inversely related to chronic cough duration ($r=-0.44$, 95% CI -0.59–-0.29; $p<0.001$), with the relationship stronger in nonsmokers ($r=-0.51$) than smokers. While these findings highlight the contribution of childhood-onset bronchiectasis to adult respiratory morbidity, we clearly need more recent studies, as these studies are >15 years old.

Undifferentiated chronic wet/productive cough and breathlessness

Chronic cough and breathlessness are important as cohorts based on respiratory symptoms suggest that chronic wet/productive cough (CWC) in children and adults [83] and breathlessness in young adults are also likely important determinants of future adult respiratory health, and are linked to lung function decline, which is a predictor of all-cause mortality [14]. Chronic cough is typically defined as cough lasting >4 weeks in children [84] and >8 weeks in adults [85]. As children often cannot expectorate, productive cough (coughing with phlegm) is described as wet cough [86]. Children with CWC have endobronchial secretions containing excess mucus, respiratory bacterial pathogens (*e.g. Haemophilus influenzae* or *Streptococcus pneumoniae*), and neutrophilic inflammation [86]. The most common cause of paediatric CWC is protracted bacterial bronchitis (PBB), but prospective studies in PBB are limited to no more than 5 years' duration [87], and there are no follow-up studies into adulthood.

Recent prospective child-based studies (supplementary file S4) describe an association between undifferentiated CWC (chronic bronchitis) in children and subsequent chronic productive cough in adults [83, 88], worse lung function trajectories, accelerated lung function decline [7, 83], increased risk of COPD [89] and premature mortality in adults [7]. In a study of 2438 people followed from the ages of 7 to 53 years, childhood bronchitis (*versus* no bronchitis) was an independent risk for an "early below-average with accelerated decline" trajectory, which also demonstrated a dose–response effect ("infrequent" group OR 1.9, 95% CI 1.1–3.1; "frequent" group (at least one episode every 3 months) OR 2.5, 95% CI 1.3–4.8) [7]. In the most recent study from this cohort, among participants with any cough at age 53 years (n=2213), those with either an intermittent (n=213) or chronic productive cough (n=153) had worse lung function trajectories than the "minimal cough" group (n=206) and higher prevalence of cough from the age of 7 years [83].

The importance of chronic productive cough in adults also needs emphasising (supplementary file S4). A cross-sectional study involving 50 991 adults (aged ⩾20 years) also described an independent association of frequent chronic childhood cough episodes with spirometry data reflecting phenotypes predisposed to COPD [90]. Previously, it was unclear if chronic cough or effort-related breathlessness in adults led to greater risk of myocardial infarction or death from cardiovascular disease (independent of coronary artery

disease risk factors), cancer or other causes [91–95]. Recent studies have suggested that, firstly, various undifferentiated respiratory symptoms (*e.g.* chronic cough, wheeze or shortness of breath) are associated with an increased risk of cardiovascular disease and all-cause mortality independent of established cardiovascular risk factors and lung function [96], and secondly, the greater the number of respiratory symptoms, the higher the risk [96]. However, one study using different definitions of CWC and older age at enrolment (40 years) found only breathlessness (walking on level ground at an ordinary pace) [97] yielded an elevated hazard ratio for early cardiovascular deaths in smokers and never-smokers. Although mechanisms linking respiratory symptoms to increased mortality risk are unknown, they may reflect elevated inflammatory mediator levels increasing risk of myocardial infarction and other cardiovascular events [96].

Of the few studies that have assessed respiratory symptoms longitudinally from childhood and their potential effect on lung function, one from TAHS [83] suggested that those with intermittent or chronic productive cough have worse FEV_1 trajectories. Analyses from the same TAHS cohort [83] combined with the CARDIA cohort depict that people with rapid decline in FEV_1/FVC trajectories (*versus* normal decline) were more likely to have respiratory symptoms, but dyspnoea was not a dominant feature [89]. By the age of 14 years, 20% of participants in TAHS with these rapid decline trajectories had wheeze and "usual phlegm" and 10% had usual phlegm [89]. In CARDIA, the respective numbers were 25% and 7% by the ages of 18–30 years [89]. Another study (n=10 491 adults) [98] concluded that lung function was inversely associated with all-cause and cardiovascular mortality and positively associated with "dyspnoea when walking" after controlling for lung function. Chronic bronchitis was associated with all-cause mortality, when unadjusted for lung function [98]. Although the mechanisms linking lung function decline to increased cardiovascular death are unknown, two recent studies provide potential possibilities. The first showed a faster decline in FVC or FEV_1 from early adulthood to midlife was independently associated with increased risk of coronary artery calcium progression (marker of subclinical coronary atherosclerosis) [99]. The second found an accelerated decline in lung function from young adulthood was associated with an increased risk of structural (decline in FVC with preserved FEV_1/FVC was associated with left ventricular hypertrophy and diastolic dysfunction) and functional (decline in FEV_1/FVC was associated with underfilling of the left heart and low cardiac output) cardiac alterations over a 25-year period [100].

Thus, cough and breathlessness and low lung function in children and adults are clinically important even in the absence of disease. Accelerated decline in FEV_1 and/or FVC increased the risk of cardiovascular death independent of cigarette smoking, elevated cholesterol or hypertension [101, 102] and those with a low FEV_1 with normal decline had a greater risk of death [103]. Unfortunately, adverse cardiovascular outcomes and premature all-cause mortality related to poor respiratory health in adults remain underappreciated.

Intervention priorities for healthcare workers and health services

Although lung growth and development begin antenatally and continue from birth until 20–25 years of age [13], the most critical period impacting lifelong lung function trajectories and respiratory health is the first 1000 days, spanning pregnancy and the first 2 years of life [12, 104–106]. By the time the child is old enough to perform spirometry, irreversible changes in lifelong lung function trajectories may have occurred already. A key research focus is to identify those at risk of CRD and to evaluate effectiveness of interventions that may modify or reverse aberrant lung function trajectories. This research should include periconception, pregnancy and/or early childhood periods. Nevertheless, some interventions and monitoring may remain important beyond the first years of life for older children and adolescents capable of catch-up in lung function [7–9, 18] and in adults whose lung function trajectories indicate risk of later CRD, especially asthma [16] and COPD [63, 107].

Identifying abnormal lung function trajectories by spirometry from school age or tidal breathing measures (*e.g.* oscillometry) for infants and preschool children [108] will require either a population-based screening programme or targeting those exposed to adverse risk factors (*e.g.* preterm birth, parental smokers, early-life hospitalisation for ALRI). Currently, evidence to support either approach, including feasibility and cost–benefit analyses of interventions that consider benefits and potential harms, is lacking [12]. Adverse exposures appear to impact lung health in a multiplicative way [108], hence benefits of screening may be most useful in identified high-risk groups (*e.g.* preterm, early-life ALRI, obesity, parental smoking).

Additionally, since CWC [96], breathlessness on exertion [109] and declining lung function [14] are associated with cardiovascular disease and premature mortality, consideration should be given to evaluating if spirometry being offered routinely to adolescents and young adults to identify, investigate and treat those at risk of these complications is beneficial [102, 103].

Given the overlapping and complex interaction of risk factors throughout the life course (figure 1), successful interventions should be integrated with a whole-of-society approach. Moreover, interventions should be prioritised for those that need them most (*e.g.* high-risk groups, including Indigenous peoples [4]). Population-based interventions are aimed at preventing or arresting CRD by decreasing exposure to modifiable risk factors identified by longitudinal epidemiological studies [21]. An important caveat for observational studies is detecting risk or protective factors associated with outcomes does not invariably confirm causation [110]. In contrast, randomised controlled trials have evaluated protective factors in maternal and infant subjects but lack long-term follow-up of participants [17, 111, 112]. Consequently, without stronger evidence, our recommendations are provisional, while awaiting more definitive studies. Overall, we recommend evaluating a "bundle" of interventions for preventing CRD at either a population level (figure 3) or prioritised for at-risk populations summarised in table 1. In all settings, it is important to further educate policymakers, health professionals and the community of the childhood origins of many adult CRDs, especially the adult disease burden related to continuation of childhood diseases or pre-clinical disease beginning in childhood.

Investing in children's health is expected to pay long-term societal and economic dividends. Policies to address social determinants of health (*e.g.* decreasing poverty and domestic violence, improving housing, indoor/outdoor air quality, proximity to green spaces [113], health literacy and access to healthcare) are likely to reduce inequity in respiratory health across the life course [20]. Improving maternal health before, during and after pregnancy is important and should be prioritised [114], to reduce preterm birth, BPD and low birthweight, and maximise maternal health, including mental health, with life-long health impact [38, 108]. Similarly, avoiding tobacco (including vaping) in both parents, including pre-conception and during pregnancy in the mother, its passive exposure in childhood and active smoking in adolescence and adulthood reduces the risk of preterm delivery and low birthweight, low lung function and trajectories from birth, optimises lung growth, and mitigates progression of pre-existing lung injury to adult CRD [7–9, 107]. Promoting breastfeeding and establishing healthy behaviours from early childhood for nutrition, including

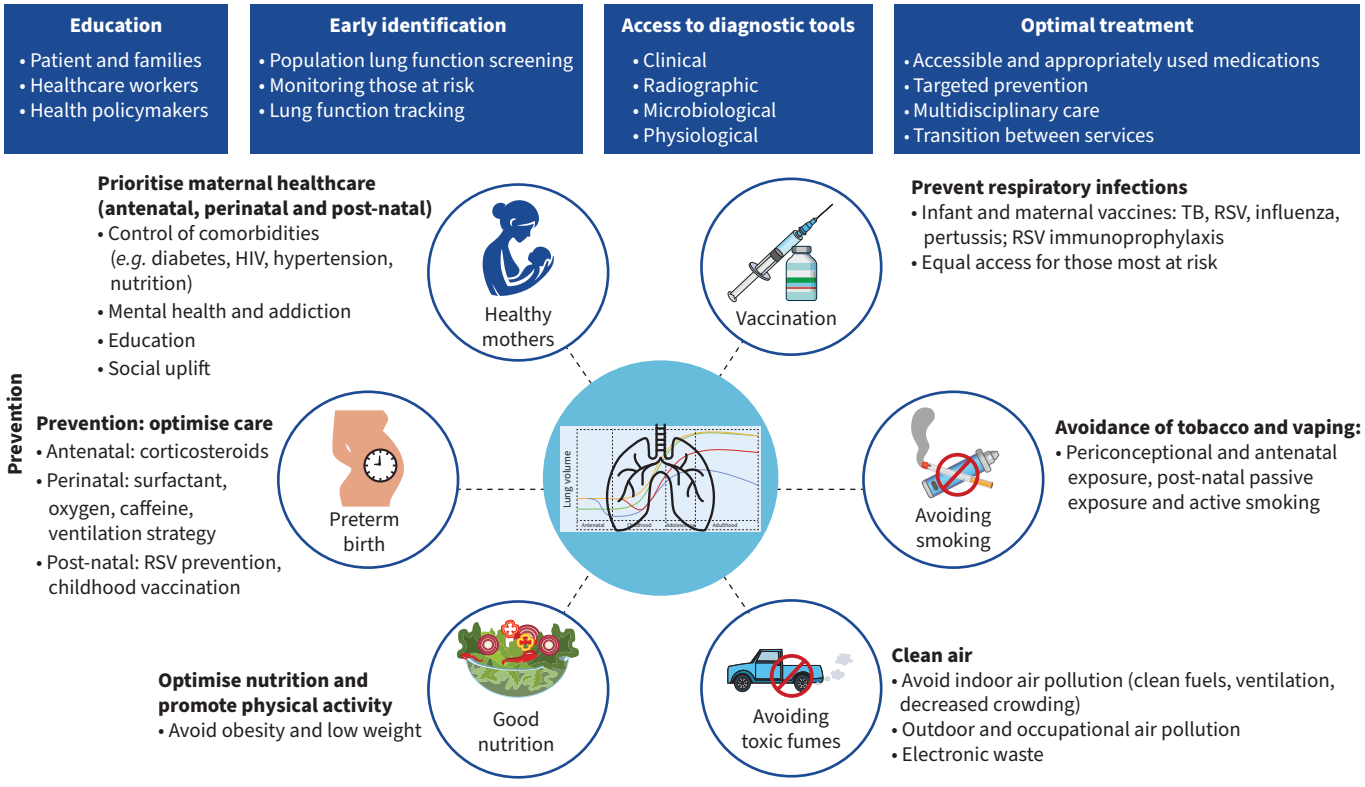

FIGURE 3 Potential interventions to promote good respiratory health and to either prevent or identify and treat childhood respiratory diseases early so they may not progress to chronic respiratory disease in adults. RSV: respiratory syncytial virus; TB: tuberculosis.

micronutrients, and exercise, while avoiding obesity throughout the life course, offers the prospect of preserving lung function and reducing risk of later asthma and COPD [17, 115, 116]. Early childhood ALRIs can lead to lower lung function independent of baseline lung function, particularly if recurrent or severe enough to require hospitalisation [23, 108]. Vaccination against childhood ALRI, including against

TABLE 2 Questions for future research to address important knowledge gaps linking lung growth and development with future pulmonary and nonpulmonary disease [5, 12, 13, 17, 20, 45, 83, 88, 114]

Discovery research	Can the underlying pathophysiological pathways in CRD be identified by integrating multi-omic approaches[#] and time-varying exposome[¶] data leading to novel biomarker and therapeutic target discoveries?
	How do environmental exposures during pregnancy and infancy trigger gene expression, induce oxidative states, and epigenetic mechanisms that impact lung growth and immune development?
	What factors contribute to severe viral ALRIs and abnormal lung function trajectories? Genetic susceptibility, epigenetics, respiratory microbiome and/or adverse environmental exposures, including social determinants of respiratory health?
	What are the complex interactions between the host genome and epigenome, respiratory and gut microbiome (gut–lung axis), persistent inflammation (eosinophilic or neutrophilic) and early allergen sensitisation, and their effects upon immunological and metabolic priming and future lung growth and function?
	What are the mechanisms linking lung function impairment and poor respiratory health with cardiovascular morbidity and all-cause premature mortality?
	Can heart–lung pheno-endotypes be identified to institute therapies that pre-emptively interrupt progression of cardiovascular and pulmonary disease?
	Other than relying upon spirometry, are there other easily obtained biomarkers (*e.g.* in blood, exhaled breath or nasal epithelial cells) that can accurately predict impaired lung function, poor respiratory health and their link with nonpulmonary diseases?
Intervention and implementation research	Can mesenchymal stromal cell therapy or other novel therapies (anti-inflammatory cytokines, growth factors, antioxidants) prevent/treat BPD?
	To build the evidence base for public health interventions (*e.g.* exercise, nutrition, air quality, vaccines).
	Will screening high-risk infants (*e.g.* preterm birth (especially <28 weeks' gestation, BPD), parental smoking, hospitalisation for ALRI) for micronutrients with antioxidant, anti-inflammatory and antiviral properties, and supplementing them when deficient, protect future lung function and respiratory health?
	Do measures to modulate the gut–lung axis and the early respiratory microbiome (*e.g.* pre-biotics, pro-biotics, bacterial lysates) influence immune development and lung function trajectories in high-risk infants (*e.g.* preterm birth (especially <28 weeks' gestation, BPD), paternal smoking, severe (hospitalised) or recurrent ALRIs)?
	Does preventing respiratory syncytial virus-associated ALRIs in infants protect against future impaired lung function trajectories and CRD, including asthma?
	Can primary prevention studies and studies of the impact of public health intervention "bundles" on lung function and respiratory health be conducted most efficiently in primary care or community settings?
	Who should be targeted for the most cost-effective public health intervention bundles to prevent abnormal lung function trajectories and to optimise future pulmonary and nonpulmonary health? Everyone, those living in high-risk populations, or only individuals deemed to be at high risk?
	How to best implement public health policies on strategies that address social determinants of health (figures 1 and 3 and table 1).
Observational research	To gain a better understanding of interactions between host factors (*e.g.* genetic susceptibility, preterm birth, infant undernutrition, obesity) and adverse environmental exposures (*e.g.* severe (hospitalised) or recurrent ALRIs, social determinants of health) by enrolling infants from birth and following them longitudinally to identify groups at high-risk of chronic pulmonary and nonpulmonary disorders who may benefit from early interventions and ongoing monitoring
	In addition to bronchiectasis, does recurrent protracted bacterial bronchitis in children predict a future diagnosis of asthma or COPD?
	How can a "pre-COPD" phase be identified and are "pre-COPD" and early COPD reversible by treatment?
	What are the implications of impaired lung function and poor respiratory health for cardiovascular risk factor screening and treatment algorithms?
	How best to track lung function trajectories from infancy into adulthood? Should this include everyone or be limited to high-risk settings or individuals? At what age(s) should lung function be tested, by whom and how will it be tracked and monitored?
	Will conducting spirometry in primary care in individuals with an intermittent or chronic productive cough identify those with "pre-" or early COPD?

CRD: chronic respiratory disease; ALRI: acute lower respiratory infection; BPD: bronchopulmonary dysplasia. [#]: integration of genomics, epigenomics, transcriptomics, proteomics and metabolic data; [¶]: totality of nongenetic exposures that contribute to health outcomes and includes both physical and social exposures that can vary over time.

tuberculosis in countries where it is endemic, is a priority strategy to strengthen long-term respiratory health. This includes maternal and infant vaccine/immunoprophylaxis programmes. Promoting nonpharmaceutical public health interventions (*e.g.* good ventilation of crowded spaces, practising cough and hand hygiene, staying home with a respiratory infection) are also encouraged. Children identified with CRD should receive multidisciplinary care [44] and, as adolescents, undergo formal best-practice transition to adult specialist services for continuity of their care [45].

Notwithstanding challenges of cost and feasibility, these interventions are particularly important in LMICs and disadvantaged Indigenous communities in high-income countries where the burden of risk factors for CRD is high [4] and preventive interventions should be implemented with greater urgency. Emergent preventive strategies, *e.g.* maternal respiratory syncytial virus (RSV) vaccines and birth-administered long-acting RSV monoclonal antibody should be accessible, and affordable for LMICs and Indigenous infants in high-income countries as a priority, since this is where the greatest burden of severe RSV disease exists [117]. Global efforts to address social disadvantage is key to addressing many factors impacting respiratory health across the life course [4, 20]. As clinicians, researchers, policymakers, funders and community members, we must stop accepting poverty as an inevitable norm.

Conclusions and future directions

This review found that some childhood respiratory diseases and lung function impairments continue into adult life, contributing to lifetime respiratory morbidity and mortality, cardiovascular events and to cardiovascular and all-cause mortality. It emphasises the importance of child respiratory health to an ageing population globally and of having a healthy start to life by utilising primary and secondary prevention of childhood respiratory diseases. While clinical algorithms could predict the prognosis of childhood respiratory disease, identify individuals who will have CRD as adults, and facilitate precision management, research remains scarce in this area. Converting such algorithms to user friendly tools and evaluating their effectiveness will facilitate the transferability of such knowledge. Other fields, *e.g.* heart disease and cancer, are ahead of lung diseases with such developments.

Consequently, future research to address important knowledge gaps in understanding origins, mechanisms and implementing cost-effective interventions of CRD is needed (table 2). GETomics (the complex interactions between genes (G) and the environment (E), encountered throughout the life course (T)), should reveal mechanisms leading to damaged lungs, impacting upon their normal development and ageing, and possibly damage to other organs [59, 63, 107]. GETomics and carefully conducted longitudinal clinical studies will generate accurate pheno-endotyping and biomarkers of CRD, which will help identify infants and young children most at risk of abnormal lung development and poor respiratory health, including the subset whose respiratory disease will persist into adulthood. These results will help inform studies into tailored prevention and management strategies, including their cost-effective implementation in community and healthcare settings when converted to user friendly tools. For these studies to be successful, they must include populations in LMICs and Indigenous people in high-income countries who are most at risk and where local researchers are lead investigators who understand the context and are well placed to translate and implement findings for maximal impact.

Points for clinical practice

- Children born preterm have increased risk of chronic respiratory disease, with up to 50% of those whose preterm birth was complicated by BPD later developing chronic respiratory symptoms (wheeze, cough, dyspnoea) and being at increased risk (up to OR 8.17, 95% CI 5.15–12.93 compared to term-born infants) of developing future COPD. All children with BPD should be monitored, evaluated and treated appropriately for chronic respiratory disease.
- While children with asthma may appear to “outgrow” their disease, some have a low lung function trajectory and are at risk of developing COPD. As such, children with asthma, especially when allergies are also present, should have their lung function monitored over time.
- Children with risk factors for COPD, restrictive lung function impairment and premature all-cause mortality should be monitored for ongoing low lung function and symptoms of chronic respiratory disease. These include those born preterm (especially <28 weeks’ gestation or with a history of BPD), and early-life acute hospitalised respiratory infections.
- Similarly, children with low lung function without any clear disease are also at risk of future COPD; restrictive lung function impairment and premature all-cause mortality should be monitored for ongoing low lung function and symptoms of chronic respiratory disease.
- Although optimum management of children in bronchiectasis is associated with stable lung function, they continue to have recurrent chronic cough as adolescents and thus should continue to be monitored.

- Children with chronic wet/productive cough should be evaluated for its multiple underlying causes, as its presence is associated with future premature mortality from respiratory and cardiovascular disease as well as all-cause mortality.
- As child respiratory health and lung function trajectories are inextricably linked to adult respiratory health, and cardiovascular events, as well as all-cause mortality, those with low lung function should be followed clinically and counselled to undertake activities that promote lung health (*e.g.* exercise, appropriate and timely vaccinations, optimal nutrition) and avoid risk factors (*e.g.* obesity, smoking, air pollutants).

Provenance: Submitted article, peer reviewed.

Author contributions: All authors had access to the manuscript at all times and were free to contribute to the manuscript at all stages. All authors accept responsibility to submit.

Conflict of interest: W. Boonjindasup, W. Feng, E. Beltetón, R. Fortescue, Z. Powell, R.S. Irwin and S.O. Shaheen do not have any interests to declare. A.B. Chang and K. Grimwood declare multiple grants to their institutions from the Australian National Health Medical Research Council (NHMRC) and Medical Research Future Funds (MRFF) related to studies on children's Indigenous lung health, chronic cough and bronchiectasis. A.B. Chang received funds to her institution for being an independent data management committee member for clinical trials of unlicensed vaccines (GlaxoSmithKline and Moderna) and a monoclonal antibody (AstraZeneca); an advisory member of study design for unlicensed products for bronchiectasis (Boehringer-Ingelheim and Zambon), advisory diversity committee member (Boehringer-Ingelheim) and personal fees from being an author of two UpToDate chapters that are outside the submitted work. D.M. Gray has received grant funding and consulting fees from the Wellcome Trust unrelated to this manuscript. S.C. Dharmage has received investigator-initiated grants and/or honoria to her institution from GlaxoSmithKline, AstraZeneca, Sanofi-Aventis, Limbic, NHMRC and MRFF, as well as funds to attend a conference from AstraZeneca.

Support statement: A.B. Chang (L3 grant 2025379) and S.C. Dharmage (L3 grant 2041755) hold fellowships funded by the Australian National Health and Medical Research Council. We had no funding to write the manuscript. Specifically, we have not been paid to write this review by a pharmaceutical company or other agency. Funding information for this article has been deposited with the Open Funder Registry.

References

1 Forum of International Respiratory Societies. The Global Impact of Respiratory Disease. 3rd Edn. European Respiratory Society, 2021. Date last accessed: 2 August 2024. https://firsnet.org/publication/the-global-impact-of-respiratory-disease-3rd-edition/
2 Williams S, Sheikh A, Campbell H, *et al.* Respiratory research funding is inadequate, inequitable, and a missed opportunity. *Lancet Respir Med* 2020; 8: e67–e68.
3 GBD 2019 Chronic Respiratory Diseases Collaborators. Global burden of chronic respiratory diseases and risk factors, 1990–2019: an update from the Global Burden of Disease Study 2019. *EClinicalMedicine* 2023; 59: 101936.
4 Chang AB, Kovesi T, Redding GJ, *et al.* Improving the respiratory health of Indigenous peoples globally: a framework to address inequity and strengthen respiratory health and health care globally. *Lancet Respir Med* 2024; 12: 556–574.
5 Meghji J, Mortimer K, Agusti A, *et al.* Improving lung health in low-income and middle-income countries: from challenges to solutions. *Lancet* 2021; 397: 928–940.
6 World Health Organization. The top 10 causes of death. 2020. Date last accessed: 2 August 2024. www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death/
7 Bui DS, Lodge CJ, Burgess JA, *et al.* Childhood predictors of lung function trajectories and future COPD risk: a prospective cohort study from the first to the sixth decade of life. *Lancet Respir Med* 2018; 6: 535–544.
8 Zhang X, Gray AR, Hancox RJ. Distinct trajectories of lung function from childhood to mid-adulthood. *Thorax* 2024; 79: 754–761.
9 Koch S, Peralta GP, Carsin AE, *et al.* Physical activity and body mass related to catch-up lung function growth in childhood: a population-based accelerated cohort study. *Thorax* 2024; 79: 762–769.
10 Fleming TP, Watkins AJ, Velazquez MA, *et al.* Origins of lifetime health around the time of conception: causes and consequences. *Lancet* 2018; 391: 1842–1852.
11 Heindel JJ, Vandenberg LN. Developmental origins of health and disease: a paradigm for understanding disease cause and prevention. *Curr Opin Pediatr* 2015; 27: 248–253.

12 Hopkinson NS, Bush A, Allinson JP, *et al.* Early life exposures and the development of chronic obstructive pulmonary disease across the life course. *Am J Respir Crit Care Med* 2024; 210: 572–580.
13 Melén E, Faner R, Allinson JP, *et al.* Lung-function trajectories: relevance and implementation in clinical practice. *Lancet* 2024; 403: 1494–1503.
14 Duong M, Islam S, Rangarajan S, *et al.* Mortality and cardiovascular and respiratory morbidity in individuals with impaired FEV_1 (PURE): an international, community-based cohort study. *Lancet Glob Health* 2019; 7: e613–e623.
15 Collaro AJ, Chang AB, Marchant JM, *et al.* Associations between lung function and future cardiovascular morbidity and overall mortality in a predominantly First Nations population: a cohort study. *Lancet Reg Health West Pac* 2021; 13: 100188.
16 Tan DJ, Lodge CJ, Walters EH, *et al.* Longitudinal asthma phenotypes from childhood to middle-age: a population-based cohort study. *Am J Respir Crit Care Med* 2023; 208: 132–141.
17 Melén E, Zar HJ, Siroux V, *et al.* Asthma inception: epidemiologic risk factors and natural history across the life course. *Am J Respir Crit Care Med* 2024; 210: 737–754.
18 Wang G, Hallberg J, Faner R, *et al.* Plasticity of individual lung function states from childhood to adulthood. *Am J Respir Crit Care Med* 2023; 207: 406–415.
19 Guerra S, Lombardi E, Stern DA, *et al.* Fetal origins of asthma: a longitudinal study from birth to age 36 years. *Am J Respir Crit Care Med* 2020; 202: 1646–1655.
20 Bush A, Byrnes CA, Chan KC, *et al.* Social determinants of respiratory health from birth: still of concern in the 21st century? *Eur Respir Rev* 2024; 33: 230222.
21 Schraufnagel DE, Balmes JR, De Matteis S, *et al.* Health benefits of air pollution reduction. *Ann Am Thorac Soc* 2019; 16: 1478–1487.
22 Collaro AJ, McElrea MS, Marchant JM, *et al.* A systematic review of the effect of early childhood respiratory infections and pneumonia on lifelong lung function: a systematic review. *Lancet Child Adolesc Health* 2023; 7: 429–440.
23 Gray DM, Turkovic L, Willemse L, *et al.* Lung function in African infants in the Drakenstein Child Health Study: impact of lower respiratory tract illness. *Am J Respir Crit Care Med* 2017; 195: 212–220.
24 Voraphani N, Stern DA, Zhai J, *et al.* The role of growth and nutrition in the early origins of spirometric restriction in adult life: a longitudinal, multicohort, population-based study. *Lancet Respir Med* 2022; 10: 59–71.
25 Schraufnagel DE, Balmes JR, Cowl CT, *et al.* Air pollution and noncommunicable diseases: a review by the Forum of International Respiratory Societies' environmental committee, part 1: the damaging effects of air pollution. *Chest* 2019; 155: 409–416.
26 Maritz GS, Harding R. Life-long programming implications of exposure to tobacco smoking and nicotine before and soon after birth: evidence for altered lung development. *Int J Environ Res Public Health* 2011; 8: 875–898.
27 Pratt CA, Brown AGM, Dixit S, *et al.* Perspectives: on precision nutrition research in heart, lung, and blood diseases and sleep disorders. *Adv Nutr* 2022; 13: 1402–1414.
28 Arigliani M, Spinelli AM, Liguoro I, *et al.* Nutrition and lung growth. *Nutrients* 2018; 10: 919.
29 Harding R, Maritz G. Maternal and fetal origins of lung disease in adulthood. *Semin Fetal Neonatal Med* 2012; 17: 67–72.
30 Berthon BS, Wood LG. Nutrition and respiratory health – feature review. *Nutrients* 2015; 7: 1618–1643.
31 Gough A, Spence D, Linden M, *et al.* General and respiratory health outcomes in adult survivors of bronchopulmonary dysplasia: a systematic review. *Chest* 2012; 141: 1554–1567.
32 Gibbons JTD, Course CW, Evans EE, *et al.* Increasing airway obstruction through life following bronchopulmonary dysplasia: a meta-analysis. *ERJ Open Res* 2023; 9: 00046-2023.
33 van Boven MR, Hutten GJ, Richardson R, *et al.* Impaired lung function and associated risk factors in children born prematurely: a systematic review and meta-analysis. *Eur Respir Rev* 2024; 33: 240114.
34 Doyle LW, Andersson S, Bush A, *et al.* Expiratory airflow in late adolescence and early adulthood in individuals born very preterm or with very low birthweight compared with controls born at term or with normal birthweight: a meta-analysis of individual participant data. *Lancet Respir Med* 2019; 7: 677–686.
35 Kaminsky DA, Simpson SJ, Berger KI, *et al.* Clinical significance and applications of oscillometry. *Eur Respir Rev* 2022; 31: 210208.
36 Hagman C, Björklund LJ, Bjermer L, *et al.* Lung function deficits and bronchodilator responsiveness at 12 years of age in children born very preterm compared with controls born at term. *Pediatr Pulmonol* 2023; 58: 3156–3170.
37 Thunqvist P, Gustafsson PM, Schultz ES, *et al.* Lung function at 8 and 16 years after moderate-to-late preterm birth: a prospective cohort study. *Pediatrics* 2016; 137: e20152056.
38 Smith EF, Hemy NR, Hall GL, *et al.* Risk factors for poorer respiratory outcomes in adolescents and young adults born preterm. *Thorax* 2023; 78: 1223–1232.

39 Yang J, Kingsford RA, Horwood J, *et al.* Lung function of adults born at very low birth weight. *Pediatrics* 2020; 145: e20192359.
40 Carregã M, Sousa P, Rocha G, *et al.* Respiratory and non-respiratory outcomes of bronchopulmonary dysplasia in adolescents: a systematic review. *Early Hum Dev* 2023; 180: 105756.
41 Doyle LW, Irving L, Haikerwal A, *et al.* Airway obstruction in young adults born extremely preterm or extremely low birth weight in the postsurfactant era. *Thorax* 2019; 74: 1147–1153.
42 Simpson SJ, Du Berry C, Evans DJ, *et al.* Unravelling the respiratory health path across the lifespan for survivors of preterm birth. *Lancet Respir Med* 2024; 12: 167–180.
43 Pulakka A, Risnes K, Metsälä J, *et al.* Preterm birth and asthma and COPD in adulthood: a nationwide register study from two Nordic countries. *Eur Respir J* 2023; 61: 2201763.
44 Chang AB, Fortescue R, Grimwood K, *et al.* European Respiratory Society guidelines for the management of children and adolescents with bronchiectasis. *Eur Respir J* 2021; 58: 2002990.
45 Moss R, Farrant B, Byrnes CA. Transitioning from paediatric to adult services with cystic fibrosis or bronchiectasis: what is the impact on engagement and health outcomes? *J Paediatr Child Health* 2021; 57: 548–553.
46 Ferrand RA, McHugh G, Rehman AM, *et al.* Effect of once-weekly azithromycin *vs* placebo in children with HIV-associated chronic lung disease: the BREATHE randomized clinical trial. *JAMA Netw Open* 2020; 3: e2028484.
47 Burgess JA, Matheson MC, Gurrin LC, *et al.* Factors influencing asthma remission: a longitudinal study from childhood to middle age. *Thorax* 2011; 66: 508–513.
48 Sears MR, Greene JM, Willan AR, *et al.* A longitudinal, population-based, cohort study of childhood asthma followed to adulthood. *N Engl J Med* 2003; 349: 1414–1422.
49 Burgess JA, Walters EH, Byrnes GB, *et al.* Who remembers whether they had asthma as children? *J Asthma* 2006; 43: 727–730.
50 Jenkins MA, Hopper JL, Bowes G, *et al.* Factors in childhood as predictors of asthma in adult life. *BMJ* 1994; 309: 90–93.
51 Michel G, Silverman M, Strippoli MP, *et al.* Parental understanding of wheeze and its impact on asthma prevalence estimates. *Eur Respir J* 2006; 28: 1124–1130.
52 Ödling M, Wang G, Andersson N, *et al.* Characterization of asthma trajectories from infancy to young adulthood. *J Allergy Clin Immunol Pract* 2021; 9: 2368–2376.
53 Horak E, Lanigan A, Roberts M, *et al.* Longitudinal study of childhood wheezy bronchitis and asthma: outcome at age 42. *BMJ* 2003; 326: 422–423.
54 Owens L, Laing IA, Zhang G, *et al.* Infant lung function predicts asthma persistence and remission in young adults. *Respirology* 2017; 22: 289–294.
55 Strachan DP, Butland BK, Anderson HR. Incidence and prognosis of asthma and wheezing illness from early childhood to age 33 in a national British cohort. *BMJ* 1996; 312: 1195–1199.
56 Oksel C, Granell R, Haider S, *et al.* Distinguishing wheezing phenotypes from infancy to adolescence. A pooled analysis of five birth cohorts. *Ann Am Thorac Soc* 2019; 16: 868–876.
57 Haider S, Granell R, Curtin J, *et al.* Modeling wheezing spells identifies phenotypes with different outcomes and genetic associates. *Am J Respir Crit Care Med* 2022; 205: 883–893.
58 Weber P, Jarvis D, Baptista Menezes AM, *et al.* Wheezing trajectories from childhood to adulthood in a population-based cohort. *Allergol Int* 2022; 71: 200–206.
59 Owora AH, Zhang Y. Childhood wheeze trajectory-specific risk factors: a systematic review and meta-analysis. *Pediatr Allergy Immunol* 2021; 32: 34–50.
60 Bui DS, Lodge CJ, Perret JL, *et al.* Trajectories of asthma and allergies from 7 years to 53 years and associations with lung function and extrapulmonary comorbidity profiles: a prospective cohort study. *Lancet Respir Med* 2021; 9: 387–396.
61 McGeachie MJ, Yates KP, Zhou X, *et al.* Patterns of growth and decline in lung function in persistent childhood asthma. *N Engl J Med* 2016; 374: 1842–1852.
62 Bui DS, Burgess JA, Lowe AJ, *et al.* Childhood lung function predicts adult chronic obstructive pulmonary disease and asthma–chronic obstructive pulmonary disease overlap syndrome. *Am J Respir Crit Care Med* 2017; 196: 39–46.
63 Dharmage SC, Faner R, Agusti A. Treatable traits in pre-COPD: time to extend the treatable traits paradigm beyond established disease. *Respirology* 2024; 29: 551–562.
64 Stolz D, Mkorombindo T, Schumann DM, *et al.* Towards the elimination of chronic obstructive pulmonary disease: a Lancet Commission. *Lancet* 2022; 400: 921–972.
65 Global Initiative for Chronic Obstructive Lung Disease (GOLD). GOLD 2024 Report. 2024. Date last accessed: 3 May 2025. https://goldcopd.org/2024-gold-report/
66 Portas L, Pereira M, Shaheen SO, *et al.* Lung development genes and adult lung function. *Am J Respir Crit Care Med* 2020; 202: 853–865.

67 Hernandez-Pacheco N, Kilanowski A, Kumar A, *et al.* Exploring the genetics of airflow limitation in lung function across the lifespan – a polygenic risk score study. *EClinicalMedicine* 2024; 75: 102731.
68 Tai A, Tran H, Roberts M, *et al.* The association between childhood asthma and adult chronic obstructive pulmonary disease. *Thorax* 2014; 69: 805–810.
69 Tagiyeva N, Devereux G, Fielding S, *et al.* Outcomes of childhood asthma and wheezy bronchitis. A 50-year cohort study. *Am J Respir Crit Care Med* 2016; 193: 23–30.
70 Håland G, Carlsen KC, Sandvik L, *et al.* Reduced lung function at birth and the risk of asthma at 10 years of age. *N Engl J Med* 2006; 355: 1682–1689.
71 Shaheen SO. Early life origins of impaired adult lung function. *In*: Burney PGJ, ed. Small Lungs and Obstructed Airways. London, Elsevier, 2024; pp.111–120.
72 Vameghestahbanati M, Hiura GT, Barr RG, *et al.* CT-assessed dysanapsis and airflow obstruction in early and mid adulthood. *Chest* 2022; 161: 389–391.
73 Smith BM, Kirby M, Hoffman EA, *et al.* Association of dysanapsis with chronic obstructive pulmonary disease among older adults. *JAMA* 2020; 323: 2268–2280.
74 Lange P, Celli B, Agustí A, *et al.* Lung-function trajectories leading to chronic obstructive pulmonary disease. *N Engl J Med* 2015; 373: 111–122.
75 Dharmage SC, Bui DS, Walters EH, *et al.* Lifetime spirometry patterns of obstruction and restriction, and their risk factors and outcomes: a prospective cohort study. *Lancet Respir Med* 2023; 11: 273–282.
76 Tan DJ, Lodge CJ, Walters EH, *et al.* Can we use lung function thresholds and respiratory symptoms to identify pre-chronic obstructive pulmonary disease? A prospective, population-based cohort study. *Am J Respir Crit Care Med* 2024; 209: 1431–1440.
77 Ullah A, Granell R, Haider S, *et al.* Obstructive and restrictive spirometry from school age to adulthood: three birth cohort studies. *EClinicalMedicine* 2024; 67: 102355.
78 Collaro AJ, Chang AB, Marchant JM, *et al.* Pediatric patients of outreach specialist Queensland clinics have lung function improvement comparable to that of tertiary pediatric patients. *Chest* 2020; 158: 1566–1575.
79 McCallum GB, Singleton RJ, Redding GJ, *et al.* A decade on: follow-up findings of indigenous children with bronchiectasis. *Pediatr Pulmonol* 2020; 55: 975–985.
80 Sibanda D, Singleton R, Clark J, *et al.* Adult outcomes of childhood bronchiectasis. *Int J Circumpolar Health* 2020; 79: 1731059.
81 Pasteur MC, Helliwell SM, Houghton SJ, *et al.* An investigation into causative factors in patients with bronchiectasis. *Am J Respir Crit Care Med* 2000; 162: 1277–1284.
82 King PT, Holdsworth SR, Farmer M, *et al.* Phenotypes of adult bronchiectasis: onset of productive cough in childhood and adulthood. *COPD* 2009; 6: 130–136.
83 Zhang J, Lodge CJ, Walters EH, *et al.* Association of novel adult cough subclasses with clinical characteristics and lung function across six decades of life in a prospective, community-based cohort in Australia: an analysis of the Tasmanian Longitudinal Health Study (TAHS). *Lancet Respir Med* 2024; 12: 129–140.
84 Chang AB, Oppenheimer JJ, Irwin RS. Managing chronic cough as a symptom in children and management algorithms: CHEST guideline and expert panel report. *Chest* 2020; 158: 303–329.
85 Irwin RS, French CL, Chang AB, *et al.* Classification of cough as a symptom in adults and management algorithms: CHEST guideline and expert panel report. *Chest* 2018; 153: 196–209.
86 Chang AB, Redding GJ, Everard ML. Chronic wet cough: protracted bronchitis, chronic suppurative lung disease and bronchiectasis. *Pediatr Pulmonol* 2008; 43: 519–531.
87 Ruffles TJC, Marchant JM, Masters IB, *et al.* Outcomes of protracted bacterial bronchitis in children: a 5-year prospective cohort study. *Respirology* 2021; 26: 241–248.
88 Perret JL, Wurzel D, Walters EH, *et al.* Childhood 'bronchitis' and respiratory outcomes in middle-age: a prospective cohort study from age 7 to 53 years. *BMJ Open Respir Res* 2022; 9: e001212.
89 Perret JL, Bui DS, Pistenmaa C, *et al.* Associations between life-course FEV_1/FVC trajectories and respiratory symptoms up to middle age: analysis of data from two prospective cohort studies. *Lancet Respir Med* 2025; 13: 130–140.
90 Lei J, Huang K, Wu S, *et al.* Heterogeneities and impact profiles of early chronic obstructive pulmonary disease status: findings from the China Pulmonary Health Study. *Lancet Reg Health West Pac* 2024; 45: 101021.
91 Ebi-Kryston KL. Respiratory symptoms and pulmonary function as predictors of 10-year mortality from respiratory disease, cardiovascular disease, and all causes in the Whitehall Study. *J Clin Epidemiol* 1988; 41: 251–260.
92 Carpenter L, Beral V, Strachan D, *et al.* Respiratory symptoms as predictors of 27 year mortality in a representative sample of British adults. *BMJ* 1989; 299: 357–361.
93 Jousilahti P, Vartiainen E, Tuomilehto J, *et al.* Symptoms of chronic bronchitis and the risk of coronary disease. *Lancet* 1996; 348: 567–572.

94 Haider AW, Larson MG, O'Donnell CJ, *et al.* The association of chronic cough with the risk of myocardial infarction: the Framingham Heart Study. *Am J Med* 1999; 106: 279–284.

95 Rosengren A, Wilhelmsen L. Respiratory symptoms and long-term risk of death from cardiovascular disease, cancer and other causes in Swedish men. *Int J Epidemiol* 1998; 27: 962–969.

96 Feng W, Zhang Z, Liu Y, *et al.* Association of chronic respiratory symptoms with incident cardiovascular disease and all-cause mortality: Findings from the Coronary Artery Risk Development in Young Adults study. *Chest* 2022; 161: 1036–1045.

97 Stavem K, Schirmer H, Gulsvik A. Respiratory symptoms and cardiovascular causes of deaths: a population-based study with 45 years of follow-up. *PLoS One* 2022; 17: e0276560.

98 Leivseth L, Nilsen TI, Mai XM, *et al.* Lung function and respiratory symptoms in association with mortality: the HUNT study. *COPD* 2014; 11: 59–80.

99 Gao JW, Han JJ, Xiong ZC, *et al.* Lung function decline in young adulthood and coronary artery calcium progression in midlife. *Am J Med* 2023; 136: 910–917.

100 Cuttica MJ, Colangelo LA, Shah SJ, *et al.* Loss of lung health from young adulthood and cardiac phenotypes in middle age. *Am J Respir Crit Care Med* 2015; 192: 76–85.

101 Tockman MS, Pearson JD, Fleg JL, *et al.* Rapid decline in FEV_1. A new risk factor for coronary heart disease mortality. *Am J Respir Crit Care Med* 1995; 151: 390–398.

102 Cheng YJ, Chen ZG, Li ZY, *et al.* Longitudinal change in lung function and subsequent risks of cardiovascular events: evidence from four prospective cohort studies. *BMC Med* 2021; 19: 153.

103 Backman H, Blomberg A, Lundquist A, *et al.* Lung function trajectories and associated mortality among adults with and without airway obstruction. *Am J Respir Crit Care Med* 2023; 208: 1063–1074.

104 Granell R, Haider S, Deliu M, *et al.* Lung function trajectories from school age to adulthood and their relationship with markers of cardiovascular disease risk. *Thorax* 2024; 79: 770–777.

105 Navaratnam V, Forrester DL, Chang AB, *et al.* Association between perinatal and early life exposures and lung function in Australian Indigenous young adults: the Aboriginal Birth Cohort study. *Respirology* 2024; 29: 166–175.

106 Lloyd CM, Saglani S. Early-life respiratory infections and developmental immunity determine lifelong lung health. *Nat Immunol* 2023; 24: 1234–1243.

107 Bui DS, Perret JL, Walters EH, *et al.* Association between very to moderate preterm births, lung function deficits, and COPD at age 53 years: analysis of a prospective cohort study. *Lancet Respir Med* 2022; 10: 478–484.

108 McCready C, Zar HJ, Chaya S, *et al.* Determinants of lung function development from birth to age 5 years: an interrupted time series analysis of a South African birth cohort. *Lancet Child Adolesc Health* 2024; 8: 400–412.

109 Sethi DK, Rhodes J, Ferris R, *et al.* Breathlessness predicts mortality in adults: a systematic review and meta-analysis. *Cureus* 2023; 15: e39192.

110 Hill AB. The environment and disease: association or causation? 1965. *JR Soc Med* 2015; 108: 32–37.

111 Agyapong PD, Jack D, Kaali S, *et al.* Household air pollution and child lung function: the Ghana Randomized Air Pollution and Health Study. *Am J Respir Crit Care Med* 2024; 209: 716–726.

112 Scheltema NM, Nibbelke EE, Pouw J, *et al.* Respiratory syncytial virus prevention and asthma in healthy preterm infants: a randomised controlled trial. *Lancet Respir Med* 2018; 6: 257–264.

113 Fernandes A, Avraam D, Cadman T, *et al.* Green spaces and respiratory, cardiometabolic, and neurodevelopmental outcomes: an individual-participant data meta-analysis of >35.000 European children. *Environ Int* 2024; 190: 108853.

114 Dini G, Ceccarelli S, Celi F. Strategies for the prevention of bronchopulmonary dysplasia. *Front Pediatr* 2024; 12: 1439265.

115 Zhang X, Gray AR, Hancox RJ. Predictors of lung function in early adulthood: a population-based cohort study. *Respirology* 2024; 29: 897–904.

116 Bush A, Buonsenso D, Peroni D, *et al.* Early-life respiratory infection: how do we react to this red flag? *Pediatr Pulmonol* 2024; 59: 1817–1819.

117 The Lancet Respiratory Medicine. Respiratory syncytial virus vaccines: the future is bright. *Lancet Respir Med* 2024; 12: 499.