Indices of Childhood Socioeconomic Status and Dysanapsis among Older Adults: The Multi-Ethnic Study of Atherosclerosis Lung Study

To the Editor:

Dysanapsis refers to a developmental mismatch between airway tree caliber and lung size (1). The concept was first proposed by Green and colleagues as a potential mechanism to explain interindividual differences in maximal expiratory airflow among healthy adults (1). Dysanapsis assessed by computed tomography (CT) is strongly associated with chronic obstructive pulmonary disease (COPD) risk (2) and all-cause mortality, but the origins of dysanapsis remain poorly understood.

CT-assessed dysanapsis is evident by early adulthood (3), suggesting that factors that arise in childhood may contribute to the phenotypic differences in airway caliber relative to lung size. Socioeconomic status (SES), a marker of relative social and economic position and opportunities, can be measured across the life-course and operationalized as a composite of education, income, and occupation. SES is a known predictor of early-life anthropometric growth and lung function, as well as COPD risk and premature mortality (4–17). However, the association between early-life SES and dysanapsis in adulthood has yet to be investigated.

We hypothesized that lower childhood SES, assessed by lower parental educational attainment, would be associated with smaller adult airway tree caliber relative to lung volume. Furthermore, we hypothesized that associations between SES and dysanapsis would be consistent across sex and racial and ethnic groups, given that dysanapsis is a risk predictor, and risk related to low lung function is fairly consistent across racial and ethnic groups in this and other cohorts (16, 18).

Methods

MESA (the Multi-Ethnic Study of Atherosclerosis) recruited a multiethnic sample of adults (45–84 yr), who self-reported Asian, Black, Hispanic, or White race and/or ethnicity, free of clinical cardiovascular disease, from six U.S. sites. Institutional review board approval was obtained from each site, and written informed consent was obtained.

Childhood SES was quantified by participant-reported educational attainment of each parent. Response options were grouped into three categories: both parents with at least a college degree, both parents with at least a high school degree, at least one parent without a college or high school degree. Secondary indices included the sum of both parents' educational attainment, with 1 = no schooling; 2 = some schooling, no degree; 3 = high school degree; 4 = some college; 5 = college degree; 6 = graduate degree; and each parent's individual educational attainment.

The MESA Lung Study quantified dysanapsis using airway measurements from cardiac CT at full inspiration on cardiac-gated multidetector-row and electron-beam scanners and analyzed using a modified version of Pulmonary Analysis Software Suite with semiautomated airway and lung analysis, as previously described (19–22). The primary outcome was dysanapsis quantified as the mean of airway lumen diameters in centimeters divided by the cube-root of cardiac-CT estimated total lung volume in centimeters cubed (airway-to-lung ratio$_{CardiacCT}$) (2, 23, 24). To evaluate whether variation in airway tree caliber specifically (rather than lung volume) was associated with childhood SES (25), a secondary outcome was mean CT-measured airway lumen diameter in millimeters.

Multivariable linear regression models adjusted for: model 1 (base model): participant age, height (at time of CT), sex, self-identified race and/or ethnicity, principal components of genetic ancestry (26); model 2 (base model plus confounders): self-reported cigarette, pipe, or cigar smoking status and years (19); self-reported secondhand smoke exposure and duration; self-reported parent smoking status during childhood; asthma diagnosis; dysanapsis genetic risk score (27); residential air pollutant concentrations (fine particulate matter [particulate matter $\leq$2.5 μm in aerodynamic diameter], nitrogen oxides [NO_x], and ozone [O_3]) from spatiotemporal MESA Air models (28); model 3 (base model plus confounders and precision variables): study site, number and spatial distribution of airways measured on CT, and voxel size; model 4 (base model plus confounders, precision variables, and participant's adult SES): participant's educational attainment, household income, employment status, and wealth index. Secondary analyses were: *1*) modeled mean airway lumen diameter instead of airway-to-lung ratio; *2*) adjusted for percentage of emphysema-like lung (29) and for forced expiratory volume in 1 second/forced vital capacity (FEV_1/FVC; measured at a follow-up visit); *3*) replaced the highest joint parent educational attainment with each parent's individual educational attainment; and *4*) assessed for interactions by sex, race, and ethnicity using cross-product terms.

Results

Demographic characteristics for the 6,069 participants in this analysis are summarized in Table 1. Mean (standard deviation) airway-to-lung ratio$_{CardiacCT}$ was 0.218 (0.059). There were 391 (6.4%) participants who reported both parents with a college degree or higher; 1,704 (28.1%) reported both parents with a high school degree (no college) and 3,977 (65.5%) reported at least one parent

A full list of participating MESA investigators and institutions can be found at http://www.mesa-nhlbi.org.

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Table 1. Characteristics of Multi-Ethnic Study of Atherosclerosis Lung Study participants stratified by highest educational degree obtained by both parents

	Both Parents with College Degree ($n = 391$)	Both Parents with High School Degree ($n = 1,723$)	<2 Parents with High School Degree ($n = 4,038$)	Incomplete Data on Parental Education ($n = 641$)
Age, mean (SD), yr	59.2 (10.3)	60.1 (9.9)	62.9 (10.1)	64.5 (10.5)
Sex				
Female	195 (49.9)	878 (51.0)	2,141 (53.0)	375 (58.5)
Male	196 (50.0)	845 (49.0)	1,897 (47.0)	266 (41.5)
Height, mean (SD), cm	169.5 (9.7)	168.6 (9.7)	165.5 (10.0)	164.2 (9.8)
BMI, mean (SD), kg/m^2	27.3 (5.6)	28.3 (5.5)	28.5 (5.6)	28.8 (6.2)
Race-ethnicity				
Black	79 (20.2)	453 (26.3)	1,117 (27.6)	238 (37.1)
Chinese	55 (14.1)	119 (6.9)	550 (13.6)	78 (12.2)
Hispanic	10 (2.6)	155 (9.0)	1,172 (29.0)	154 (24.0)
White	247 (63.2)	996 (57.8)	1,199 (29.7)	171 (26.7)
Participant educational attainment				
Less than high school	7 (1.8)	65 (3.8)	935 (23.2)	209 (32.6)
High school	4 (1.0)	201 (11.7)	903 (22.4)	127 (19.8)
Some college or technical degree	69 (17.6)	573 (33.3)	1,116 (27.6)	174 (27.1)
Completed college or higher	310 (79.3)	879 (51.0)	1,072 (26.5)	126 (19.7)
Participant household income				
<$30,000	73 (18.7)	335 (19.4)	1,701 (42.1)	331 (51.6)
$30,000–$74,999	134 (34.3)	732 (42.5)	1,556 (38.5)	185 (28.9)
>$75,000	177 (45.3)	594 (34.5)	633 (15.7)	73 (11.4)
Missing	7 (1.8)	62 (3.6)	148 (3.7)	52 (8.1)
Participant cigarette smoking status				
Never	186 (47.6)	795 (46.1)	2,118 (52.5)	308 (48.0)
Former	168 (43.0)	697 (40.5)	1,403 (34.7)	212 (33.1)
Current	36 (9.2)	226 (13.1)	506 (12.5)	116 (18.1)
Missing	1 (0.3)	5 (0.3)	11 (0.3)	5 (0.8)
Pack-years (IQR)	11.6 (3.5–26)	15.0 (5.5–30)	15.8 (5.5–33)	19.5 (8.4–39.8)
Participant cigar smoking status				
Never	344 (88.0)	1,504 (87.3)	3,681 (91.2)	594 (92.7)
Former	37 (9.5)	152 (8.8)	242 (6.0)	30 (4.7)
Current	6 (1.5)	47 (2.7)	63 (1.6)	8 (1.2)
Missing	4 (1.0)	20 (1.2)	52 (1.3)	9 (1.4)
Participant pipe smoking status				
Never	344 (88.0)	1,529 (88.4)	3,726 (92.3)	602 (93.9)
Former	42 (10.7)	160 (9.3)	256 (6.3)	26 (4.1)
Current	2 (0.5)	17 (0.1)	18 (0.4)	2 (0.3)
Missing	3 (0.8)	17(0.1)	38 (0.9)	1 (0.2)
Adult secondhand smoke exposure	130 (33.2)	673 (39.1)	1,394 (34.5)	199 (31.0)
Parent smoking status during childhood				
Mother	79 (20.2)	358 (20.8)	564 (14.0)	29 (4.5)
Father	118 (30.2)	617 (35.8)	1,391 (34.4)	61 (9.5)
Air pollution exposures, mean (SD)				
$PM_{2.5}$, μm/m^3	16.1 (3.19)	16.0 (3.17)	16.6 (3.97)	16.9 (3.97)
NO_X, ppb	44.9 (22.8)	44.7 (24.6)	50.0 (27.0)	49.6 (24.3)
O_3, ppb	20.4 (3.75)	20.9 (4.29)	20.4 (4.40)	20.7 (4.20)
Self-reported respiratory diagnoses				
Asthma	37 (9.5)	167 (9.7)	393 (9.7)	69 (10.4)
Emphysema	3 (0.77)	20 (1.16)	60 (1.49)	21 (3.28)
Lung cancer	0 (0.00)	5 (0.29)	4 (0.10)	0 (0.00)
Spirometry, mean (SD)*	($n = 239$)	($n = 1,036$)	($n = 2,466$)	($n = 109$)
FEV_1, L/s	2.68 (0.77)	2.51 (0.77)	2.31 (0.70)	2.19 (0.70)
FVC, L	3.60 (1.00)	3.37 (1.01)	3.08 (0.90)	2.95 (0.89)
FEV_1/FVC	0.75 (0.08)	0.75 (0.08)	0.75 (0.09)	0.75 (0.08)
Percent lung volume <−950 HU, mean (SD)	5.4 (4.8)	4.6 (4.5)	3.9 (4.0)	3.9 (5.1)

TABLE 1. (*Continued*)

	Both Parents with College Degree ($n = 391$)	Both Parents with High School Degree ($n = 1,723$)	<2 Parents with High School Degree ($n = 4,038$)	Incomplete Data on Parental Education ($n = 641$)
CT assessment of dysanapsis, mean (SD)				
Airway-to-lung ratio, unitless	0.216 (0.057)	0.215 (0.060)	0.219 (0.060)	0.181 (0.053)
Mean airway lumen diameter, mm	4.09 (1.12)	4.02 (1.13)	4.01 (1.09)	3.29 (0.97)

Definition of abbreviations: BMI = body mass index; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; HU = Hounsfield units; IQR = interquartile range; NO_x = nitrogen oxides; O_3 = ozone; $PM_{2.5}$ = particulate matter ≤2.5 μm in aerodynamic diameter.
Data are presented as *n* (%) unless otherwise noted.
*The earliest study visit with spirometry occurred 2–6 years after the baseline study visit with cardiac computed tomography and childhood socioeconomic status variables.

without a high school or college degree. Compared with participants reporting both parents with a college degree or higher, those in the other groups exhibited lower airway-to-lung $ratio_{CardiacCT}$ (Figure 1). Consistent associations were observed for mean airway lumen diameter (less than high school vs. college degree or higher: $P = 0.0081$), with additional adjustment for percentage emphysema-like lung ($P = 0.0216$) and FEV_1/FVC ($P = 0.0377$), and when using each parent's individual attainment (mother: $P = 0.0130$; father: $P = 0.026$). There was no evidence of interaction by sex (P-interaction = 0.082) or race or ethnicity (P-interaction = 0.788).

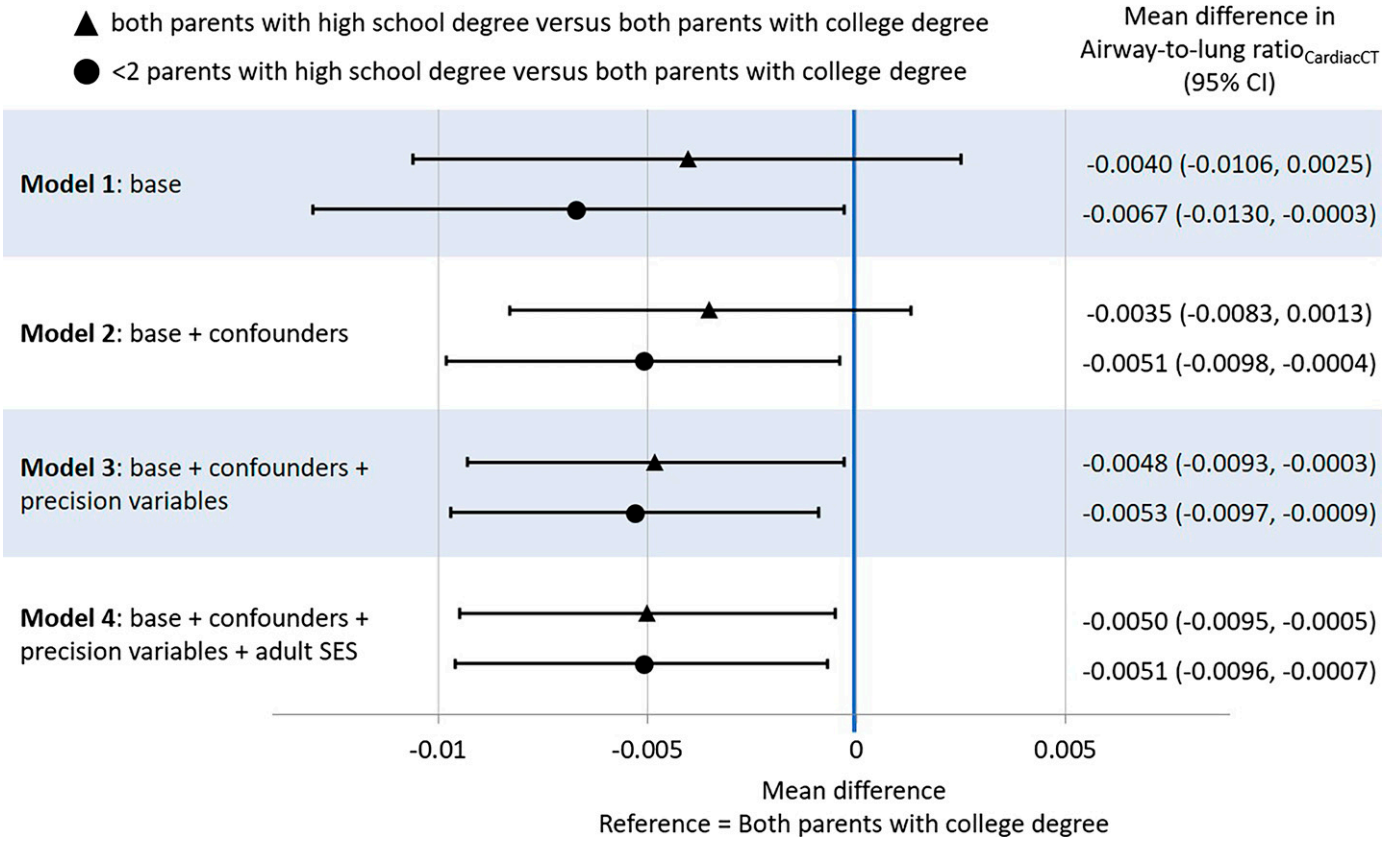

Figure 1. Mean difference in airway-to-lung ratio by parent educational attainment. Model 1 (base): participant age, height, (at time of computed tomography [CT]), sex, self-identified race-ethnicity, principal components of genetic ancestry. Model 2 (base plus potential confounders) model 1 + self-reported cigarette, pipe, cigar smoking status and years; self-reported secondhand smoke exposure and duration; self-reported parent smoking status during childhood; asthma diagnosis; dysanapsis genetic risk score; residential air pollutant concentrations (particulate matter ≤2.5 μm in aerodynamic diameter, nitrogen oxides, ozone). Model 3 (base plus potential confounders and precision variables) model 2 + study site, number and spatial distribution of airways measured on CT, and voxel size. Model 4 (base plus potential confounders, precision variables, and participant's adult socioeconomic status [SES]) participant's educational attainment, household income, employment status, and wealth index. CI = confidence interval.

Discussion

Lower childhood SES assessed by parental education attainment was associated with dysanapsis in adulthood, even after accounting for participants' adult SES, smoking status, and other potential confounders. Our findings in this large, multiethnic U.S. sample suggest that early-life social conditions contribute to differences in later-life airway lumen diameter relative to lung volume that may place individuals at risk for COPD.

Our findings are consistent with prior studies that have demonstrated strong correlations between early-life social conditions and lung growth and function in both childhood and adulthood (30, 31). Although we did not assess underlying mechanisms in the present study, others have demonstrated that lower childhood SES is associated with environmental exposures that are known risk factors for airway dysfunction (32, 33). In addition, the lack of effect modification by race and ethnicity suggests early-life social conditions play a critical role in the structural development of the airways and lungs that are more important than race and ethnicity.

Our study is limited by potential recall bias, as participants were asked about parental educational attainment while in adulthood. Currently there is no standardized metric of SES. We used parental educational attainment as a proxy for childhood SES because other factors, such as parental occupation and income, are often recalled less reliably (30). As participants in existing birth cohorts of respiratory health mature into mid- and later adulthood (34), prospectively assessed early-life SES, mediators (e.g., prematurity, childhood respiratory infections, family circumstances), and confounders (e.g., later-life smoking, occupational exposures) will become feasible.

Despite limitations, in this large racial and ethnically diverse sample of adults we identified significant associations between childhood SES and CT-assessed dysanapsis that have implications for risk stratification for COPD. These findings underscore the importance of addressing early-life social conditions as a means of addressing future risk of respiratory morbidity. ■

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Specialists in Chronic Respiratory Failure Should Serve More than Just Ventilator-Dependent Patients

To the Editor:

Cao and colleagues have suggested a subspecialty that addresses the needs of people with chronic *ventilatory* failure (1). This is an important and neglected population that deserves focus on research and translation of salient findings into clinical practice and policies.

Most people with chronic *respiratory* insufficiency do not need mechanical ventilation. The population covered by this proposed subspecialy needs to be broader to realize its full benefits. All people with chronic respiratory insufficiency have long-term physical symptoms (especially pathological breathlessness and fatigue) (2, 3); psychological (depression, anxiety) and social consequences (isolation, fear of being a burden); and existential suffering, which they experience daily and live with most often for years, or even decades (4). The population served by respiratory clinicians today comprise large numbers of such patients whose chronic problems are mostly underrecognized and, even when recognized, are frequently not addressed (5). In the vast field of pulmonology, physicians alone are unable to address all the needs of these patients and their families.

The proposal does not encompass the breadth of this population or the burden of illness experienced. Cao and colleagues speak of "ventilatory failure" rather than "respiratory insufficiency," or just oxygenation failure, whether continuous or just ambulatory (1). The authors understandably advocate for "continuity (of) care," but their proposal neglects the fact that chronic respiratory diseases