Ethnic Differences in Adolescent Lung Function

Anthropometric, Socioeconomic, and Psychosocial Factors

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Rationale: The relative contribution of body proportion and social exposures to ethnic differences in lung function has not previously been reported in the United Kingdom.

Objectives: To examine ethnic differences in lung function in relation to anthropometry and social and psychosocial factors in early adolescence.

Methods: The subjects of this study were 3,924 pupils aged 11 to 13 years, of whom 80% were ethnic minorities with satisfactory lung function measures. Data were collected on economic disadvantage, psychological well-being, tobacco exposure, height, FEV₁, and FVC.

Measurements and Main Results: The lowest FEV₁ was observed for Black Caribbean/African children after adjusting for standing height (SH) (white boys: 2.475 L; 95% confidence interval [CI], 2.442–2.509; white girls: 2.449 L; 95% CI, 2.464–2.535); Black Caribbean boys: –14% [95% CI, –16 to –12]; Black Caribbean girls: –13% [95% CI, –16 to –11]; Black African boys: –15% [95% CI, –17 to –13]; Black African girls: –17% [95% CI, –19 to –14]; Indian boys: –13% [95% CI, –16 to –11]; Indian girls: –11% [95% CI, –14 to –8]; Pakistani/Bangladeshi boys: –7% [95% CI, –9 to –5]; Pakistani/Bangladeshi girls: –9% [95% CI, –11 to –6]). Adjustment for upper body segment instead of SH achieved a further reduction in ethnic differences of 41 to 51% for children of Black African origin and 26 to 39% for the other groups. Overcrowding (boys) and poor psychological well-being (boys and girls) were independent correlates of FEV₁, explaining up to a further 10% of ethnic differences. Similar patterns were observed for FVC. Social exposures were also related to height components.

Conclusions: Differences in upper body segment explained more of the ethnic differences in lung function than SH, particularly among Black Caribbeans/African subjects. Social correlates had a smaller but significant impact. Future research needs to consider how differential development of lung capacity is compromised by the social patterning of growth trajectories.

Keywords: anthropometry; spirometry; ethnicity; socioeconomic factors; adolescence

Ethnic differences in spirometric lung capacity in childhood and adulthood have been reported (1). In the United Kingdom, The National Study of Health and Growth (NSHG) of children aged 5 to 11 years provided the first detailed examination of respiratory health in ethnic minority children (2). Black African/Caribbean and South Asian (Indian, Pakistani, or Bangladeshi) children were found to have lower FEV₁ and FVC than white children, the lowest values observed for Black African/Caribbean boys. Apart from the NSHG, three small-scale studies found Black Caribbean and Indian children (primary school aged [3, 4] and 5–16 years of age [5]) had FEV₁ and FVC values 8 to 13% lower than whites after adjustment for standing height.

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AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Studies in the United States have reported differences in lung function between African American and white children that are due to both differences in body proportions and social exposures.

What This Study Adds to the Field

In this United Kingdom study on ethnic differences in adolescent lung function, shorter trunks in ethnic minorities were the main reason for lower lung function, whereas psychosocial factors were found to be less relevant.

Studies in the United States have reported that differences in FEV₁ and FVC between African American and white children seem to be due in part to differences in body proportions, sitting height (SiH) being less in proportion to standing height (SH) in African Americans (6). There is some evidence to suggest that psychosocial factors, and family problems in particular, may influence truncal length (7) and height (8) in childhood. The factors influencing lung growth are not fully understood but may include prenatal exposures, such as *in utero* growth and maternal smoking during pregnancy (9–14), and postnatal exposures, such as poverty in childhood (15–17). Socioeconomic status (SES) contributes to ethnic differences in adult health (18), but little is known about its influence on ethnic differences in lung function. A recent study in the United States found that anthropometric differences explain about 50 to 60%; low birth weight about 3 to 5%; and SES, nutrition, and tobacco exposure about 10% of the black–white difference in FEV₁ and FVC in childhood (age, 8–17 yr) (6). There are no comparable studies in the United Kingdom.

In this article we use the MRC Determinants of Adolescent Social well-being and Health (DASH) study to investigate the extent to which anthropometry, SES, tobacco exposure, and psychological well-being contribute to ethnic differences in lung function in early adolescence. We also examine the effect of being born in countries other than the United Kingdom, the hypothesis being that children born outside the United Kingdom may have pre- and postnatal exposures that compromise growth and lung capacity. Preliminary results from this work have been previously reported in the form of an abstract (19).

METHODS

Design and Sample

The DASH study has been described previously (20). The sample was recruited from schools in 10 London boroughs with high proportions of the main ethnic minority groups (Black Africans, Black Caribbeans, Indians, Pakistanis, and Bangladeshis). Pupils in 51 schools from Years 7 and 8 (aged 11–13 yr) in randomly selected mixed academic ability classes were invited to join the study. Approvals from the Multicenter Research Ethics Committee and from local education authorities were obtained. Parents were notified in advance by letters and information packs sent via the head teachers. Active (opt-in) consent was used for pupils, and

passive (opt-out) consent was used for parents. The pupil response rate was 81%. Pupils completed questionnaires under supervision and had a suite of physical measures taken by fieldworkers who were trained for 5 days before the start of the study and were recertified during the study.

The ethnicity of United Kingdom white (referred to hereafter as whites), Black Caribbean, Black African, Indian, and Pakistani or Bangladeshi origin was self-defined and checked against reported details of the parents and grandparents. The ethnic categories provided in the questionnaire were the same as those on the 2001 Census (21). Consistency with ancestral background was taken to be present if at least one parent was reported to have the same ethnicity as the pupil and at least three grandparents were born in home countries. Pupils who reported "Black British" or "Asian British" or who did not report their ethnicity were classified using parental ethnicity and parental and grandparental country of birth. The generational status of pupils was defined as born abroad or born in the United Kingdom.

In a total sample of 6,643 pupils, 3,924 had satisfactory lung function (using the American Thoracic Society [ATS] and European Respiratory Society [ERS] guidelines) (22) and anthropometry measures and did not have a self-reported diagnosis of cystic fibrosis. The sample used in this analysis contained 757 white pupils, 518 Black Caribbeans, 597 Black Africans, 307 Indians, and 381 Pakistani or Bangladeshis. The remaining sample consisted of ethnic minority groups (mostly Irish, Eastern Europeans, Eastern Asians, and Middle Eastern ethnicities) that were too small for reliable analyses. The measures of FEV₁ and FVC need to be repeatable as per ATS/ERS guidelines (the difference between the largest and next largest FEV₁ and FVC is ≤ 0.15 L or if the FVC is ≤ 1 L the difference is ≤ 0.1 L [22]). Black Caribbean boys (odds ratio [OR], 1.33; 95% confidence interval [CI], 1.05–1.69) and Black African boys (OR, 1.47; 95% CI, 1.16–1.86) and girls (OR, 1.29; 95% CI, 1.02–1.63) were more likely to be excluded than white children because of this.

Outcome Measures, Risk Factors, and Confounders

Lung function tests were undertaken using a portable Micro Plus spirometer (Micro Medical Ltd., Kent, UK) (protocols based on ATS/ERS guidelines [22]). FEV₁ and FVC were recorded for each maneuver. Ambient air temperature, known to affect spirometry, was measured with a digital thermometer. The best FEV₁ and FVC for each child were used in analysis. Age (6 monthly) was calculated from reported date of birth. SH and SiH were carefully measured using a portable stadiometer, a standard stool, and recommended protocols (23). Femur leg length (LL) was equal to SH minus SiH, and upper body segment (UBS) was equal to SiH minus the height of the stool. Pubertal status was assessed using the self-complete Tanner questionnaire (24) supervised by a nurse. For these analyses, pupils were subdivided into two pubertal groups. Prepuberty (Tanner stage 1 for breasts or genitalia and pubic hair) and early puberty (Tanner stages 2 and 3 for breasts and genitalia) were combined due to very small numbers in the prepubertal group (<5% in any group). Late puberty consisted of Tanner stages 4 and 5 for breasts and genitalia. Affirmative asthma status was determined by ever having asthma, breathing difficulties, or wheeze.

SES was measured by a combination of indices: whether or not pupils had access to several standard of living items (family vehicle, CD player/hi fi system, television/DVD player, garage, bedrooms, computer, toilet, holiday abroad each year, deep freeze or fridge freezer, dishwasher, garden, washing machine, microwave oven, satellite/cable/digital TV, tumble dryer) expressed as tertiles; overcrowding (>1 person per bedroom, adjusted for two parents sharing a room); and parental employment status. Two measures of psychosocial factors were used: Goodman's Strengths and Difficulties Questionnaire (25) to measure psychological well-being (the lower the score, the better well-being) and a global question asking the pupils about their relationship with their parents (scaled response: 1 = very well; 2 = quite well; 3 = not so well). Exposure to cigarette smoking was affirmed if the pupil reported ever having smoked or living with a parent or parental figure who currently smokes.

Model Building

As recommended by Chinn and Rona (2), lung function, height, and age variables were transformed by natural logarithm. Multiple linear regression models were used to examine the interrelationships between

ethnicity, anthropometry, social and psychosocial factors, and lung function. Separate models were run for FEV₁ and FVC. The influence of each height component (SH, LL, UBS) on FEV₁ or FVC was examined in separate models. All models were sex specific; were adjusted for age, room temperature, and asthma and included ethnicity as the main explanatory variable. Pubertal stage was then added to these models and referred to as the baseline model. In relation to social exposures, our assumption was that differences in these exposures may affect ethnic differences in lung function directly or indirectly by affecting the height component. We examined each height component in relation to tobacco smoking, SES, and psychosocial variables. We examined whether these variables had independent effects on FEV₁ or FVC or modified the relationship between height components and FEV₁ or FVC by adding generational status, tobacco smoking, SES, and psychosocial variables in a stepwise manner to the baseline model. Metabolic mass is expected to be associated with lung function (26), so all models were rerun with body mass index (BMI) percentiles (external age and gender specific percentiles based on the 1990 British growth reference curves [27]). Primary and secondary interactions were investigated in all models. Data are presented as mean liters (95% CI) for white boys or girls and percent decrease from white for each of the main ethnic minority groups. The effects of the height components and social exposures are evaluated relative to the baseline model with SH, expressed as further percentage change in ethnic differences. This method enabled a direct comparison with the findings of the recent United States study (6).

RESULTS

Table 1 shows unadjusted characteristics by gender and ethnicity for the main ethnic groups. Ethnic minority groups had lower unadjusted FEV₁ and FVC than whites. Pakistani/Bangladeshi girls had higher FEV₁/FVC. Compared with whites, Black Caribbeans and Black Africans were taller, mainly due to disproportionately longer LL. With the exception of Pakistani/Bangladeshi boys, South Asians were shorter, mainly due to shorter UBS. Black African, Indian, and Pakistani/Bangladeshi girls were less likely to report asthma than white girls. Black Caribbean boys and girls and Black African girls were more likely to be in late puberty than whites.

Compared with whites, Black African and Pakistani/Bangladeshi boys were more disadvantaged by the standard of living measure, and boys and girls from these groups were more likely to live in an overcrowded household. Indian boys and girls and Black African girls were less likely to be smokers than whites. Reported exposure to passive smoking at home was generally relatively lower in ethnic minorities. Exceptions included Pakistani/Bangladeshi boys and girls and Black Caribbean and Indian girls, among whom the reported levels of paternal smoking were similar to that for whites.

Table 2 show ethnic differences in FEV₁ and FVC associated with the different height measures, adjusted for age, asthma status, room temperature, and pubertal stage. Regardless of which measure was adjusted for in the models, ethnic minority groups had significantly lower FEV₁ and FVC relative to whites. The largest reduction in ethnic differences in FEV₁ and FVC was achieved by adjusting for differences in UBS. On adjustment for SH alone, the largest ethnic differences in FEV₁ and FVC were seen for Black Africans and Black Caribbeans, and the smallest ethnic differences were seen for Pakistani/Bangladeshis. With adjustment for UBS instead of SH, these differences attenuated, more so for the Black African origin groups. Compared with adjustment for SH, adjusting for UBS led to a further reduction in ethnic differences in FEV₁ for boys of 48% for Black Caribbeans, 51% for Black Africans, 29% for Indians, and 39% for Pakistani/Bangladeshis. The corresponding figures for girls were 48% for Black Caribbeans, 41% for Black Africans, 26% for Indians, and 32% for Pakistani/Bangladeshis. Similar sized further reductions were observed for FVC after adjustment for UBS rather than SH

TABLE 1. BASELINE STATISTICS OF THE DETERMINANTS OF ADOLESCENT SOCIAL WELL-BEING AND HEALTH SAMPLE

	Boys					Girls				
	White (n = 388)	Black Caribbean (n = 260)	Black African (n = 260)	Indian (n = 171)	Pakistani/ Bangladeshi (n = 252)	White (n = 369)	Black Caribbean (n = 258)	Black African (n = 337)	Indian (n = 136)	Pakistani/ Bangladeshi (n = 129)
Unadjusted mean (SE)										
FEV ₁ , L	2.53 (0.03)	2.32 (0.03)*	2.30 (0.03)*	2.13 (0.04)*	2.36 (0.03)*	2.54 (0.02)	2.39 (0.03)*	2.27 (0.02)*	2.16 (0.04)*	2.26 (0.04)*
FVC, L	2.91 (0.03)	2.66 (0.04)*	2.61 (0.04)*	2.43 (0.04)*	2.66 (0.04)*	2.83 (0.03)	2.71 (0.03)*	2.55 (0.03)*	2.39 (0.04)*	2.46 (0.04)*
FEV ₁ /FVC, %	86.9 (0.32)	87.1 (0.43)	88.0 (0.40)	87.4 (0.67)	88.5 (0.47)	89.6 (0.35)	88.2 (0.47)	89.8 (0.43)	90.6 (0.74)	92.0 (0.56)*
SH, cm	153.8 (0.43)	156.8 (0.59)*	156.5 (0.57)*	151.6 (0.65)*	154.0 (0.54)	154.8 (0.39)	158.6 (0.47)*	157.7 (0.37)*	151.4 (0.56)*	152.5 (0.58)*
LL, cm	30.1 (0.24)	33.6 (0.35)*	33.7 (0.38)*	30.1 (0.37)	31.0 (0.30)	29.2 (0.21)	33.2 (0.30)*	32.9 (0.24)*	28.7 (0.32)	29.1 (0.34)
UBS, cm	76.7 (0.22)	76.2 (0.29)	75.8 (0.27)	74.5 (0.34)*	76.0 (0.29)	78.6 (0.22)	78.4 (0.24)	77.8 (0.20)	75.7 (0.35)*	76.4 (0.38)*
SDQ†	11.3 (0.26)	10.7 (0.31)	9.9 (0.30)*	10.3 (0.43)	10.2 (0.33)	11.6 (0.29)	11.1 (0.32)	10.8 (0.28)	9.6 (0.41)*	10.9 (0.44)
Percentage (95% CI)										
Asthma‡	28.4 (24.1–33.1)	31.9 (26.5–37.9)	21.9 (17.3–27.4)	28.1 (21.8–35.3)	27.8 (22.6–33.7)	34.2 (29.5–39.2)	30.2 (24.9–36.1)	23.2 (18.9–28.0)*	12.5 (7.9–19.2)*	20.9 (14.7–28.8)*
Late pubertal stage	33.5 (29.0–38.4)	47.3 (41.3–53.4)*	39.6 (33.8–45.7)	24.0 (18.2–31.0)	27.8 (22.6–33.7)	33.6 (29.0–38.6)	60.9 (54.8–66.6)*	57.0 (51.6–62.2)*	27.2 (20.4–35.3)	24.8 (18.1–33.0)
Most disadvantaged standard of living tertile	16.0 (12.7–20.0)	19.2 (14.9–24.5)	28.9 (23.7–34.7)*	16.4 (11.5–22.7)	27.4 (22.2–33.2)*	24.7 (20.5–29.3)	26.7 (21.7–32.5)	28.5 (23.9–33.6)	19.9 (14.0–27.4)	28.7 (21.5–37.1)
Overcrowded household	44.6 (39.7–49.6)	41.5 (35.7–47.6)	56.9 (50.8–62.8)*	52.6 (45.1–60.0)	69.8 (63.9–75.2)*	42.0 (37.1–47.1)	46.1 (40.1–52.3)	67.4 (62.2–72.2)*	48.5 (40.2–56.9)	79.8 (72.0–85.9)*
Student smokes	24.2 (20.2–28.8)	15.8 (11.8–20.7)	18.5 (14.2–23.7)	7.0 (4.0–12.0)*	18.3 (14.0–23.5)	23.9 (19.8–28.5)	28.3 (23.1–34.1)	10.7 (7.8–14.5)*	9.6 (5.6–15.8)*	15.5 (10.2–22.9)
Mother smoker	34.0 (29.5–38.9)	19.6 (15.2–24.9)*	4.2 (2.4–7.5)*	1.8 (0.6–5.3)*	4.8 (2.7–8.2)*	37.1 (32.3–42.2)	26.4 (21.3–32.1)*	1.8 (0.8–3.9)*	5.9 (3.0–11.4)*	5.4 (2.6–11.0)*
Father smoker	34.0 (29.5–38.9)	18.1 (13.9–23.3)*	10.4 (7.2–14.7)*	17.0 (12.0–23.4)*	27.4 (22.2–33.2)	30.1 (25.6–35.0)	20.5 (16.0–25.9)	10.4 (7.6–14.1)*	22.1 (15.9–29.8)	27.9 (20.8–36.3)

Definition of abbreviations: CI = confidence interval; LL = leg length; SH = standing height; UBS = upper body segment.

White refers to white children from the United Kingdom.

* $P < 0.05$ compared with white subjects.

† Total difficulties score from Goodman's Strengths and Difficulties Questionnaire (lower score represents better psychological well-being)

‡ Asthma is defined as asthma or wheeze or breathing difficulties.

(Table 2). The R^2 values were also highest for models that included UBS or SH. Adjustment for LL was associated with an increase in ethnic differences in lung function.

Late pubertal stage was a significant correlate of FEV₁ and FVC in models with or without height components, but the effect was reduced with the addition of SH or UBS. For example, in a model with age, room temperature, and asthma status, FEV₁ in boys in late puberty was greater by 4.9% (95%

CI, 5.9–9.8) compared with those in pre- or early puberty. When UBS was added to the model, this advantage was reduced to 1.8% (95% CI, 0.4–3.2), indicating a partial effect via UBS. BMI was a significant correlate of FEV₁ (coefficient 0.05%; 95% CI, 0.03–0.07 for boys; coefficient, 0.07%; 95% CI, 0.05–0.10 for girls, also adjusted for UBS) and FVC (coefficient, 0.07%; 95% CI, 0.050–0.09 for boys; coefficient, 0.09%; 95% CI, 0.07–0.12 for girls). The addition of BMI to each of the models

TABLE 2. EFFECT OF ADJUSTMENT OF DIFFERENT HEIGHT MEASURES ON ETHNIC DIFFERENCES IN FEV₁ AND FVC

	White UK as Reference (L) (95% CI)	Black Caribbean (% decrease from white) (95% CI)	Black African (% decrease from white) (95% CI)	Indian (% decrease from white) (95% CI)	Pakistani/Bangladeshi (% decrease from white) (95% CI)	R ²
FEV ₁						
Boys						
Pubertal stage*	2.475 (2.428–2.523)	9.8 [†] (12.9–6.8)	11.5 [†] (8.5–14.6)	15.4 [†] (11.9–18.9)	6.6 [†] (3.5–9.7)	0.23
SH‡	2.475 (2.442–2.509)	14.1 [†] (11.9–16.2)	14.8 [†] (12.6–17.0)	13.0 [†] (10.5–15.5)	7.2 [†] (5.0–9.4)	0.61
LL‡	2.475 (2.435–2.517)	15.7 [†] (13.1–18.4)	16.8 [†] (14.2–19.5)	16.4 [†] (13.3–19.4)	8.6 [†] (5.9–11.2)	0.42
UBS‡	2.475 (2.442–2.509)	7.3 [†] (5.1–9.4)	7.3 [†] (5.2–9.4)	9.2 [†] (6.7–11.6)	4.4 [†] (2.2–6.5)	0.62
Girls						
Pubertal stage*	2.449 (2.456–2.543)	9.0 [†] (6.2–11.8)	13.0 [†] (10.4–15.6)	16.2 [†] (12.8–19.7)	11.7 [†] (8.3–15.2)	0.25
SH‡	2.449 (2.464–2.535)	13.2 [†] (11.0–15.5)	16.5 [†] (14.4–18.6)	11.2 [†] (8.4–14.1)	8.5 [†] (5.7–11.3)	0.51
LL‡	2.449 (2.459–2.540)	14.0 [†] (11.3–16.6)	17.8 [†] (15.4–20.3)	15.5 [†] (12.3–18.7)	11.6 [†] (8.4–14.8)	0.35
UBS‡	2.449 (2.465–2.534)	6.8 [†] (4.6–9.0)	9.8 [†] (7.7–11.8)	8.3 [†] (5.5–11.0)	5.8 [†] (3.1–8.6)	0.53
FVC						
Boys						
Pubertal stage*	2.838 (2.783–2.894)	10.0 [†] (6.9–13.1)	12.5 [†] (9.4–15.6)	16.1 [†] (12.5–19.6)	8.5 [†] (5.4–11.7)	0.23
SH‡	2.838 (2.798–2.878)	14.3 [†] (12.1–16.5)	15.8 [†] (13.6–18.1)	13.6 [†] (11.1–16.2)	9.1 [†] (6.8–11.3)	0.60
LL‡	2.838 (2.790–2.887)	15.9 [†] (13.2–18.7)	17.8 [†] (15.1–20.6)	17.0 [†] (13.9–20.1)	10.5 [†] (7.7–13.2)	0.42
UBS‡	2.838 (2.799–2.878)	7.4 [†] (5.2–9.6)	8.2 [†] (6.0–10.4)	9.7 [†] (7.2–12.2)	6.2 [†] (4.0–8.4)	0.62
Girls						
Pubertal stage*	2.781 (2.731–2.832)	7.4 [†] (4.5–10.3)	12.9 [†] (10.2–15.6)	16.6 [†] (13.1–20.2)	13.9 [†] (10.4–17.5)	0.23
SH‡	2.781 (2.740–2.822)	11.7 [†] (9.3–14.1)	16.4 [†] (14.2–18.7)	11.5 [†] (8.6–14.5)	10.7 [†] (7.8–13.6)	0.49
LL‡	2.781 (2.734–2.828)	12.5 [†] (9.8–15.3)	17.9 [†] (15.3–20.4)	15.9 [†] (12.5–19.2)	13.9 [†] (10.5–17.2)	0.34
UBS‡	2.781 (2.741–2.821)	5.2 [†] (2.9–7.5)	9.6 [†] (7.5–11.8)	8.6 [†] (5.7–11.5)	8.0 [†] (5.1–10.9)	0.51

Definition of abbreviations: CI = confidence interval; LL = leg length; SH = standing height; UBS = upper body segment.

* Adjusted for room temperature, natural logarithm of age, asthma status and pubertal stage.

† $P < 0.01$.

‡ Adjusted for room temperature, natural logarithm of age, asthma status, pubertal stage, and natural logarithm of height measure.

presented in Table 2 did not alter the size of the ethnic differences in FEV₁ and FVC and did not change the R^2 values.

To assess whether social exposures could operate via height to affect lung function, we examined their impact on the different height measures. Several significant relationships were observed, with some distinct differences by gender and measure of height. For example, overcrowding was associated with shorter SH (coefficient, -1.1 cm; 95% CI, -1.9 to -0.3), UBS (coefficient, -0.5 ; 95% CI, -0.9 to -0.1), and LL (coefficient, -0.5 ; 95% CI, -1.0 to -0.1) among boys and with UBS among girls (coefficient, -0.4 ; 95% CI, -0.8 to -0.003). Perceived relationship with parents was inversely related to measures of height among girls: SH (coefficient, -1.2 ; 95% CI, -2.0 to -0.4), UBS (coefficient, -0.6 ; 95% CI, -1.0 to -0.2), and LL (coefficient, -0.6 ; 95% CI, -1.1 to -0.1). Compared with those born in the United Kingdom, boys (coefficient, -0.6 ; 95% CI, -1.2 to -0.1) and girls (coefficient, -1.2 ; 95% CI, -1.7 to -0.7) born abroad had shorter LL. Girls born abroad also had shorter SH than those born in the United Kingdom (coefficient, -1.1 ; 95% CI, -2.0 to -0.3). Tobacco exposure was not associated with any of the height components.

Given that UBS seemed to explain more of the ethnic differences in FEV₁ and FVC than other height measures, all subsequent multivariable analyses were based on UBS. Table 3 shows the additional effect of adjustment for generational status, tobacco exposure, SES, and psychosocial variables on FEV₁ and FVC. The addition of generational status, tobacco exposure, and SES to the baseline model with UBS generally led to some reduction in ethnic differences in FEV₁ and FVC, although the R^2 values changed little. Compared with a baseline model with SH, the adjustments for generational status, tobacco

exposure, and SES reduced ethnic differences in FEV₁ further for Black Caribbean boys (6%), Black Caribbean girls (8%), Black African boys (3%), Black African girls (10%), Indian girls (7%), and Pakistani/Bangladeshi girls (9%). This reduction was mainly due to overcrowding. The addition of psychosocial variables did not lead to further reduction in ethnic differences. There were no significant interactions between ethnicity and height, pubertal, or social variables in these models.

In the fully adjusted models in Table 3, overcrowding was an independent correlate of FEV₁ (coefficient, -1.6% ; 95% CI, -3.0 to -0.3) and FVC (coefficient, -1.7% ; 95% CI, -3.1 to -0.3) among boys. Poor psychological well-being was also an independent correlate of FEV₁ in boys (coefficient, -0.1% ; 95% CI, -0.3 to -0.02) and girls (coefficient, -0.1% ; 95% CI, -0.3 to -0.000) and with FVC in boys (coefficient, -0.2% ; 95% CI, -0.3 to -0.1).

DISCUSSION

This study is the first in the United Kingdom to systematically examine the effects of anthropometry and social and psychosocial exposures to ethnic differences in lung function in adolescence. We found the largest reduction in ethnic differences in FEV₁ and FVC was achieved by adjusting for differences in UBS rather than SH or LL. Social correlates were associated with smaller but significant effects and differed by gender.

The NSHG involved children aged 5 to 11 years, and a comparison provides some insight about the pace of growth and the relationship with the development of lung capacity between childhood and adolescence. Black African/Caribbean

TABLE 3. EFFECT OF STEPWISE ADJUSTMENT FOR SOCIAL AND PSYCHOSOCIAL VARIABLES ON ETHNIC DIFFERENCES IN FEV₁ AND FVC

	White as Reference (L) (95% CI)	Black Caribbean (% decrease from white) (95% CI)	Black African (% decrease from white) (95% CI)	Indian (% decrease from white) (95% CI)	Pakistani/Bangladeshi (% decrease from white) (95% CI)	R^2
FEV ₁						
Boys						
Model* 1	2.475 (2.442–2.509)	7.3 [†] (5.1–9.4)	7.3 [†] (5.2–9.4)	9.2 [†] (6.7–11.6)	4.4 [†] (2.2–6.5)	0.62
Model 2	2.475 (2.442–2.509)	7.2 [†] (5.1–9.4)	7.3 [†] (5.1–9.6)	9.1 [†] (6.7–11.6)	4.4 [†] (2.2–6.6)	0.62
Model 3	2.475 (2.442–2.509)	6.8 [†] (4.6–9.0)	7.4 [†] (5.1–9.6)	9.7 [†] (7.2–12.3)	4.9 [†] (2.7–7.1)	0.62
Model 4	2.475 (2.443–2.509)	6.4 [†] (4.2–8.6)	6.9 [†] (4.6–9.2)	9.3 [†] (6.8–11.8)	4.9 [†] (2.6–7.2)	0.63
Model 5	2.476 (2.444–2.509)	6.6 [†] (4.4–8.7)	7.4 [†] (5.1–9.7)	9.3 [†] (6.8–11.8)	5.0 [†] (2.7–7.4)	0.64
Girls						
Model 1	2.499 (2.465–2.534)	6.8 [†] (4.6–9.0)	9.8 [†] (7.7–11.8)	8.3 [†] (5.5–11.0)	5.8 [†] (3.1–8.6)	0.53
Model 2	2.499 (2.465–2.534)	6.5 [†] (4.3–8.7)	9.1 [†] (6.9–11.2)	8.1 [†] (5.3–10.8)	5.5 [†] (2.8–8.3)	0.53
Model 3	2.499 (2.465–2.534)	6.1 [†] (3.9–8.4)	8.7 [†] (6.5–10.9)	8.1 [†] (5.2–10.9)	5.4 [†] (2.6–8.2)	0.54
Model 4	2.499 (2.465–2.534)	5.8 [†] (3.5–8.1)	8.1 [†] (5.8–10.3)	7.9 [†] (5.1–10.7)	5.0 [†] (2.0–7.9)	0.54
Model 5	2.501 (2.467–2.536)	6.2 [†] (3.9–8.5)	8.2 [†] (5.9–10.5)	8.2 [†] (5.3–11.0)	5.2 [†] (2.3–8.1)	0.54
FVC						
Boys						
Model 1	2.838 (2.799–2.878)	7.4 [†] (5.2–9.6)	8.2 [†] (6.0–10.4)	9.7 [†] (7.2–12.2)	6.2 [†] (4.0–8.4)	0.62
Model 2	2.838 (2.799–2.878)	7.2 [†] (5.0–9.4)	7.8 [†] (5.6–10.1)	9.5 [†] (7.0–12.1)	6.1 [†] (3.8–8.3)	0.62
Model 3	2.838 (2.799–2.878)	6.8 [†] (4.5–9.1)	7.7 [†] (5.3–10.0)	9.5 [†] (6.9–12.2)	6.2 [†] (3.9–8.5)	0.62
Model 4	2.838 (2.799–2.877)	6.6 [†] (4.4–8.9)	7.3 [†] (4.9–9.6)	9.1 [†] (6.4–11.7)	6.0 [†] (3.6–8.4)	0.62
Model 5	2.839 (2.800–2.879)	6.8 [†] (4.5–9.0)	7.8 [†] (5.4–10.2)	9.1 [†] (6.5–11.7)	6.2 [†] (3.8–8.6)	0.63
Girls						
Model 1	2.781 (2.741–2.821)	5.2 [†] (2.9–7.5)	9.6 [†] (7.5–11.8)	8.6 [†] (5.7–11.5)	8.0 [†] (5.1–0.9)	0.51
Model 2	2.781 (2.741–2.821)	4.8 [†] (2.4–7.1)	8.7 [†] (6.5–10.9)	8.2 [†] (5.3–11.1)	7.7 [†] (4.8–0.6)	0.51
Model 3	2.781 (2.741–2.821)	4.4 [†] (2.0–6.8)	8.2 [†] (5.9–10.5)	8.1 [†] (5.1–11.1)	7.4 [†] (4.5–0.4)	0.51
Model 4	2.781 (2.741–2.821)	4.3 [†] (1.9–6.7)	7.8 [†] (5.4–10.2)	8.0 [†] (5.0–11.0)	6.8 [†] (3.7–9.9)	0.51
Model 5	2.783 (2.743–2.824)	4.5 [†] (2.0–6.9)	7.6 [†] (5.2–10.1)	8.1 [†] (5.0–11.1)	6.8 [†] (3.7–10.0)	0.51

* Model 1 = adjusted for room temperature, natural logarithm of age, pubertal stage, asthma status and natural logarithm of upper body segment; Model 2 = Model 1 + generational status; Model 3 = Model 2 + tobacco exposure (self and parental); Model 4 = Model 3 + socioeconomic status (standard of living, parental employment, overcrowding); Model 5 = Model 4 + psychosocial variables (total difficulties scores from Goodman's Strengths and Difficulties Questionnaire, parental relationship).

[†] $P < 0.01$.

children in the NSHG were consistently taller than whites at every age. Indian children were the shortest at most ages but experienced the most catch-up growth in NSHG (28). The rankings remained the same in DASH for these groups in early adolescence. The NSHG results pointed to the heterogeneity among the South Asians, Urdu/Punjabi-speaking boys being of similar height to whites. Most of the Pakistanis in DASH could be expected to be from Urdu/Punjabi-speaking backgrounds, but they were combined with the Bangladeshis because of small sample sizes. This may have obscured the effect shown in the NSHG. The mean height of the Pakistani boys (154.8 cm; $n = 167$) was greater than white boys (153.8 cm; $n = 388$), whereas Bangladeshi boys (152.3 cm; $n = 85$) were shorter. In the NSHG, Black African/Caribbean children had the lowest FEV₁ and FVC values relative to white children after adjusting for SH. We have shown a similar finding, but in addition we have shown that this pattern changes on adjusting for differences in UBS. In a previous United Kingdom study, chest dimensions of South Asian children aged 6 to 11 years did not explain their lower lung function compared with whites (4). There was little ethnic difference in chest dimensions in these children (4), which suggests that the pattern of catch-up growth of South Asian children between these younger ages and early adolescence contributes to disproportionate growth in LL. It is difficult to compare the effects of social factors in the NSHG because few ethnic and sex-specific results were reported. Increasing family size was associated with decreasing FEV₁ and FVC in South Asians but not in Black African/Caribbeans. To some extent the effect of overcrowding in the household among boys in the DASH study provides a comparison, but we did not find an interaction between overcrowding and ethnicity suggesting similar adverse effects across all ethnic groups. Some caution is required with these comparisons because the DASH study was London based, whereas the NSHG was a national study. A regional bias is likely because London is more affluent than most other regions in the United Kingdom.

A comparison with studies of groups with similar racial ancestry in different countries is useful because differences in lung function may signal a role for environmental exposures. A large proportion of the Black Caribbeans in the United States originate from Jamaica. In Jamaica in the 1970s, Miller and colleagues (29) found that FEV₁ and FVC in children of African origin were lower than in children of European origin. Similar to results from DASH, this was partly due to the smaller cormic index (SiH to SH ratio) in children of African origin. To our knowledge, there have been no recent studies in Jamaica. A study in India found that social deprivation was associated with a reduction in FEV₁ and FVC by 14 to 17% in children aged 5 to 15 years (16), which is a much larger effect size than reported here or in the United States. Generational status was a significant correlate of lung function for Indian subjects in the United States, where United States-born Indian women (aged 18–35 yr), but not United States-born men, have greater FEV₁ and FVC than Indians born abroad (30). Generational status was not a significant correlate in our analyses, possibly due to lack of statistical power.

Harik-Khan and colleagues (2004) conducted a similar study to DASH examining FEV₁ and FVC differences between African American and white Americans at ages 8 to 12 years (6). The ethnic difference in the United States after adjustment for SH was larger than observed in DASH. For example, the difference in FEV₁ between African American and white American boys was 364 ml, whereas in the United Kingdom the difference between Black Caribbean and white boys was 207 ml, and the difference between Black African and white boys was 232 ml. They found that adjusting for UBS reduced the difference by an

additional 53% for FEV₁ for boys and by 43% for girls. This represents a larger effect compared with that for Black Caribbean or Black African boys in DASH but a smaller effect compared with that for Black Caribbean girls in DASH. Social variables (poverty index and educational level of family head) in the United States reduced differences in FEV₁ by an additional 8% in boys and 5% in girls, similar to results reported here for children of Black African origin in DASH.

There are some important limitations to our study. UBS is generally used as a proxy of chest height, but this may be subverted by systematic differences in the length of the head and neck between ethnic groups. The nature of school-based studies may mean that school avoiders, in particular long-term truants, and pupils who were more likely to be absent due to illness were underrepresented in the sample. This group may be more likely to live in poor social conditions and have poor psychological well-being. Ethnicity is a difficult concept to measure, partly due to its fluidity and responsiveness to context; it is essentially a social concept (31). Self-defined ethnicity is key to this type of analysis, but we also checked for consistency against parental and grandparental background. It is possible that children may report their ethnicity differently as they grow older, an issue that we will be able to examine in the follow-up study. There may be merit in further disaggregation of the Pakistani/Bangladeshi group and the Black African group due to variations in SH (Nigerian/Ghanaian girls, 158.7 cm; other African girls, 156.2 cm) and historic exposures (Nigerian and Ghanaians arrived in the United Kingdom mainly in the 1950s and 1960s following political independence from Britain, whereas other Africans, such as Somalis and Ethiopians, arrived in the 1980s as refugees). The use of strict ATS/ERS guidelines on the acceptable repeatability of lung function maneuvers meant a loss of some of the sample ($n = 1,683$). We reanalyzed the data with less stringent criteria (two measures each of FEV₁ and FVC within 500 ml). The ethnic differences in lung function remained unchanged, as did the additional effect of UBS. Maternal smoking (coefficient, -1.4% ; 95% CI, -2.8 to -0.03) and decreasing quality of parent/child relationship (coefficient, -1.4% ; 95% CI, -2.9 to -0.03) among boys and being born abroad in girls (coefficient, -1.7% ; 95% CI, -3.2 to -0.3) became independent correlates of FEV₁. This suggests some loss of statistical power with the stricter guidelines.

Current clinical and research practice involves comparing lung function and SH to reference values usually derived from white populations (1). Our results suggest that this approach may be simplistic and may mislead health professionals about the complex relationship between ethnicity, social exposures, height components, and lung function. Physicians need to be aware not only of ethnic differences in standing height but in the components of height and that the growth trajectories of these are socially patterned. The practical implications require cooperation between medical and other professionals to address issues related to social exposures (e.g., overcrowding) to optimize growth and lung function potential in ethnic minority children. The recently completed follow-up of the DASH respondents at ages 14 to 16 years will provide novel longitudinal data on the interrelationship between growth trajectories, social exposures, and respiratory health in general.

Conclusions

Differences in the length of UBS explained more of the ethnic differences in lung function than SH. Social correlates had a smaller but significant impact. Future research needs to consider how differential development of lung capacity among ethnic minority children is compromised by the social patterning of

growth trajectories. Our findings also have a cautionary message to clinicians. The use of reference values that adjust for ethnic differences in anthropometric differences may obscure the effect of environmental exposures and lead to complacency toward lower spirometric indices.

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