Patterns of childhood body mass index (BMI), overweight and obesity in South Asian and black participants in the English National child measurement programme: effect of applying BMI adjustments standardising for ethnic differences in BMI-body fatness associations

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BACKGROUND: The National Child Measurement Programme (NCMP) records weight and height and assesses overweight-obesity patterns in English children using body mass index (BMI), which tends to underestimate body fatness in South Asian children and overestimate body fatness in Black children of presumed African ethnicity. Using BMI adjustments to ensure that adjusted BMI was similarly related to body fatness in South Asian, Black and White children, we reassessed population overweight and obesity patterns in these ethnic groups in NCMP.

METHODS: Analyses were based on 2012–2013 NCMP data in 582 899 children aged 4–5 years and 485 362 children aged 10–11 years. Standard centile-based approaches defined weight status in each age group before and after applying BMI adjustments for English South Asian and Black children derived from previous studies using the deuterium dilution method.

FINDINGS: Among White children, overweight-obesity prevalences (boys, girls) were 23% and 21%, respectively, in 4–5 year olds and 33% and 30%, respectively, in 10–11 year olds. Before adjustment, South Asian children had lower overweight-obesity prevalences at 4–5 years (19%, 19%) and slightly higher prevalences at 10–11 years (42%, 34%), whereas Black children had higher overweight-obesity prevalences both at 4–5 years (31%, 29%) and 10–11 years (42%, 45%). Following adjustment, overweight-obesity prevalences were markedly higher in South Asian children both at 4–5 years (39%, 35%) and at 10–11 years (52%, 44%), whereas Black children had lower prevalences at 4–5 years (11%, 12%); at 10–11 years, prevalences were slightly lower in boys (32%) but higher in girls (35%).

INTERPRETATION: BMI adjustments revealed extremely high overweight-obesity prevalences among South Asian children in England, which were not apparent in unadjusted data. In contrast, after adjustment, Black children had lower overweight-obesity prevalences except among older girls.

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INTRODUCTION
Childhood obesity is a major public health problem both globally1 and in England, where approximately one-third of children aged 2–15 years were recently reported to be overweight or obese using body mass index (BMI).2 Childhood overweight-obesity is associated with adult overweight-obesity,3 and with higher risks of type 2 diabetes and cardiovascular disease.4–6 Overweight-obesity in English South Asian and Black children of African origin is of particular concern; both ethnic groups have high type 2 diabetes and cardiovascular disease risks in adulthood,7–10 originating in childhood.11,12

Accurate assessment of overweight-obesity prevalence in English South Asian and Black children is therefore important. Most national surveys, including the National Child Measurement Programme (NCMP) and the Health Survey for England,2,13 use BMI to categorise overweight and obesity identically in all ethnic groups. However, the relations between BMI and body fatness differ by ethnicity both in adults and children. Asian adults tend to have a lower BMI for a given body fatness than Whites.14 Among English children, more specifically, BMI systematically underestimates body fatness in South Asians and overestimates it in Blacks.15,16 We recently developed ethnic-specific BMI adjustments, which provide adjusted BMI values for South Asian and Black children, which have the same relation to body fatness as in White children.17 In this report, we have applied these BMI adjustments to recent NCMP data to obtain an improved picture of the burdens of body fatness, as reflected in adjusted overweight-obesity prevalences in South Asian and Black children and in the English child population as a whole.
METHODS
National Child Measurement Programme (NCMP)

Participants. The NCMP is an annual survey of the weights and heights of
English children aged 4–5 years (reception year) and 10–11 years (Year 6)
carried out since 2006–2007, currently directed by Public Health England;
data collection is conducted by Local Authority (LA) public health
departments.18 All state primary schools in England (n ~ 17 000) are invited to
participate; within participating schools, all relevant pupils are invited to
participate on an opt-out basis. This report is based on the 2012/13 survey,
the most recent for which relevant information including pupil ethnicity
was available from the HSCIC (Health and Social Care Information Centre),
now NHS Digital. Overall, 93% of eligible children participated.13

Data collection. Weight and height were measured by assessment teams
recruited, trained and supervised by LA public health departments. Public
Health England provided detailed instructions on instrument choice and
calibration (requiring the use of annually checked Class III weight scales)
and measurements, made without shoes in light indoor clothing. Weight
was measured to the nearest 0.1 kg and height with the child’s heels
together and the head in the Frankfurt plane to the nearest 0.1 cm. BMI was
considered as weight per height2. School record information on name, date
of birth, sex and parentally defined ethnicity was collected. Data were
entered using the NCMP IT system and collated by HSCIC.

NCMP BMI category definitions. The NCMP uses the British 1990 child
growth reference population (UK90) to assign each child a BMI centile
taking into account their height, weight, sex and age.18,19 Children are
classified using population level thresholds as underweight (2nd centile or
below), healthy weight (above 2nd centile, below 85th centile), overweight
(on or above the 85th centile and below the 95th centile), or obese (on or
above the 95th centile) as a basis for informing parents of their child
weight status.18 Clinical ‘overweight-obesity’ refers to children on or above
the 91st BMI centile.

Ethnicity. Ethnicity was defined using the National Health Service
classification.20 For the present analyses, children identified as ‘White
British’, ‘White Irish’ and ‘any other White background’ were grouped as
‘White’. Children identified as ‘Black African’, ‘Black Caribbean’ or ‘any
other Black background’ were of presumed African origin and grouped
together as ‘Black’. Children of ‘Indian’, ‘Pakistani’ or ‘Bangladeshi’ origin
were grouped as ‘South Asian’. Children of ‘Chinese’ or ‘Asian other’ origins
were grouped as ‘Other Asian’. Children of ‘any other ethnic background’
and ‘mixed ethnicity’ were grouped as ‘Other ethnicity’. Children with
missing ethnicity data formed a separate category of ‘Unknown’.

Adjusted BMI values for black and South Asian children. Ethnic-specific BMI
adjustments for Black and South Asian children were derived using pooled
data from four recent studies that used the deuterium dilution reference
method and expressed as a height independent fat mass index (fat mass
per height5)) in the same way as in Whites.17 Regression models were
adjusted to account for Black and South Asian children aged 4–12 years17 BMI adjustments were derived using sex-stratified regression models, which ensured that
adjusted BMI values were associated with fat mass (based on the reference
method and expressed as a height independent fat mass index (fat mass
per height5)) in the same way as in Whites.17 Regression models were
adjusted for ethnic group and age group (in 3-year age groups (4.0–6.9,
7.0–9.9 and 10.0–12.5 years)) to provide robust and stable estimates. Model
building was conducted using a stepwise forwards approach; two-way

Table 1. Characteristics of participants in the national child measurement programme (2012–13): by age–sex group

| Variable | 4–5 Year olds N = 582 899 | 10–11 Year olds N = 485 362 |
|----------|---------------------------|---------------------------|
|          | Boys N = 297 887 | Girls N = 285 012 | Boys N = 248 783 | Girls N = 236 579 |
| Age (years), mean (s.d.) | 5.0 (0.3) | 5.0 (0.3) | 10.9 (0.4) | 10.9 (0.4) |
| Height (cm), mean (s.d.) | 110.0 (5.1) | 109.0 (5.1) | 144.7 (7.0) | 145.4 (7.5) |
| Weight (kg), median (LQ–UQ) | 19.3 (17.7–21.1) | 18.9 (17.3–20.8) | 37.5 (32.9–44.1) | 39.0 (33.5–46.2) |
| BMI (kg m⁻²), median(LQ–UQ) | 16.0 (15.2–16.9) | 15.9 (15.1–17.0) | 17.9 (16.3–20.4) | 18.3 (16.5–21.0) |
| Variable, n (%) | | | | |
| Ethnicity | | | | |
| White | 197 691 (66.4) | 188 663 (66.2) | 160 278 (64.4) | 151 146 (64.0) |
| Black | 14 468 (4.9) | 13 970 (4.9) | 11 347 (4.6) | 11 319 (4.8) |
| Black African | 9003 (3.0) | 8520 (3.0) | 6172 (2.5) | 6154 (2.6) |
| Black Caribbean | 2838 (1.0) | 2788 (1.0) | 2971 (1.2) | 2927 (1.2) |
| Black–Other | 2627 (0.9) | 2662 (0.9) | 2204 (0.9) | 2238 (1.0) |
| South Asian | 23 191 (7.8) | 22 109 (7.8) | 19 406 (7.8) | 18 636 (7.9) |
| South Asian–Indian | 7474 (2.5) | 7200 (2.5) | 5817 (2.3) | 5493 (2.3) |
| South Asian–Pakistani | 11 502 (3.9) | 10 855 (3.8) | 9675 (3.9) | 9322 (3.9) |
| South Asian–Bangladeshi | 4215 (1.4) | 4054 (1.4) | 3914 (1.6) | 3821 (1.6) |
| Other Asian | 6184 (2.1) | 6062 (2.1) | 4325 (1.7) | 41745 (1.8) |
| Other ethnicity | 18 832 (6.3) | 18 168 (6.4) | 12 914 (5.2) | 12 547 (5.3) |
| Unknown | 37 521 (12.6) | 36 040 (12.7) | 40 513 (16.3) | 38 756 (16.4) |
| Region | | | | |
| East Midlands | 25 212 (8.5) | 23 837 (8.4) | 21 496 (8.6) | 20 232 (8.6) |
| East of England | 34 041 (11.4) | 32 391 (11.4) | 28 195 (11.3) | 26 143 (11.1) |
| London | 47 613 (16.0) | 46 331 (16.3) | 37 346 (15.0) | 36 701 (15.5) |
| North East | 12 603 (4.2) | 12 509 (4.4) | 10 856 (4.4) | 10 432 (4.4) |
| North West | 40 997 (13.6) | 38 947 (13.7) | 34 734 (14.0) | 32 848 (13.9) |
| South East | 45 948 (15.4) | 43 628 (15.3) | 38 988 (15.7) | 37 052 (15.7) |
| South West | 26 481 (8.9) | 25 377 (8.9) | 22 370 (9.0) | 21 136 (8.9) |
| West Midlands | 33 353 (11.2) | 31 636 (11.1) | 28 430 (11.4) | 26 999 (11.4) |
| Yorkshire and The Humber | 30 590 (10.3) | 29 206 (10.3) | 25 026 (10.1) | 23 696 (10.0) |
| Unknown | 1049 (0.4) | 1150 (0.4) | 1342 (0.5) | 1340 (0.6) |

Abbreviations: LQ, lower quartile; UQ, upper quartile.
interaction terms between FMI, ethnic group and age group were included in the model and three way interactions were only considered if their corresponding two-way interactions were statistically significant at the 5% significance level. For South Asian children, single sex-specific positive BMI adjustments of +1.12 kg m$^{-2}$ for boys and +1.07 kg m$^{-2}$ for girls were applicable for all age groups and body fatness levels. For Black children, negative BMI adjustments were needed which were modified by age and body fatness (Supplementary Table 1). Fuller details are provided in a previous report.

Statistical analysis
The distributions of weight, height and BMI were reviewed for outliers. BMI was positively skewed and therefore medians rather than means were presented. Median BMI and the prevalences of specific BMI categories (underweight, normal weight, overweight, obese) defined using the UK90\textsuperscript{19} were determined for each ethnic group and for all participants before and after the application of BMI adjustments. Mann–Whitney U-tests were used to compare the distributions of BMI (or adjusted BMI) and indirectly to compare the differences in medians; z-tests for differences in proportions were used to compare prevalences of overweight-obesity between each of the ethnic minority groups and the White children. The prevalence of overweight-obesity was also determined for each LA in England to allow geographical comparisons to be made (including both prevalence and prevalence rankings) before and after BMI adjustment.

Role of the funding source
The funder had no role in the study design, data analysis, data interpretation or writing of the report. The authors had full access to all the data in the study and had final responsibility to submit the manuscript for publication.

RESULTS
Participants and data exclusions
In the 2012–13 school year, 1,076,824 children participated in NCMP. Of these, we excluded 8,563 children (0.01%) from analyses. Four children had implausible weight or height values and 324 children were outside the study age-range. A further 8,235 children who were measured in LAs identified by NCMP as having data quality concerns (Redcar-Cleveland, Torbay and Middlesbrough) were excluded. Children from one further area (Bassetlaw) flagged up by NCMP for potential data quality concerns were not excluded; Bassetlaw was part of a substantially larger LA district (Nottinghamshire) without quality concerns. LA analyses specifically excluded 684 children from three LAs each with fewer than 1000 participants (The City and County of the City of London ($n=11$), Isles of Scilly ($n=21$) and Rutland ($n=652$)) to avoid unnecessary imprecision in the results.

Characteristics of study participants
Table 1 summarises participant characteristics for each age–sex group, including 582,899 children aged 4–5 years and 485,362 children aged 10–11 years from 152 LAs. Ethnicity prevalences (≈60% Whites, ≈5% Blacks, ≈8% South Asians) did not differ

Figure 1. Correlation of prevalences of overweight-obesity in local authorities before and after BMI adjustments by age–sex group in the national child measurement programme (2012–13). Local authorities are colour coded by ethnic composition. Legend: open circles = South Asian & Blacks < 20%, green diamond = South Asian ≥ 20% & Blacks < 20%, red triangle = Blacks ≥ 20% & South Asian < 20%, blue square = South Asian & Blacks ≥ 20% Based on the overweight-obesity population thresholds: overweight-obese: ≥ 85th centile Excluding areas with potential data quality issues and areas with < 1000 individuals.
appreciably by age–sex group. Data on ethnicity were not available for ∼13% of 4–5 year olds and ∼16% of 10–11 year olds. As expected, older children were heavier and taller on average and had higher median BMIs. At 4–5 years, boys were heavier and taller than girls, with a marginally higher median BMI; at 10–11 years, girls were heavier and taller than boys and had a higher median BMI.

Median BMI and prevalences of overweight, obesity and overweight-obesity by ethnicity: effect of BMI adjustments

Median BMI and prevalences of BMI categories by ethnicity before and after BMI adjustment are shown for 4–5 year olds in Tables 2 and 3 and for 10–11 year olds in Tables 4 and 5. In White children, the prevalences of overweight-obesity, boys (girls) were 23.0% and 20.9% in 4–5 year olds, 32.8% and 30.4% in 10–11 year olds, respectively.

Black children. Before BMI adjustment, Black children had higher median BMI than Whites for all age–sex groups (Mann–Whitney U-tests, all $P < 0.0001$). The prevalences of overweight-obesity and obesity were higher than those of White children, both for boys and girls at 4–5 years and at 10–11 years ($z$-tests, all $P < 0.0001$). However, after adjustment, Black children aged 4–5 years (both boys and girls) and 10–11-year-old boys had slightly lower median adjusted BMI whilst Black 10–11-year-old girls had higher adjusted BMI (compared with Whites) (Mann–Whitney U-tests, all $P < 0.0001$). Overweight-obesity prevalences were slightly lower in Black children aged 4–5 years (both boys and girls) ($z$-tests, both $P < 0.0001$) and in 10–11-year-old boys ($z$-test, $P = 0.04$). However, black girls aged 10–11 years had a higher overweight-obesity prevalence than their White peers ($z$-test, $P < 0.0001$). There were no consistent differences in median adjusted BMI and overweight-obesity prevalence between Black African, Black Caribbean and other Black children either before or after adjustment.

South Asian children. Before BMI adjustment, BMI patterns in South Asian children differed by age group. At 4–5 years, median BMI was lower in South Asians than in White children (Mann–Whitney $U$-tests, both $P < 0.0001$). Overweight-obesity prevalences were also lower in 4–5-year-old South Asians than in White children ($z$-tests, both $P < 0.0001$). At 10–11 years, South Asian boys had an appreciably higher median BMI than Whites (Mann–Whitney $U$-test, $P < 0.0001$) but there was no marked difference in girls (Mann–Whitney $U$-test, $P = 0.77$). However, overweight-obesity prevalences for both boys and girls were higher than White children ($z$-test, both $P < 0.0001$). After adjustment, South Asian children (boys and girls), both at 4–5 years and more so at 10–11 years, had higher median BMIs (Mann–Whitney $U$-tests, all $P < 0.0001$); they also had higher overweight-obesity prevalences than White children ($z$-tests, all $P < 0.0001$); more than half of older South Asian boys were overweight-obese. Within the South Asian group, children of Pakistani and Bangladeshi origin had higher median adjusted BMI, obesity and overweight-obesity.
Overall median BMI and prevalences of weight categories: effect of BMI adjustments

The effects of ethnic-specific BMI adjustments on overall BMI and overweight-obesity patterns in the NCMP population were also examined (Table 2–5). After BMI adjustment, overall population median BMI values and the prevalences of being underweight or healthy changed very little. The adjusted overall prevalences of overweight-obesity were marginally increased in all age–sex groups, all by 0.5% or less.

LA differences in overall overweight-obesity prevalence: effect of BMI adjustments

The effects of BMI adjustment on the prevalences and rankings of overweight-obesity in LA areas were examined. Prevalences of overweight-obesity in LA areas before and after BMI adjustments are plotted against one another in Figure 1, for each age–sex group. LA variations in overweight-obesity prevalence were marked in 10–11 year olds (20–50%); the Spearman rank correlations of unadjusted and adjusted prevalence were high both for boys and girls (both $p < 0.06$). LA variations in overweight-obesity prevalence were smaller in 4–5 year olds and girls (15–30%) and correlations between unadjusted and adjusted prevalence were weaker ($r = 0.62, 0.74$, respectively). After adjustment, overweight-obesity prevalences in LAs with a high South Asian population prevalence ($≥20\%$) were systematically higher, whereas prevalences in LAs with a high Black population prevalence ($≥20\%$) were systematically lower. In the small number of LAs with a high population prevalence of both ethnicities, adjustment had little effect on overweight-obesity prevalences (Figure 1). However, the effects of BMI adjustment on LA rankings were substantial. The 20 LAs with the highest overweight-obesity prevalences both before and after BMI adjustment in each age–sex group are summarised in supplementary Figures 1–4. In 4–5 year olds, more than half of the 20 LAs with high overweight-obesity rankings were different after BMI adjustment; in 10–11 year olds, at least a quarter were different. After adjustment, more LA areas with a high South Asian population prevalence were
present in the top 20 rankings, whereas the number of LA areas with a high Black population prevalence declined (Supplementary Figures 1–4). A complete summary of LA overweight-obesity prevalences before and after BMI adjustment for each age–sex group is presented in Supplementary Table 2; corresponding information on overweight-obesity prevalence rankings is presented in Supplementary Table 3.

Sensitivity analyses
To determine whether results were influenced by children with particularly high unadjusted BMI values, sensitivity analyses excluded children with severe obesity (n = 14 087), defined using age and sex-specific Extended International Obesity Task Force thresholds.21 The results were not materially affected by excluding these individuals. The results were also examined using more extreme overweight-obesity definitions, those based on the use of NCMP clinical reporting thresholds (on or above the 91st percentile). The patterns of ethnic differences in overweight-obesity prevalence were not materially changed by the use of more extreme thresholds (Supplementary Table 4).

DISCUSSION
In this study, the first to our knowledge using ethnic-specific BMI adjustments to obtain an accurate picture of the relative prevalences of overweight-obesity in English children of different ethnicity, adjusted childhood overweight-obesity prevalence was particularly high among South Asian children in all age–sex groups and among older Black girls. These patterns were markedly different from those based on unadjusted BMI data, in which higher overweight-obesity prevalences in Black children were apparent. BMI adjustment increased the prevalences and rankings of overweight-obesity in LAs with high South Asian representation (≥20%) and reduced them in LAs with high Black representation.

Relation to previous studies
In the present investigation, unadjusted median BMI and overweight-obesity prevalences were particularly high in Black children compared with Whites, both at 4–5 years and at 10–11 years. This is consistent with previous NCMP reports from the same13 and previous years,72 and with BMI data from other nationally representative studies, including the Health Survey for England7 and the Millennium Cohort Study both at 5 years23 and 11 years.24 The unadjusted BMI patterns in South Asian children, with lower unadjusted median BMI and overweight-obesity prevalences than Whites at 4–5 years but higher prevalences at 10–11 years, are also consistent with NCMP data from the same13 and previous years22 and with reports from the Millennium Cohort Study.23,24 The markedly higher adjusted median BMI and overweight-obesity prevalences levels observed among South Asian children at both 4–5 and 10–11 years are consistent with the results of other population-based studies using more direct body

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### Table 4. 10–11-year-old boys—summary of body mass index and weight categories using UK90 population thresholds by ethnic group before and after ethnic adjustments to BMI in the national child measurement programme (2012–13)

| Ethnic group               | N    | Median BMI, Kg m⁻² (LQ–UQ) | 10–11-year-old boys prevalence, % (95 CI) | Overweight-obese |
|----------------------------|------|-----------------------------|------------------------------------------|------------------|
|                            | Underweight | Healthy | Overweight | Obese |
| **Before BMI adjustment**  |      |                             |                                          |                  |
| White                      | 160 278 | 17.8 (16.3–20.1)            | 0.9 (0.8–0.9)                            | 66.3 (61.1–66.5) |
| Black                      | 11 347 | 18.5 (16.7–21.4)            | 0.9 (0.7–1.1)                            | 56.9 (56.0–57.8) |
| Black African              | 6172  | 18.6 (16.7–21.4)            | 1.0 (0.8–1.3)                            | 55.8 (54.6–57.1) |
| Black Caribbean            | 2971  | 18.3 (16.7–21.3)            | 0.6 (0.3–0.9)                            | 58.5 (56.7–60.2) |
| Black-Other                | 2204  | 18.5 (16.7–21.2)            | 1.0 (0.6–1.5)                            | 57.6 (55.6–59.7) |
| South Asian                | 19 406| 18.3 (16.0–21.4)            | 3.6 (3.4–3.9)                            | 54.6 (53.9–55.3) |
| South Asian–Indian         | 5817  | 18.1 (15.9–21.1)            | 4.6 (4.0–5.1)                            | 55.9 (54.6–57.2) |
| South Asian–Pakistani      | 9675  | 18.3 (16.0–21.4)            | 3.8 (3.5–4.2)                            | 54.9 (53.9–55.9) |
| South Asian–Bangladeshi    | 3914  | 18.8 (16.3–22.0)            | 1.8 (0.3–0.6)                            | 51.8 (50.2–53.4) |
| Other Asian                | 4325  | 18.4 (16.3–21.3)            | 2.4 (1.9–2.8)                            | 55.2 (53.7–56.7) |
| Other ethnicity            | 12 914| 18.2 (16.4–20.9)            | 1.0 (0.9–1.2)                            | 60.1 (59.3–60.9) |
| Unknown                    | 40 513| 17.9 (16.3–20.4)            | 1.0 (0.9–1.1)                            | 64.3 (63.8–64.8) |
| Overall                    | 248 783| 17.9 (16.3–20.4)            | 1.1 (1.1–1.2)                            | 64.1 (63.9–64.3) |

| Ethnic group               | N    | Median BMI, Kg m⁻² (LQ–UQ) | 10–11-year-old boys prevalence, % (95 CI) |
|----------------------------|------|-----------------------------|------------------------------------------|
|                            | Underweight | Healthy | Overweight |
| **After BMI adjustment**   |      |                             |                                          |
| Black                      | 17.6 (16.0–21.1) | 2.1 (1.8–2.4) | 66.0 (65.1–66.9) |
| Black African              | 17.7 (16.0–20.1) | 2.2 (1.8–2.6) | 65.6 (64.4–66.8) |
| Black Caribbean            | 17.4 (16.0–20.0) | 1.7 (1.2–2.2) | 66.3 (64.6–68.0) |
| Black-Other                | 17.5 (16.0–20.0) | 2.4 (1.7–3.0) | 66.7 (64.7–68.6) |
| South Asian                | 19.4 (17.1–22.6) | 0.4 (0.3–0.5) | 47.5 (46.8–48.2) |
| South Asian–Indian         | 19.2 (17.0–22.2) | 0.4 (0.2–0.5) | 49.5 (48.3–50.8) |
| South Asian–Pakistani      | 19.4 (17.1–22.5) | 0.5 (0.3–0.6) | 48.1 (47.1–49.1) |
| South Asian–Bangladeshi    | 19.9 (17.5–23.1) | 0.2 (0.0–0.3) | 42.9 (41.3–44.4) |
| Other Asian                | 17.6 (16.0–21.1) | 2.1 (1.8–2.4) | 66.0 (65.1–66.9) |
| Other ethnicity            | 17.7 (16.0–20.1) | 2.2 (1.8–2.6) | 65.6 (64.4–66.8) |
| Unknown                    | 17.9 (16.4–20.4) | 0.9 (0.9–1.0) | 64.0 (63.8–64.2) |

*Population thresholds: underweight: ≤ 2nd centile, healthy: > 2nd and ≤ 85th centiles, overweight: > 85th centile, obese: ≥ 95th centile Overweight-obese: ≥ 85th centile. *Only ethnic groups affected by the BMI adjustments presented.
fatness measures, including bioimpedance and skinfold thickness in 9–10 year olds,15 deuterium dilution in both 8–10 year olds16 and 5–11 year olds25 and dual energy X-ray absorptiometry in 5–18 year olds,26 all of which showed higher body fatness in South Asians than in Whites. The lower adjusted median BMI and overweight-obesity prevalences observed in all Black children (except older girls) are also consistent with the results of earlier studies using more direct body fatness measures, including bioimpedance and skinfold thickness in 9–10 year olds,15 deuterium dilution in 8–10 year olds16 and dual energy X-ray absorptiometry in 5–18 year olds,26 which all showed lower body fatness in Blacks than in Whites. Our results reinforce the conclusion of an earlier systematic review that observed ethnic patterns of childhood overweight-obesity are strongly dependent on the method used to assess overweight-obesity.27

Implications
Our results, based on adjustment of BMI values to achieve consistent BMI-body fatness associations in South Asian, Black and White children, provide strong evidence that English South Asian children (especially Bangladesis and Pakistanis) have elevated overweight-obesity burdens. This is a particular concern, given the high long-term risks of type 2 diabetes and cardiovascular disease in UK South Asians7,8 from childhood.11,12 A second concern is the high adjusted BMI values in older Black girls, which suggest that the patterning of high obesity prevalence in UK Black women7 is emerging between 4–5 and 10–11 years, again with implications for the focus of prevention in young age groups. The average differences in adjusted BMI of > 1 kg m\(^{-2}\) (for example between South Asians and Whites at 10–11 years) would (if sustained into adulthood, which appears likely on current trends) account for astringently higher risks of both T2D (by at least 25%)28 and CHD (by at least 5%).28 The impact of higher BMI from childhood on T2D risk is likely to be particularly marked.16 The results also reinforce earlier concerns that unadjusted BMI data may disproportionately misclassify weight status in South Asian and Black children,14,15,25 This report emphasises the scale of potential misclassification, showing that while unadjusted BMI data point to an excess of overweight-obesity in Black children, in reality the excess is greater in South Asian children—though overall overweight-obesity prevalences in the entire population of England are little affected, as the changes in South Asian and Black children tend to offset one another. The results also draw attention to uncertainties in overweight-obesity prevalence estimates at LA level, which have been reported annually by NCMP.13 These LA prevalence estimates are very sensitive to BMI adjustments and are particularly (and predictably) affected in LAs with high ethnic minority prevalences. Adjustment reduced overweight-obesity prevalence rankings in LAs with substantial Black representation and increased them in LAs with substantial South Asian populations. This underscores the need to treat LA rankings cautiously, and emphasise instead the widespread occurrence of childhood overweight-obesity in all English LAs; even among the lowest ranking LAs, overweight-obesity prevalence values are excessive. Effective population-wide strategies for overweight-obesity prevention are therefore needed in all children, with a special emphasis on South Asian children and

| Ethnic group                  | N    | Median BMI Kg m\(^{-2}\) (LQ–UQ) | 10–11-year-old girls prevalence, % (95 CI) | Overweight-obese |
|-------------------------------|------|---------------------------------|------------------------------------------|-----------------|
|                               | Underweight | Healthy | Overweight | Obese  |
| Before BMI adjustment          |      |                                  |                                          |                 |
| White                         | 151 146 | 18.3 (16.5–20.8)                 | 1.2 (1.1–1.3)                            | 68.4 (61.8–68.6) |
| Black                         | 11 319 | 19.6 (17.3–22.7)                 | 1.3 (1.1–1.5)                            | 54.1 (53.2–55.0) |
| Black African                 | 6154  | 19.6 (17.3–22.7)                 | 1.4 (1.1–1.7)                            | 53.3 (52.3–54.8) |
| Black Caribbean               | 2927  | 19.6 (17.2–22.8)                 | 1.0 (0.6–1.3)                            | 54.2 (52.4–56.0) |
| Black–Other                   | 2238  | 19.4 (17.0–22.3)                 | 1.4 (0.9–1.9)                            | 55.5 (53.5–57.6) |
| South Asian                   | 18 636| 18.4 (16.1–21.4)                 | 4.1 (3.8–4.4)                            | 61.7 (61.0–62.4) |
| South Asian–Indian            | 5493  | 18.0 (15.9–20.9)                 | 5.2 (4.6–5.7)                            | 64.4 (63.1–65.7) |
| South Asian–Pakistani          | 9322  | 18.6 (16.2–21.6)                 | 4.2 (3.8–4.6)                            | 60.3 (59.3–61.3) |
| South Asian–Bangladeshi        | 3821  | 18.7 (16.4–21.8)                 | 2.2 (0.5–0.8)                            | 61.1 (59.5–62.6) |
| Other Asian                   | 41 745| 18.2 (16.2–20.6)                 | 2.7 (2.2–3.2)                            | 68.3 (66.9–69.7) |
| Other ethnicity               | 12 547| 18.7 (16.6–21.6)                 | 1.7 (1.5–2.0)                            | 62.5 (61.7–63.4) |
| Unknown                       | 38 756| 18.3 (16.5–20.9)                 | 1.5 (1.3–1.6)                            | 67.4 (67.0–67.9) |
| Overall                       | 236 579| 18.3 (16.5–21.0)                 | 1.5 (1.5–1.6)                            | 66.7 (66.5–66.9) |
| After BMI adjustment\(b\)     |      |                                  |                                          |                 |
| White                         | 18.6 (16.6–21.4) | 2.2 (1.9–2.5) | 63.0 (62.1–63.9) | 15.7 (15.0–16.4) | 19.1 (18.4–19.8) | 34.8 (33.9–35.7) |
| Black                         | 18.7 (16.6–21.4) | 2.3 (1.9–2.7) | 62.6 (61.4–63.8) | 16.0 (15.6–16.9) | 19.1 (18.1–20.1) | 35.1 (33.9–36.2) |
| Black African                 | 18.6 (16.5–21.5) | 1.7 (1.2–2.2) | 62.7 (61.0–64.5) | 15.4 (14.1–16.7) | 20.2 (18.7–21.6) | 35.6 (33.8–37.3) |
| Black–Other                   | 18.4 (16.4–21.1) | 2.4 (1.8–3.0) | 64.5 (62.5–66.5) | 15.4 (13.9–16.9) | 17.7 (16.1–19.3) | 33.1 (31.3–35.0) |
| South Asian                   | 19.5 (17.2–22.5) | 0.6 (0.5–0.7) | 55.8 (55.1–56.5) | 17.3 (16.7–17.8) | 26.4 (25.7–27.0) | 43.6 (42.9–44.3) |
| South Asian–Indian            | 19.1 (17.0–21.9) | 0.8 (0.5–1.0) | 59.6 (58.3–60.9) | 17.1 (16.1–18.1) | 22.6 (21.5–23.7) | 39.7 (38.4–41.0) |
| South Asian–Pakistani          | 19.6 (17.2–22.6) | 0.7 (0.5–0.8) | 54.7 (53.7–55.7) | 17.1 (16.4–17.9) | 27.5 (26.6–28.4) | 44.7 (43.7–45.7) |
| South Asian–Bangladeshi        | 19.8 (17.5–22.9) | 0.3 (0.2–0.5) | 53.0 (51.4–54.6) | 17.7 (16.5–19.0) | 28.9 (27.5–30.4) | 46.7 (45.1–48.2) |
| Other Asian                   |      |                                  |                                          |                 |
| Other ethnicity               |      |                                  |                                          |                 |
| Unknown                       |      |                                  |                                          |                 |
| Overall                       | 18.4 (16.5–21.1) | 1.3 (1.3–1.3) | 66.7 (66.5–66.8) | 14.6 (14.4–14.7) | 17.5 (17.3–17.6) | 32.0 (31.9–32.2) |

*Population thresholds: underweight: < 2nd centile, healthy: > 2nd and < 85th centiles, overweight: ≥ 85th centile, obese: > 95th centile overweight-obese: ≥ 85th centile. *Only ethnic groups affected by the BMI adjustments presented.

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older Black girls. Although the present analyses focus on English children, the results are likely to be relevant for the UK as a whole. Moreover, they are likely to have relevance for other countries with substantial South Asian and African origin ethnic minority populations and could also have relevance for other ethnic minority populations (for example, Pacific Island populations) with different BMI-body fatness associations from those of majority White populations.30,31

Strengths and limitations
The NCMP is a large-scale, national survey resource with high rates of participation both by schools and individual children, with standardised data collection and quality control procedures. We used 2012–13 data, the latest year available to us. The validity of the BMI adjustments used is critical; these used the reference deuterium dilution method32 to obtain fat mass estimates based on a pooled resource of ~1750 Black, South Asian and White children. The BMI distributions of the South Asian, Black and White children in the studies used to derive BMI adjustments were very similar to those of the children in NCMP populations, suggesting that their application to NCMP data was appropriate. BMI adjustments were provided for South Asian and Black children (based on inclusion of Indian, Pakistani, Bangladeshi, Black African and Caribbean children); these groups together account for almost two-thirds of all ethnic minority participants in the NCMP. However, it was not possible to provide adjustments for other ethnic groups not represented in the deuterium studies, including children with mixed ethnicities. It is however possible that the adjustments derived for South Asian children could be applied to Others,14 which would increase their estimated overweight-obesity burden. The validity of BMI adjustments could be greater if they could be standardised in relation to visceral fat (rather than total body fat), which is particularly implicated in the development of insulin resistance and type 2 diabetes risk and may be particularly high in South Asians.8 Although the validity and practicability of such adjustments remains uncertain, the current adjustments for South Asians may be conservative, potentially underestimating their true burden of overweight-obesity.

CONCLUSION
There is a substantial excess of overweight-obesity among English South Asian children (both at 4–5 years and especially at 10–11 years) and among Black girls aged 10–11 years, with important implications for overweight-obesity prevention. These patterns are not apparent using unadjusted BMI data, which tend to underestimate overweight-obesity prevalences in South Asian children and overestimate them in Black children.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS
Study design—MTH, CMN, PHW, CGO, ARR, DGC, JCKW. Data analysis—MTH, ARR, DGC, CMN. Data interpretation—MTH, PHW, ARR, CGO, DGC, JCKW, HR, CMN. Drafting manuscript—MTH, PHW. Critical evaluation and revision of manuscript—MTH, CMN, PHW, ASD, CGO, ARR, DGC, JCKW, HRW.

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