RESEARCH ARTICLE

Differences in total and regional body fat and their association with BMI in UK-born White and South Asian children: findings from the Born in Bradford birth cohort

[version 1; peer review: 1 approved with reservations]

Gillian Santorelli ¹, Jane West ¹, Tiffany Yang ¹, John Wright ¹, Maria Bryant ², D.A. Lawlor ^{1,3,4}

¹Bradford Institute for Health Research, Bradford, BD9 6RJ, UK

²Department of Health Sciences and the Hull York Medical School, York, YO10 5DD, UK

³Population Health Sciences, Bristol Medical School, University of Bristol, Bristol, BS8 2BN, UK

⁴MRC Integrative Epidemiology Unit, University of Bristol, Bristol, BS8 2BN, Bahamas

V1 First published: 26 Mar 2021, 6:65
<https://doi.org/10.12688/wellcomeopenres.16659.1>
 Second version: 08 Nov 2021, 6:65
<https://doi.org/10.12688/wellcomeopenres.16659.2>
 Latest published: 01 Apr 2022, 6:65
<https://doi.org/10.12688/wellcomeopenres.16659.3>

Abstract

Background: Body mass index (BMI) is commonly used as a proxy to determine excess adiposity, though this may underestimate fat mass (FM) in individuals of South Asian (SA) heritage. SA tend to have greater central adiposity than white people, which is associated with a higher risk of cardiometabolic disease. In this cross-sectional study, we aimed to determine the differences in total and regional FM using Dual-energy X-ray absorptiometry (DXA), and to see if any differences in FM varied by BMI category in UK-born white and SA children aged ~9 years.

Methods: Anthropometric measurements and DXA scans were undertaken from 225 white and 269 SA children from the Born in Bradford cohort study. Linear regression was used to assess ethnic differences in total body fat percent and total and regional FM.

Results: Although the mean BMI was similar, compared to white children, the proportion of SA children who were overweight or obese was ~20% higher, they had a median of 2kg more total FM, and the proportion with > 35% total body fat (TBF) was 22% and 16% higher in boys and girls respectively. Mean TBF% was greater in each BMI category, as was truncal, android and gynoid FM, with the greatest differences between ethnic groups observed in the healthy and overweight categories.

Conclusions: Greater TBF% and total and regional FM in the healthy- and overweight BMI categories observed in SA children suggests they

Open Peer Review

Approval Status

	1
version 3 (revision) 01 Apr 2022	 view
version 2 (revision) 08 Nov 2021	 view
version 1 26 Mar 2021	 view

1. Ken K. Ong , University of Cambridge, Cambridge, UK

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may be at greater risk of future cardiometabolic disease at a BMI level below obesity threshold. However, our sample size was small, and results may be influenced by selection bias and confounding; our findings need to be replicated in a larger study.

Keywords

Ethnicity, DXA, adiposity, BMI, fat mass

This article is included in the [Born in Bradford](#) gateway.

Corresponding author: Gillian Santorelli (gillian.santorelli@bthft.nhs.uk)

Author roles: **Santorelli G:** Conceptualization, Data Curation, Formal Analysis, Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **West J:** Conceptualization, Methodology, Writing – Review & Editing; **Yang T:** Writing – Review & Editing; **Wright J:** Funding Acquisition, Writing – Review & Editing; **Bryant M:** Writing – Review & Editing; **Lawlor DA:** Funding Acquisition, Methodology, Writing – Review & Editing

Competing interests: DAL has received support from Medtronic Ltd and Roche Diagnostics.

Grant information: Born in Bradford (BiB) receives core infrastructure funding from the Wellcome Trust (WT101597MA), and a joint grant from the UK Medical Research Council (MRC) and UK Economic and Social Science Research Council (ESRC) (MR/N024397/1) and one from the British Heart Foundation (BHF) (CS/16/4/32482), with these two funding collection of DXA and anthropometric data used in this study. The National Institute for Health Research Yorkshire and Humber ARC, and Clinical Research Network both provide support for BiB research. DAL works in a unit that receives support from the University of Bristol and MRC (MC_UU_00011/6) and is an NIHR Senior Investigator (NF-SI-0611-10196). and. This work was also supported by the UK Prevention Research Partnership (MR/S037527/1), which is funded by the British Heart Foundation, Cancer Research UK, Chief Scientist Office of the Scottish Government Health and Social Care Directorates, Engineering and Physical Sciences Research Council, Economic and Social Research Council, Health and Social Care Research and Development Division (Welsh Government), Medical Research Council, National Institute for Health Research, Natural Environment Research Council, Public Health Agency (Northern Ireland), The Health Foundation and Wellcome. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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How to cite this article: Santorelli G, West J, Yang T *et al.* **Differences in total and regional body fat and their association with BMI in UK-born White and South Asian children: findings from the Born in Bradford birth cohort [version 1; peer review: 1 approved with reservations]** Wellcome Open Research 2021, 6:65 <https://doi.org/10.12688/wellcomeopenres.16659.1>

First published: 26 Mar 2021, 6:65 <https://doi.org/10.12688/wellcomeopenres.16659.1>

Introduction

Greater adiposity has been shown to increase the risk of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) in adults^{1–3} and children^{4–8}. Risk of cardiometabolic disease is greater among those of South Asian (SA) heritage, who for a given body mass index (BMI) have greater total and central adiposity and are more likely to be insulin resistant and have CVD risk factors compared to White European adults^{9–11} and children^{12–15}. Specifically, it is visceral fat mass (FM), which is located in the trunk, rather than subcutaneous FM, that has been consistently associated with a higher risk of cardiometabolic disease independently of total FM¹⁶. Thus, android fat, which is characterised by truncal obesity, may confer a greater risk of morbidity whereas gynoid fat (i.e. in the gluteofemoral region), which is subcutaneous, has been shown to be potentially protective¹⁶. Further, the android/gynoid FM ratio has been shown to be predictive of cardiometabolic dysregulation in both adults¹⁷ and children^{18–20}.

Excess adiposity is commonly determined using BMI. Though BMI is a weight-based index that cannot distinguish between fat mass (FM) and lean mass (LM), it is highly correlated with both. However, using BMI alone may underestimate FM in people of SA heritage, which has led to suggestions that BMI cut-points be adjusted in Asian adults²¹ and children¹⁵.

Studies conducted using more advanced methods to accurately quantify adiposity using Dual-energy X-ray absorptiometry (DXA) in different UK ethnic groups have found that South Asian children have significantly more total body fat compared to white children^{15,22}, but to our knowledge none have reported ethnic differences in regional FM.

The aims of this study were to (i) determine the magnitude and direction of any differences in total and regional FM measured using DXA scans, and (ii) explore whether any differences in total and regional FM vary by BMI category, in UK-born white and SA-origin children aged approximately 9 years.

Methods

Participants and setting

This cross-sectional study used data obtained from participants of the [Born in Bradford](#) (BiB) multi-ethnic pregnancy and birth cohort study, details of which have been described elsewhere²³. Briefly, 12,453 pregnant women across 13,733 pregnancies were recruited between March 2007 and December 2010, resulting in 13,858 births. In 2017, a follow-up study of BiB participants was launched²⁴, and recruitment is expected to continue to June 2021. Briefly, the main objectives were to (i) investigate the determinants of child social and emotional wellbeing, (ii) identify the determinants of healthy growth and of adiposity and cardiometabolic health, and (iii) investigate the determinants of cognitive and sensorimotor development. The minimum effect sizes detectable for a range of outcomes were calculated based on expected participation. Families were invited to participate via a letter which included information sheets, followed by a telephone call from a BiB researcher. Assessments were conducted on a mobile health research bus or, if preferable to participants, via home visits, appointments in

community locations, or through telephone or postal questionnaires. The health research bus was loaned from the University of Birmingham between February 2017 to June 2018. It comprised a procedure room, sample room and scanner room, and was equipped with a DXA machine, benchtop refrigerated centrifuge, fridge, and freezer. As the DXA scans could only be conducted on the health research bus, it was at various times located in four different areas of the city to increase the catchment area.

Ethical considerations

Ethical approval was granted by the National Health Service Health Research Authority Yorkshire and the Humber (Bradford Leeds) Research Ethics Committee (reference: 16/YH/0320). Informed consent for the data collection was provided by the child's caregiver at recruitment to the BiB cohort study, but parents were informed that they could opt-out consent for measures collected in the follow-up study at their assessment appointment.

Scan acquisition and variables

During the loan period of the mobile health research bus (February 2017 to June 2018), children who visited the bus were offered a DXA scan; scans were not available to those who were visited at home or in other community locations. Whole body scans were performed using the Lunar iDXA (GE Healthcare, Madison, WI, USA) by trained research nurses following study protocols describing how to perform daily checks and calibrations, the preparation of the study participant and the scanning procedure. Scans were delivered using the appropriate mode (paediatric or adult) and provided data on total and regional bone mineral content, FM and LM. For these analyses, we were interested total body fat percent (TBF%), and total, trunk, android, gynoid, arm and leg FM (kg). Regional boundaries were automatically demarcated using enCORE software version 14.0 and there were no instances of children not fitting within the scan field. The trunk region includes the neck, chest, abdominal and pelvic areas; the leg region includes the legs and lateral hip area; and the arms includes arms and shoulders. The android region is totally enclosed within the trunk and is defined the area between the ribs and the pelvis; the gynoid region includes the hips and upper thighs and overlaps both the leg and trunk regions.

Anthropometric measurements

At the DXA scan appointment, height was measured to the nearest millimetre using the Leicester Height Measure and weight was measured to the nearest 0.1 kg using Tanita Body composition analyser SC-240. All measurements were taken by trained research assistants following standard operating procedures which described how to prepare and position the participants for height and weight measurements and how to record measurements accurately to reduce errors. BMI was calculated as weight/height² (kg/m²) and converted to age- and sex-adjusted z-scores by comparison to the UK90 reference data²⁵. The proportion of children who were categorized as having overweight/obesity and obesity were defined as those with a z-score >85th and 95th centiles, respectively. TBF% was categorised into 15–24%, 25–34% and 35+%.

Ethnicity

Ethnicity was self-reported by the mother when completing her baseline questionnaire in pregnancy and was used to define the ethnicity of her child based on UK Office of National Statistics guidance using the same classification as the 2001 UK census²⁶. We defined white ethnicity as those who identified as White British and White Other; SA was assigned to those of Pakistani, Indian and Bangladeshi heritage.

Other measurements

To explore whether the DXA subsample included in these analyses were selected in a way that might introduce bias, we compared the following characteristics between the subgroup of white and SA children included in this study with white and SA mother and offspring dyads recruited to the full BiB cohort: maternal ethnicity, maternal age, maternal educational attainment, parity, IMD, smoking in pregnancy and early pregnancy BMI (based on height collected at the baseline questionnaire, and weight at pregnancy booking); and offspring sex, gestational age at birth, and birth weight (obtained from the hospital maternity system).

Statistical analysis

P-values for differences in anthropometric and DXA measures between ethnic groups were calculated using chi-squared or t-tests. Pearson's pairwise correlation was used to calculate the

correlation between BMI and the DXA parameters. Age-adjusted linear regression was used to assess ethnic differences in TBF% and total and regional FM by BMI categories (healthy=BMI $\leq 85^{\text{th}}$ centile; overweight= $>85^{\text{th}}$ to $\leq 95^{\text{th}}$ centile; obese> $>95^{\text{th}}$ centile). As FM outcomes were positively skewed, we used log values in the regression analysis. The results from these were exponentiated and are presented as ratios of geometric means per SD change in the outcome. Results are stratified by ethnicity and sex. All analyses were performed using STATA/SE v15 (StataCorp LP, College Station, TX, USA).

Results

A flow chart of the study sample is presented in Figure 1. Between February 2017 and June 2018 (reflecting the loan period of the health research bus), 4,554 children aged ~9 years were invited to participate in the follow-up, and 2,557 consented. Of these, 1,759 agreed to visit the health research bus and were therefore offered a DXA scan, and 1,010 agreed. The scans were not performed on 469 of these children due to participant or research logistical and other issues, leaving a total of 541 children who received a scan. Of these, 225 were white, 269 were SA, 35 were of other minority ethnicity groups, and ethnicity data were missing for 12 children. As there were very few children of other ethnic minority groups, analyses of the DXA data were restricted to white and SA children only (see Figure 1).

Figure 1. Flow chart of study sample. * Number invited between February 2017 and June 2018.

Differences in key characteristics of those who had a DXA scan compared to the full BiB cohort are presented in [Table 1](#). Within ethnic groups, the DXA sample comprised around 4% of the full cohort for white and SA participants, and 3% of other ethnic minority groups. Compared to the full BiB cohort, mothers of white children who had a DXA scan were older, more likely to live in an affluent area, be educated to degree level and less likely to have smoked during

pregnancy. The birthweight and the proportion of males in other minority ethnic groups was greater in those who had a DXA scan compared to those who did not. There was more missing data on parity in white and SA children in the DXA sample, whereas participants in other ethnic groups who did not have a scan had a higher proportion of missing data for educational attainment and smoking during pregnancy (see [Table 1](#)).

Table 1. Comparison between the full BiB cohort¹ and the DXA scan sample. Values are mean (SD), median (IQR) or n (%).

	White		South Asian		Other ethnic group	
	Full cohort	DXA sample	Full cohort	DXA sample	Full cohort	DXA sample
	N=5,009	N=225 (4.3%)	N=6,249	N=269 (4.1%)	N=1,134	N=35 (3.0%)
Maternal characteristics						
Age (years)	26.7 (5.9)	30.3 (6.1)	28.0 (5.1)	28.4 (5.0)	28.0 (6.0)	29.7 (5.6)
Parity						
Nulliparous	2,276 (45.4)	100 (44.4)	1,926 (30.8)	67 (24.9)	433 (38.3)	11 (31.4)
Multiparous	2,461 (49.1)	104 (46.2)	3,991 (63.9)	172 (63.9)	598 (52.7)	21 (60.0)
Missing	272 (5.4)	21 (9.3)	332 (5.3)	30 (11.2)	103 (9.1)	3 (8.6)
IMD						
1 (most deprived)	2,405 (48.0)	89 (39.6)	4,634 (74.2)	201 (74.7)	806 (71.1)	23 (65.7)
2	1,216 (24.3)	65 (28.9)	1,252 (20.0)	50 (18.6)	205 (18.1)	6 (17.1)
3	716 (14.3)	30 (13.3)	215 (3.4)	14 (5.2)	71 (6.3)	6 (17.1)
4	419 (8.4)	30 (13.3)	105 (1.7)	4 (1.5)	31 (2.7)	0
5 (least deprived)	253 (5.1)	11 (4.9)	43 (0.7)	0	21 (1.9)	0
Education						
Less than degree level	3,588 (71.6)	112 (49.8)	3,867 (61.9)	155 (57.6)	408 (36.0)	17 (48.6)
Degree level	877 (17.5)	95 (42.2)	1,477 (23.6)	70 (26.0)	282 (24.9)	11 (31.4)
Missing	544 (10.9)	18 (8.0)	905 (14.5)	44 (16.4)	444 (39.2)	7 (20.0)
Smoking during pregnancy						
Yes	1,502 (30.0)	33 (14.7)	171 (2.7)	5 (1.9)	100 (8.8)	2 (5.7)
No	2,964 (59.2)	174 (77.3)	5,176 (82.8)	220 (81.8)	593 (52.3)	27 (77.1)
Missing	543 (10.8)	18 (8.0)	902 (14.4)	45 (16.4)	441 (38.9)	6 (17.1)
BMI (kg/m ²)	26.7 (6.0)	26.2 (5.1)	25.5 (5.4)	25.7 (4.8)	26.3 (5.6)	27.3 (6.1)
Missing, n (%)	862 (17.2)	37 (16.4)	1,247 (20.0)	63 (23.4)	514 (45.3)	8 (22.9)
Child characteristics						
Male	2,583 (51.6)	117 (52.0)	3,204 (51.3)	144 (53.5)	282 (51.3)	24 (68.6)
Gestational age (weeks)	40 (38, 40)	40 (38, 40)	39 (38, 40)	39 (38, 40)	39 (38, 40)	39 (38, 40)
Missing, n (%)	118 (2.3)	6 (2.7)	109 (1.7)	7 (2.6)	55 (4.9)	0
Birthweight (kg)	3.33 (0.57)	3.32 (0.61)	3.12 (0.54)	3.14 (0.54)	3.22 (0.56)	3.41 (0.52)
Missing, n (%)	131 (2.6)	3 (1.3)	333 (5.3)	11 (4.1)	54 (4.8)	1 (2.9)

DXA= Dual-energy X-ray absorptiometry; IMD=Index of multiple deprivation; BMI=body mass index

¹Born in Bradford participants who did not have a DXA scan; excludes stillbirths, death, and withdrawals.

A summary of anthropometric and DXA measurements of the sample included in these analyses are presented in [Table 2](#). SA boys were taller than white boys, on average, and a larger proportion of SA children were defined as living with overweight/obesity compared to their white counterparts (boys: 39.6% vs 29.1%; girls: 36.0% vs 27.8% of girls), but the mean BMI between the two groups was similar (boys: white 17.5 kg/m², SA 17.9 kg/m², P=0.317; girls: white 18.1 kg/m², SA 18.2 kg/m², P=0.817).

The median difference in total FM in SA children compared to white children was 2.3 kg for boys and 2.1 kg in girls. SA children had on average a higher TBF% than white children, and the proportion with over 35% body fat was substantially greater: white boys 15.4%; SA boys 37.5%; white girls 37.0%; SA girls 52.8%. [Figure 2](#) shows mean TBF% by BMI category in each sex and ethnic group and demonstrates higher TBF% in girls compared with boys and in SA compared with WB in all

Table 2. Participant characteristics by ethnicity and gender.

	Boys			Girls		
	White N=117	South Asian N=144	P-value	White N=108	South Asian N=125	P-value ⁴
Age (years) ¹	9.1 (0.9)	9.1 (0.9)	0.981	9.2 (0.8)	9.2 (0.8)	0.923
Anthropometric measurements						
Height (cm) ¹	136.9 (6.8)	138.9 (8.2)	0.042	137.7 (7.7)	138.4 (7.9)	0.489
Weight (kg) ¹	33.2 (7.9)	35.1 (9.8)	0.089	35.3 (9.3)	35.3 (9.4)	0.682
BMI (kg/cm ²) ¹	17.5 (3.1)	17.9 (3.6)	0.317	18.1 (3.4)	18.2 (3.7)	0.841
BMI z-score ¹	0.33 (1.26)	0.40 (1.50)	0.680	0.37 (1.24)	0.33 (1.44)	0.833
BMI category ²			0.157			0.401
Healthy (<85 th centile)	83 (70.9)	87 (60.4)		78 (72.2)	80 (64.0)	
Overweight (≥85 th – 94 th centile)	11 (9.4)	23 (16.0)		12 (11.1)	19 (15.2)	
Obese (≥95 th centile)	23 (19.7)	34 (23.6)		18 (16.7)	26 (20.8)	
DXA data						
Mean absolute TBF% (SD) ¹	27.6 (7.1)	31.7 (7.3)	<0.001	32.1 (7.1)	35.7 (6.5)	<0.001
Avg. TBF% category ²						
15–24%	49 (41.9)	32 (22.2)	<0.001	21 (19.4)	7 (5.6)	0.002
25–34%	50 (42.7)	58 (40.3)		47 (43.5)	52 (41.6)	
35+%	18 (15.4)	54 (37.5)		40 (37.0)	66 (52.8)	
Total body FM ³	7.6 (5.4, 11.1)	9.9 (6.4, 14.6)	0.001	9.4 (6.8, 13.9)	11.5 (8.2)	0.012
Trunk FM ³	2.7 (1.7, 4.4)	3.8 (2.1, 6.1)	0.001	3.6 (2.4, 5.8)	4.7 (3.1, 7.2)	0.003
Android FM ³	0.3 (0.2, 0.6)	0.5 (0.2, 0.9)	<0.001	0.4 (0.3, 0.8)	0.6 (0.4, 1.1)	0.002
Gynoid FM ³	1.3 (0.9, 1.8)	1.6 (1.1, 2.3)	0.001	1.7 (1.2, 2.5)	2.0 (1.4, 2.6)	0.010
Android/gynoid ratio	0.27 (0.10)	0.31 (0.12)	<0.001	0.30 (0.11)	0.35 (0.11)	<0.001
Arms FM ³	0.9 (0.6, 1.3)	1.2 (0.8, 1.7)	0.006	1.2 (0.8, 1.6)	1.3 (1.0, 1.7)	0.106
Legs FM ³	3.4 (2.3, 4.5)	4.2 (2.7, 5.8)	<0.001	4.1 (3.0)	4.7 (3.5, 6.0)	0.027
Lean mass (kg) ¹	23.7 (3.8)	23.2 (4.4)	0.394	23.0 (3.9)	22.0 (4.0)	0.063
Bone mineral content (kg) ¹	1.12 (0.18)	1.20 (0.22)	0.489	1.17 (0.19)	1.16 (0.20)	0.549

DXA= Dual-energy X-ray absorptiometry; BMI=body mass index; TBF% = total body fat percentage; FM=fat mass (kg). ¹Mean (SD). ²N (%). ³Median (IQR). ⁴Calculated using t-tests, chi-squared tests or Mann-Whitney tests, as appropriate.

Figure 2. Mean % body fat by body mass index (BMI) category, stratified by sex and ethnic group. W=white; SA=South Asian.

three categories of healthy weight, overweight and obesity. It also shows that in each sex and ethnic group TBF% was increased across the three BMI categories. BMI and all DXA measurements were highly correlated with each other in both ethnic groups (Table 3).

Figure 3 shows the age-adjusted ratios of geometric means of total and compartmental FM in SA compared to white children, by BMI category. Healthy- and overweight SA boys and girls had greater total and regional FM compared to white boys and girls in the same BMI category, with the greatest differences observed in the android region: in healthy weight SA boys and girls this was 28% and 27% higher respectively compared to white children, and in overweight children android FM was 25% higher in SA boys and 31% higher in SA girls. Healthy or overweight SA boys also had 14% greater adiposity in their arms and legs compared to white boys, but there was no difference between ethnic group in girls. No ethnic differences in total and compartmental FM were observed in children living with obesity.

Discussion

We have demonstrated some evidence of ethnic differences in the distribution and amount of directly measured total and regional adiposity, and their relationship with established categories of BMI. Whilst no statistically significant difference in BMI was observed between white and SA children, on average SA children had higher TBF%, with over one-third of boys and half of girls having >35% TBF. Age adjusted relative differences (ratios of

geometric means) in FM in general support higher total and truncal fat mass in SA compared with white children. A previous study of the BiB cohort at 4–5 years found that triceps skinfolds – an indicator of peripheral fat – was lower in SA boys and girls compared to white children²⁷; this contrasts with the higher arm and leg FM observed in SA boys (but not girls) in the present study, which may indicate that in addition to greater central adiposity, SA boys may also be susceptible to increased peripheral adiposity as they grow.

Our findings of ethnic differences in TBF% fat but not BMI in white and SA children is consistent with other UK studies which measured adiposity using precise techniques^{15,22} thereby adding further evidence that using BMI alone may underestimate adiposity in SA children. One of these studies, which included 339 SA and 654 white children between the ages of 6 to 18 years, reported the proportion of children in three different categories of TBF%: less than 15%, 15–25% and more than 25%, and found that a higher proportion of SA children were in the highest category²². When we used these definitions, we found there were no children in the lowest category, meaning that we needed to apply higher thresholds in our analyses. The difference in the proportion of SA compared to white children in the highest category was far greater than the previous study. There is a 15–20-year difference between the data collection of the sample in that study and ours and our results possibly demonstrate a worrying trend in the increasing adiposity in children, particularly in UK-born SA children. This is

Table 3. Correlation matrix of BMI with DXA parameters in white (not italic) and South Asian (italic) children.

	BMI	Fat mass (kg)					
		Total body	Trunk	Android	Gynoid	Arms	Legs
BMI	1.00						
Total body	0.942 0.939	1.00					
Trunk	0.912 0.918	0.980 0.984	1.00				
Android	0.921 0.927	0.975 0.983	0.990 0.990	1.00			
Gynoid	0.894 0.919	0.974 0.983	0.967 0.960	0.953 0.954	1.00		
Arms	0.937 0.918	0.974 0.977	0.931 0.952	0.935 0.952	0.935 0.958	1.00	
Legs	0.922 0.913	0.970 0.965	0.903 0.904	0.903 0.916	0.932 0.964	0.962 0.945	1.00

DXA= Dual-energy X-ray absorptiometry; BMI=body mass index

reflected in the UK National Child Measurement Programme (NCMP) figures for 4–5- and 10–11-year olds over the past 15 years²⁸, which show a temporal increase in the proportion of children classified as obese: between 2006/07 and 2019/20, the percentage of 10–11 year olds living with obesity has increased from 16% to 19% in white children, and from 21% to 25% in SA children.

Only one other study exploring the associations of BMI with directly measured regional fat mass in UK adolescents was identified⁸. It included 2,840 children, and reported similar associations between BMI and DXA FM with cardiometabolic risk factors as other studies in that it was abdominal fatness that was the primary driver of cardiometabolic dysfunction. Again, this study was conducted in a predominantly white European population, so the increased risk of cardiometabolic disease in other ethnic groups who display greater central adiposity remains unknown. We also found that SA children had greater android and gynoid FM, and higher android/gynoid ratio compared to white children, though it is acknowledged that the confidence intervals are wide due to the sample size. A handful of studies have found that android/gynoid ratio was more strongly associated with cardiometabolic health in children^{18–20}. This appears to persist into adulthood, with co-mingling of android and gynoid adiposities being associated with greater cardiometabolic risk than android or gynoid adiposity alone¹⁷.

Our findings suggest that SA children may be at increased risk of adipose-related morbidity even when they are considered a healthy weight according to their BMI, and that their risk when overweight is potentially far greater than that of white children. SA children who are defined as healthy or overweight could

therefore be more metabolically unhealthy than white children in the same BMI category.

Strengths and limitations

We were able to report total and regional FM in a bi-ethnic sample measured using DXA, which is an extremely accurate method of measuring body composition. However, a limitation is that DXA cannot distinguish between visceral and subcutaneous fat, and it is the former that appears to be the primary driver of cardiometabolic dysfunction.

There were some differences between the sample in the current study and the wider BiB cohort. Whilst most characteristics were similar in SA with DXA scans and the full original cohort, white mothers whose children attended a DXA scan tended to be older, educated to degree level and less likely to smoke during pregnancy or reside in deprived areas compared to the white population in the full BiB cohort. As higher levels of obesity are associated with increasing deprivation²⁹, the sample in the current study may be biased in that these children were less likely to be overweight/obese than those in the full cohort. However, whilst SA children in this sample were mostly disadvantaged, two thirds of white children were also from the two most deprived IMDs. The observed differences between the full cohort and the DXA sample may also be partly driven by the proximity of participants residence to the location of the mobile unit where the DXA scans were conducted, though it was, at various times, sited at four different areas of the city to widen the catchment area. We found no difference in measurements of height, weight, or BMI z-scores in the DXA sample compared to the other participants of the follow-up study, and we see no reason why levels of adiposity would be systematically different.

(a) Boys

(b) Girls

Figure 3. Age-adjusted ratios of geometric means (95% CI) for total and compartmental fat mass comparing South Asian to white children, in each body mass index (BMI) category.

We acknowledge that our study sample is small; we did not adjust for any confounders or factors related to selection into the DXA study, beyond age and were not able to detect differences between BMI categories or sex, with all estimates having wide confidence intervals. Thus, our findings need to be treated with some caution unless replicated in larger studies with greater ability to adjust for potential confounders and explore possible selection bias. Further, our sample, although representative of the region it was drawn from, may not reflect the same characteristics found in other multi-ethnic areas, including those with SA populations that are not predominantly of Pakistani heritage, as in our study. Finally, as this is a cross-sectional study, we were not able to observe any changes in regional FM throughout childhood and adolescence.

To conclude, we have demonstrated that although there were no differences in BMI between white and SA children, SA children had greater total and regional FM compared to white children. Further, although the proportion of SA children classified as overweight and obese was higher than in white children, the greatest differences in total and regional FM between the two ethnic groups were observed in children of a healthy weight and who were overweight; no differences were apparent in children living with obesity. The implications of this are that SA children may be at greater risk of cardiometabolic disease compared to white children with a similar BMI, and failure to recognise this at an early age may delay appropriate action, such as referrals to obesity interventions. Given the size of our study

and lack of adjustment, findings need to be replicated in a larger study with power to adjust for confounders. Further research on the associations of these differences with cardiometabolic risk, and the use of ethnic-adjusted BMI thresholds where indicated to better identify children at risk, is required.

Data availability

Underlying data

Harvard Dataverse: Replication Data for: Differences in total and regional body fat and their association with BMI in UK-born White and South Asian Children: Findings from the Born in Bradford birth cohort. <https://doi.org/10.7910/DVN/WEO4XI>³⁰.

This project contains the following underlying data:

- Raw dataset including demographic and outcome variables of the sample

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

Acknowledgements

BiB is only possible because of the enthusiasm and commitment of the children and parents in BiB. We are grateful to all the participants, health professionals, researchers and data teams who have made BiB happen.

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<http://www.doi.org/10.7910/DVN/WE04XI>

Open Peer Review

Current Peer Review Status: ?

Version 1

Reviewer Report 24 May 2021

<https://doi.org/10.21956/wellcomeopenres.18370.r43559>

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Ken K. Ong

MRC Epidemiology Unit & Department of Paediatrics, Institute of Metabolic Science, School of Clinical Medicine, University of Cambridge, Cambridge, UK

This cross sectional analysis of 9 year old children in the Born in Bradford cohort reports that despite having the same level of BMI, South Asian children had greater total body and central fat mass than white children.

1. However part of this difference may be because South Asian children were taller at age 9 years, especially the boys. This will contribute to having higher absolute fat mass, whereas BMI is (mostly) corrected for height. All fat mass comparisons should be adjusted for height.
2. Other UK cohorts have described that early puberty is 3x more likely in SA girls than white girls <https://pubmed.ncbi.nlm.nih.gov/27672135/>.¹ As puberty leads to accelerated fat gains in girls, this is another potential confounder. Do they have information on puberty status at this timepoint? If not, this should be discussed as a limitation.
3. South Asian children had a similar mean BMI to white children, yet SA have a higher prevalence of OW & OB. How can they be sure then that BMI is adequately controlled for? Discussion (line 2-3, also 1st line of the concluding paragraph) "no statistically significant difference in BMI was observed" - clarify that this refers to 'mean BMI' but that there were differences in BMI category.
4. Introduction (para 1): "gynoid fat (i.e. in the gluteofemoral region), which is subcutaneous..." This line confuses different ways to partition types of fat. Central:peripheral partitioning is quite different to visceral:subcutaneous and even intramuscular.
5. Introduction (para 2): "(BMI) is highly correlated with both (fat mass and lean mass)" - BMI is a good proxy marker of adiposity because, at least in adults, its correlations with fat mass are stronger than those with lean mass (e.g. see <https://pubmed.ncbi.nlm.nih.gov/28096530/>).² However, this is not necessarily true in children.

6. Methods: "Ethnicity was self-reported by the mother...in pregnancy" i.e. only by one parent. How big a limitation is this as a proxy for the child's ethnicity? What is the prevalence of mixed marriages in this setting?
7. Methods: The included sample here comprises only 4% of the full cohort for white and SA participants. While this was mostly for logistical issues, e.g. having visits within a certain timescale, there was a substantial drop from visits to DXA scans: "1,759 agreed to visit the health research bus and were therefore offered a DXA scan, and (only) 1,010 agreed". This is surprising as it seems only a small step in practice to have a DXA once you visit the research bus. What were the reasons for refusing DXA and more importantly did this proportion differ by ethnicity and BMI category?

Some typo errors:

1. Methods - Anthropometry: Definition of OW and obesity should read "defined as those with a BMI >85th or >95th centile" i.e. don't confuse z-scores and percentiles
2. Statistical analyses: "presented as ... per SD change in the outcome", I think should be 'in the exposure' (not the outcome)
3. Table 2: "Mean absolute TBF%" - 'absolute' is unnecessary. What is "Avg. TBF%"? (simply 'TBF%?')

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Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology, child growth and body composition

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Comments on this article

Version 1

Author Response 29 Oct 2021

Gillian Santorelli, Bradford Institute for Health Research, Bradford, UK

We thank Professor Ong for his review of our manuscript, and would like to respond to his comments.

Comment 1: However part of this difference may be because South Asian children were taller at age 9 years, especially the boys. This will contribute to having higher absolute fat mass, whereas BMI is (mostly) corrected for height. All fat mass comparisons should be adjusted for height.

Our response: Thank you for your guidance on this. We have calculated fat mass index for total and regional fat mass and regressed these against BMI. Accounting for height has greatly enhanced the differences observed between the two ethnic groups.

Comment 2: Other UK cohorts have described that early puberty is 3x more likely in SA girls than white girls <https://pubmed.ncbi.nlm.nih.gov/27672135/>.¹ As puberty leads to accelerated fat gains in girls, this is another potential confounder. Do they have information on puberty status at this timepoint? If not, this should be discussed as a limitation.

Our response: The reviewer has raised an important point. The paper referenced reports ORs for early menstruation in the fully adjusted model for a small sample SA girls are: Indian 3.66 (95% CI 2.3, 5.9), Pakistani 1.45 (0.9, 2.3) and Bangladeshi 2.15 (1.3, 3.5). Most of the SA girls in the present study are Pakistani (n=92, 83.6%), followed by Indian (n=13, 11.8%) and Bangladeshi (n=5, 4.5%) ethnic groups. Further, the mean age of children in the referenced study is two years older than those in our sample (11.2 vs 9.2 years), and older age was associated with a 5-fold increase in early menstruation. Although we do not have information on puberty status for our cohort, the small increase observed in Pakistani girls in the referenced paper and the older age of the sample suggests that early menstruation is unlikely to be a factor in our population. We have acknowledged that one of the limitations of our small study is that we did not adjust for any confounders and larger studies with the ability to adjust for potential confounders are required.

Comment 3: South Asian children had a similar mean BMI to white children, yet SA have a higher prevalence of OW & OB. How can they be sure then that BMI is adequately controlled for? Discussion (line 2-3, also 1st line of the concluding paragraph) "no statistically significant difference in BMI was observed" - clarify that this refers to 'mean BMI' but that there were differences in BMI category.

Our response: We have included histograms to show the distribution of BMI by ethnic group. These show the difference in the degree of positive skew between the groups, with a greater number of South Asian children having a BMI greater than the threshold for overweight/obesity. We have amended the manuscript to clarify the second point as follows:
Whilst no statistically significant difference in mean BMI was observed between white and SA children, a greater proportion of SA girls and boys were overweight and obese compared to their white counterparts and on average SA children had higher TBF%, with over one-third of boys and half of girls having >35%

Comment 4: Introduction (para 1): "gynoid fat (i.e. in the gluteofemoral region), which is subcutaneous..." This line confuses different ways to partition types of fat. Central:peripheral partitioning is quite different to visceral:subcutaneous and even intramuscular.

Our response: We have amended the manuscript to:
...subcutaneous adipose tissue in the gluteofemoral region has been shown to be potentially protective.

Comment 5: Introduction (para 2): "(BMI) is highly correlated with both (fat mass and lean mass)" - BMI is a good proxy marker of adiposity because, at least in adults, its correlations with fat mass are stronger than those with lean mass (e.g. see <https://pubmed.ncbi.nlm.nih.gov/28096530/>).
² However, this is not necessarily true in children.

Our response: We have amended the manuscript to reflect this as follows:
Though BMI is a weight-based index that cannot distinguish between fat mass (FM) and lean mass (LM), in adults its correlations with fat mass are stronger than with lean mass, however this is not necessarily true in children.

Comment 6: Methods: "Ethnicity was self-reported by the mother...in pregnancy" i.e. only by one parent. How big a limitation is this as a proxy for the child's ethnicity? What is the prevalence of mixed marriages in this setting?

Our response: Basing child's ethnicity on their mother's is standard in many cohort studies, for example ALSPAC and the Millennium Cohort Study, and the ONS base ethnicity on self-report but only for people aged 16 and over. In the baseline questionnaire, which was administered at recruitment to the Born in Bradford cohort study, we did not ask women their partners ethnicity, but we did ask their partner's country of birth. Of women who reported their ethnicity as White British, less than 1% had partner's who were born in South Asia. The partners of 95% of Indian

ethnicity women were born in India, 99% of Bangladeshi women's partners were born in Bangladesh, and 97% of Pakistani women's partners were born in Pakistani. Further, a Labour Force Survey conducted in 2010 (<https://www.equalityhumanrights.com/sites/default/files/research-paper-ethnicity-and-family-relationships-within-and-between-ethnic-groups.pdf>) found that 92% of Pakistani couples belonged to the same ethnic group as their partner. This suggests that using mother's ethnicity as a proxy for child's ethnicity is appropriate and has resulted in little misclassification.

Comment 7: Methods: The included sample here comprises only 4% of the full cohort for white and SA participants. While this was mostly for logistical issues, e.g. having visits within a certain timescale, there was a substantial drop from visits to DXA scans: "1,759 agreed to visit the health research bus and were therefore offered a DXA scan, and (only) 1,010 agreed". This is surprising as it seems only a small step in practice to have a DXA once you visit the research bus. What were the reasons for refusing DXA and more importantly did this proportion differ by ethnicity and BMI category?

Our response: As is correct ethical practice, the reasons for any participant declining to consent for specific measures, as that might seem coercive. However, many families visited the health research bus rather than other community locations simply because it was more convenient for them, irrespective of whether they consented to a DXA scan or not. We have amended the text to clarify this.

We have corrected the typo errors in the second version.

Competing Interests: No competing interests.