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Birth anthropometry among three Asian racial groups in Singapore: proposed new growth charts

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ABSTRACT

Objective We analysed birth anthropometry of babies of Chinese, Malay and Indian ancestry living in Singapore with an aim to develop gestational age (GA) and gender-specific birth anthropometry charts and compare these with the widely used Fenton charts.

Design Retrospective observational study.

Setting Department of Neonatology, National University Hospital, Singapore.

Population We report data from 52 220 infants, born between 1991–1997 and 2010–2017 in Singapore.

Methods Anthropometry charts were built using smoothened centile curves and compared with Fenton's using binomial test. Birth weight (BW), crown-heel length and head circumference (HC) were each modelled with maternal exposures using general additive model.

Main outcome measures BW, crown-heel length and HC.

Results There were 22 248 Chinese (43%), 16 006 Malay (31%) and 8543 Indian (16%) babies. Mean BW was 3103 g (95% CI 3096 to 3109), 3075 g (95% CI 3067 to 3083) and 3052 g (95% CI 3041 to 3062) for Chinese, Malays and Indians, respectively. When exposed to a uniform socioeconomic environment, intrauterine growth and birth anthropometry of studied races were almost identical. From our GA-specific anthropometric charts until about late prematurity, Asian growth curves mirrored that of Fenton's; thereafter, Asian babies showed a reduction in growth velocity.

Conclusions These findings suggest that Asian babies living in relatively uniform socioeconomic strata exhibit similar growth patterns. There is a slowing of growth among Asian babies towards term, prompting review of existing birth anthropometry charts. The proposed charts will increase accuracy of identification of true fetal growth restriction as well as true postnatal growth failure in preterm infants when applied to the appropriate population.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Viewpoints diverge on homogeneity of human fetal growth under ideal nurturing conditions.
⇒ Infants born to Chinese, Indians and Malays parents living in their country of origin differ markedly in birth parameters.

WHAT THIS STUDY ADDS

⇒ Birth anthropometries are near identical among babies born to Chinese, Indian and Malay parents living in Singapore.
⇒ When compared with Fenton's growth chart, a progressive slowing of fetal growth is noticed among the studied Asian races starting from 37 weeks of gestation.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ At or near term Chinese, Indian and Malay newborns risk misclassification of their growth unless local growth charts are used.

INTRODUCTION

Birth anthropometry, especially birth weight (BW), is an important determinant of childhood and future adult health.[1–3] The developmental origins of health and disease theory posits that a lower BW increases the risk of perinatal mortality[4] and chronic conditions in later life.[1–3 5] Significant differences in BW have been found among different countries and ethnicities.[6–8] Although such differences may be the result of modifiable exposures such as maternal nutrition,[9] perinatal care and socioeconomic disparities,[10] some of the variability may have its origins in genetic differences.[11] Reference growth charts, such as Fenton growth charts,[12] were developed in populations in which European ancestry predominates. If these references are used as global norms, it is possible that babies of Asian ancestry that are on the lower range of normal size for their races may erroneously be classified as small-for-gestational age (SGA).

The three main population centres of Asia—East (eg, Chinese), South-East (eg, Indonesia and Malaysia) and South (eg, India)—were previously shown to have striking differences in BW: neonates weigh 3200 g in China on average, 2900 g in Indonesia and between 2600 and 2800g in India.[6] Significant differences in socioeconomic and health determinant exposures among these population groups were likely. Singapore is a microcosm of Asia with a Chinese majority and large minorities of Indians and Malays. Although there remain socioeconomic[13] and health[14] disparities between Singaporeans of these three racial groups, these differences are much less pronounced than between people in territorial China, India and Singapore's neighbours in the Malay Archipelago. Singaporean birth cohort thus provides two unique opportunities. First, a controlled opportunity to quantify differences in birth anthropometry between East, South-East and South Asians exposed to relatively homogeneous socioeconomic and health determinants. Second, high per capita income and excellent health outcomes in Singapore[15] allow us to compare norms of birth anthropometry between Asians and Europeans.

To this end, we investigated the epidemiology of birth anthropometry with the aim of developing GA and gender-specific growth charts that are more representative of Chinese, Malays and Indians living in a high-income country and compare these with the widely used Fenton charts.

METHODS

Population

All infants (n=52 220) born in 1991–1997 and 2010–2017 at National University Hospital, Singapore, were included. This hospital is a public healthcare institution with an unrestricted admission policy regardless of paying status.

Data for the 1991–1997 cohort were extracted from a database originally intended to investigate birth defects,[16] whereas data from the 2010–2017 cohort were extracted from electronic neonatal clinical records which captured data from birth through discharge. Variables affecting fetal growth that were available for both cohorts were GA, gender, maternal race, number of births, birth order and diabetes. Race was categorised according to maternal race as listed in an individual's Singapore national identity card. Neonates born to mixed parentage were categorised as per their mother's race. Data on maternal age, height, hypertension, anaemia, education, duration of marriage, household income, smoking, alcohol and coffee intake, as well as neonatal congenital anomalies, were available only for the 1991–1997 cohort.

Data collection

All birth anthropometry measurements were recorded by trained staff within the first 24 hours of birth. BW was measured using calibrated digital weighing scales accurate to the nearest gram. Head circumference (HC) was measured by non-stretchable measuring tape. Crown-heel length was measured from the top of the head to the soles of the feet using a stadiometer to the nearest centimetre. Gestational age (GA) was determined by early ultrasound dating or by last menstrual period.

Trained interviewers collected selected data such as household income, maternal education, existing maternal diabetes mellitus, smoking, alcohol consumption and coffee intake using structured questionnaires for the 1991–1997 cohort. These interviews were conducted after delivery and before maternal discharge. Maternal height, blood pressure and haemoglobin value were collected from clinical record at delivery. Diabetes included both gestational diabetes and pre-existing diabetes mellitus. Hypertension was defined as blood pressure >140/90 mm Hg. Anaemia was defined as haemoglobin level < 110 g/L. Household income was in Singapore dollar (S$) which was mostly in the range S$1=USD0.60–0.80 for these two periods. We defined categories of GA as follows: extremely preterm: $27^{6}/_{7}$ weeks or below; very preterm: $28^{0}/_{7}$ to $31^{6}/_{7}$ weeks; moderately preterm: $32^{0}/_{7}$ to $33^{6}/_{7}$ weeks; late preterm: $34^{0}/_{7}$ to $36^{6}/_{7}$ weeks; early term: $37^{0}/_{7}$ weeks to $38^{6}/_{7}$ weeks; full term: $39^{0}/_{7}$ weeks to $40^{6}/_{7}$ weeks; late term: $41^{0}/_{7}$ weeks to $41^{6}/_{7}$ weeks; post term: $42^{0}/_{7}$ weeks and above.

Statistical analysis

All statistical analyses were carried out by a trained statistician (YM). To address possible erroneous data entry, measurement or recording of BW, HC and length, the measurements were excluded if their values were impossible (eg, negative) or if their Z-scores were less than −5 or more than +5 (ie, outliers). In regression analysis, we also excluded covariates outside chosen boundaries: GA (<23 or >42 weeks), maternal age (<10 years), maternal height (<138 or >200 cm), systolic blood pressure (<70 or >250 mm Hg), diastolic blood pressure (<40 or >180 mm Hg), haemoglobin level (0 or >400 g/L). Births from both cohorts with any missing size measurements were excluded from all analyses and are shown in figure 1.

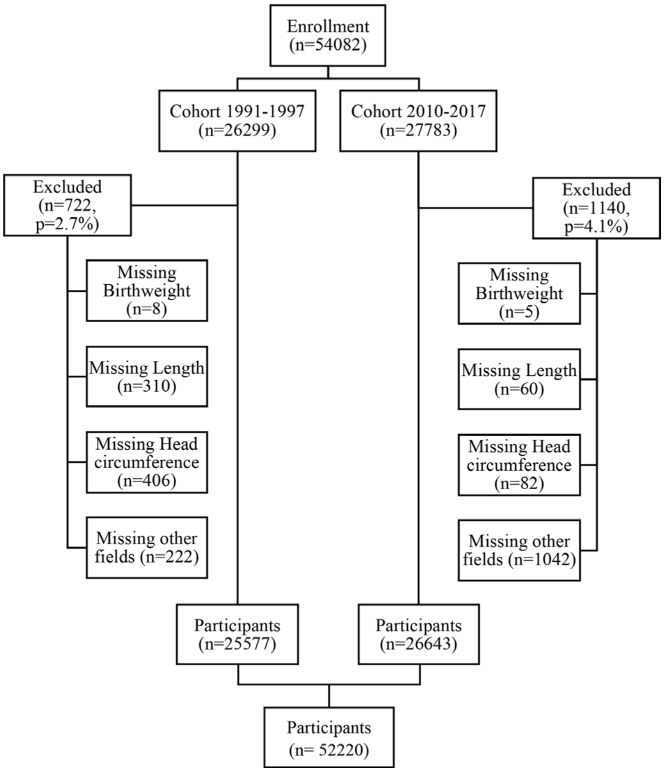

Figure 1 Data exclusion flowchart. Other fields under the excluded subset are maternal race, birth order, number of babies, being diabetic. Note that the categories of missingness are non-exclusive, that is, some births have multiple missing fields, and thus, the numbers excluded for specific reasons sum to more than the number of unique births excluded.

To create plots in the style of the Fenton growth charts,[12] we created growth charts using generalised additive models for location, scale and shape[17] using gamlss package in R.[18] We used natural cubic splines to regress the mean and SD of an assumed Gaussian distributional family on GA, fit using the Rigby and Stasinopoulos algorithm. From these, we derived quantiles (3rd, 50th and 97th percentiles) for each GA, whence we plotted smoothed estimates of the centile curves. We repeated this process for different demographic strata (sex and race and both). Reference centile curves for each week of GA were derived from the cpeg-gcep website implementation of the Fenton chart and compared against ours.[19]

We also regressed anthropometrics (BW, HC, length) against covariates (sex, maternal race, number of births, birth order, diabetes, hypertension, anaemia, household income, maternal education, smoking, alcohol, daily coffee consumption, coffee consumption during pregnancy, maternal age and height) in a series of regressions each with one covariate and one anthropometric.

RESULTS

Table 1 presents baseline characteristics. Participants in the combined cohort (1991–1997 and 2010–2017) included 25 017

Table 1 Basic characteristics of the study population (1991–1997 cohort n=21 897, combined cohort n=52 220)

	1991–1997 cohort (n=21 897)		Combined cohort (n=52 220)	
	Count	Per cent	Count	Per cent
Sex of child				
Female	10 319	47%	25 017	48%
Male	11 578	53%	27 203	52%
Maternal race				
Chinese	10 485	48%	22 248	43%
Indian	2811	13%	8543	16%
Malay	7621	35%	16 006	31%
Others	980	4%	5423	10%
Gestational term				
Extremely preterm	31	0%	122	0%
Very preterm	166	1%	428	1%
Moderately preterm	214	1%	475	1%
Late preterm	1368	6%	3506	7%
Early term	6523	30%	18 593	36%
Full term	10 931	50%	25 040	48%
Late term	2128	10%	3393	6%
Post-term	536	2%	663	1%
Maternal age in years (mean=30; SD=5)				
<26	4216	19%		
26~30	8486	39%		
31~35	6729	31%		
>35	2466	11%		
Maternal height in cm (mean=156; SD=6)				
<151	3555	16%		
151~155	6606	30%		
156~160	7395	34%		
>160	4341	20%		
Household income				
<$1500	6092	28%		
$1500~$3000	7170	33%		
>$3000	8635	39%		

female (48%) and 27 203 male (52%) births, which is in accordance with the sex ratio at birth in Singapore.[20] The racial breakdown consisted of 22 248 Chinese (43%), 16 006 Malay (31%), 8543 Indian (16%) and 5423 of other races (10%).

Figure 1 shows the study flow diagram. After data exclusion, there were 1306 multiple births (2.5%; 1306/52 220); 480 (1.9%) from 1991 to 1997 cohort and 826 (3.1%) from later cohort. Multiple births were included in study. No data were collected on stillbirths.

Mean BW was 3103 g (95% CI 3096 to 3109), 3075 g (95% CI 3067, 3083) and 3052 g (95% CI 3041 to 3062) for Chinese, Malays and Indians, respectively. Maternal education and household income were associated with birth anthropometry in a gradient-dependent manner. Babies born to mothers with university education were likely to be heavier by 109 g (95% CI 89 to 130) as compared with mothers with primary education. Similarly, there was a 91 g (95% CI 74 to 108) increase in mean BW between children whose household's income was more than $3000 as compared with ones below $1500. In regression analysis, maternal race, birth order, household's income, maternal education, age, height, diabetes, hypertension, anaemia, smoking and alcohol were associated with BW, HC and length (figure 2).

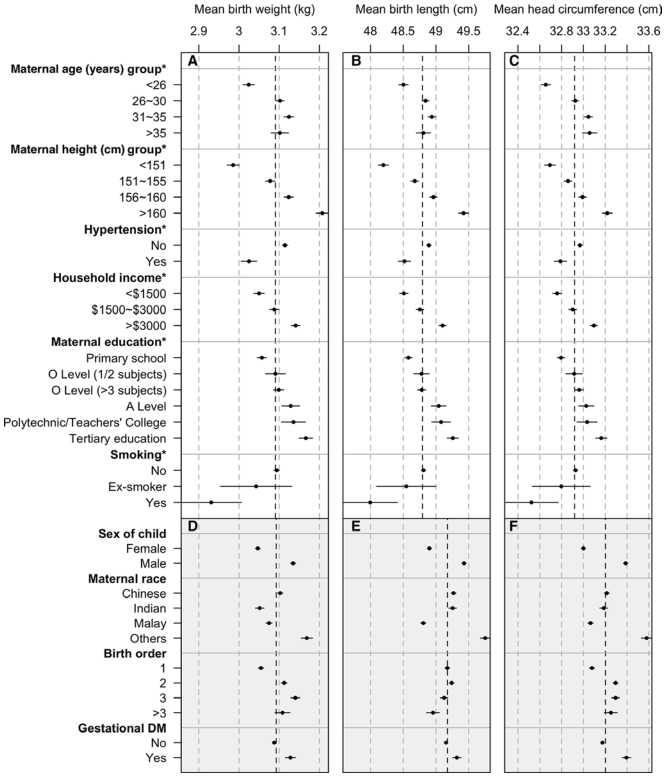

Figure 2 Association between birth weight (A), length (B) and head circumference (C) and determinants in Singapore. Lines are 95% CI. (Cohort 1991-1997 n=21 897 for subplots A, B and C; combined cohort n=52 220 for shaded subplots D, E and F.) These are unadjusted relationships.

Boys were heavier than girls (by 107 g, 95% CI 100 to 113). Multiple births had lower BW than singletons (by −320 g, 95% CI −343 to −298). Increasing birth order was associated with higher BW. Mothers with diabetes had heavier babies (by 97 g, 95% CI 86 to 107). Mothers who smoked during pregnancy had infants with lower BW than those who never smoked (by −116 g; 95% CI −180 to −51). There was no significant difference in BW between ex-smokers or non-smokers. Alcohol and coffee intake did not affect BW. BW increased by 135 g (95% CI 125 to 145) for every additional 10 cm in maternal height. Similar to BW, length and HC had significant association with race, sex, number of births, birth order, diabetes, household income, maternal education, height and smoking.

Babies in the 2010–2017 cohort were heavier by 12 g (95% CI 5 to 19) compared with the 1991–1997 cohort. Malay and Indian babies were slightly lighter than Chinese (by −28 g, 95% CI −38 to −17 for Malay, by −51 g, 95% CI −64 to −38 for Indian). These differences are clinically insignificant. An overlay of the birth anthropometry for the three races was created (online supplemental figures 1 and 2). The growth curve quantiles were near identical (10th, 50th and 90th) among them. Hence, we opted to create unified growth charts (online supplemental figures 3 and 4) for the three races using the combined cohort because Chinese, Malays and Indians babies had similar anthropometries and there was no meaningful difference in BW between 1991–1997 and 2010–2017 cohorts. A single growth chart, as currently practised, is more pragmatic for clinical practice.

The gender-specific combined growth chart from our cohort mirrored Fenton growth chart for premature gestation

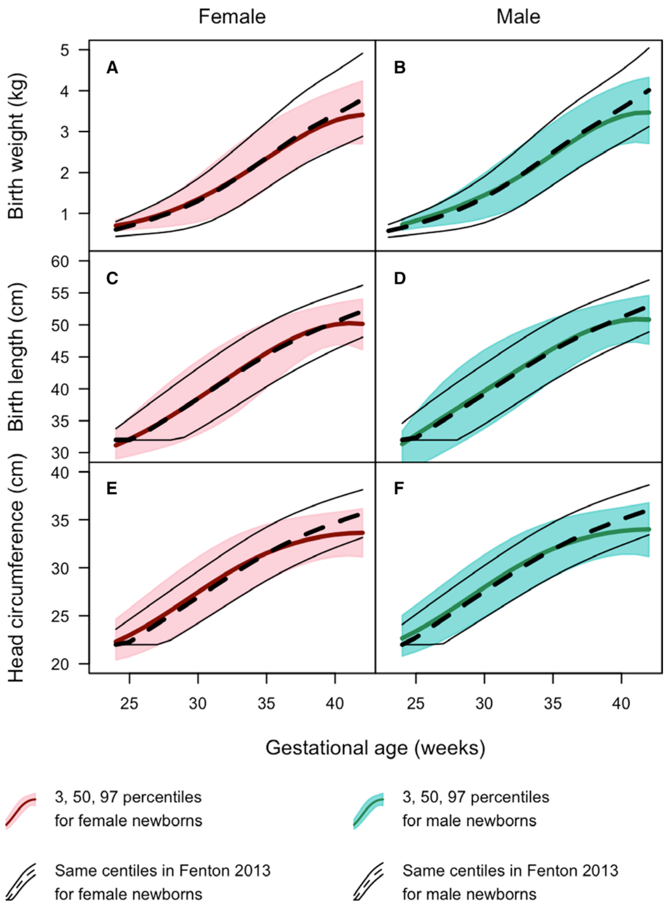

Figure 3 Smoothened centile charts of birth weight, birth length and head circumference for boys and girls by gestational age in weeks in comparison to international standard. Pink and green shades for girls and boys, respectively, show the 3rd, 50th and 97th percentiles, compared with baseline curves from Fenton 2013.

(figure 3). However, from 37 weeks of gestation, there was a marked slowing of growth trajectory for all three anthropometric measurements among both genders in our Singapore cohort as compared with Fenton's. This effect was more pronounced for HC where the 50th centile for a Singaporean boy approached the 3rd centile in Fenton's chart at 40 weeks of GA.

DISCUSSION

Main findings

We constructed a unified growth chart for three major racial groups in Asia living in Singapore. We found that BW between Chinese, Malays and Indians living in Singapore are similar. Consistent with previous research,[10 21–23] we found BW to be significantly associated with maternal height, household income, maternal education, smoking during pregnancy, diabetes and parity.

We noted that there is a striking similarity in the distributions of birth anthropometry among ours and Fenton's up to 37 weeks. However, after 37 weeks, these trajectories diverge markedly, with statistically significant differences between all three reference quantiles (3rd, median, 97th). The Fenton charts involve some smoothening around term, which may contribute minimally to some of the differences observed.[12 24]

Interpretations

Racial differences in BW exist, probably due to interplay between genetics, socioeconomic and environmental factors.[25 26] In the Asian context, a WHO study[6] showed differences in BW among Chinese, Indian and Indonesian populations residing in their country of origin. In our cohort, BW between Singapore's three main races were similar. We postulate that the large reported differences in birth anthropometry between these three Asian races living in their country of origin[6] were largely due to differences in socioeconomic status (SES) and perinatal care rather than genetic factors.

Despite Singapore's excellent maternal and child health indicators, BW at term in our population was substantially lower than international standards (eg, female baby at 40 weeks at 50th percentile: Fenton 3415 g, Singapore 3220 g). This could be partly explained by shorter maternal height in the Singapore population (median=158 cm for Singapore girls at age 18).[27] Specifically the mothers in our 1991–1997 cohort were shorter than the WHO growth reference for age 18, with a mean height of 156 cm, corresponding to the 15th percentile of the WHO reference distribution; an SD of 6 cm; and quartiles of 152–160 cm. A lower maternal height is not unique to Singapore. For example, a recent nationally representative study cohort from Japan, a high-income country with comparable SES to Singapore, reported the mean height of Japanese women at age 17.5 years was 157.8 cm, which is similar to our cohort, and infants born in this cohort were also smaller compared with Fenton (male term 3.0 kg, female term 2.95 kg).[28]

We noted that until 37 weeks GA, Asian babies grew in a remarkably similar fashion as those reported in the seminal Fenton charts, but there was a marked divergence after this. Previous studies have found average gestational length to be shorter by 1 week in Asian than in Western pregnancies,[29] and that shorter maternal height was associated with shorter gestation and earlier senescence of the feto-placental unit.[21 30 31] If the hypothesis is indeed true that the length of gestational period is race-specific, we may need to change the definition of 'term gestation' using race-specific cut-off points. Further research on this point is called for.

Separately, our new birth anthropometry charts will impact clinical practice by being able to more accurately define normality in birth anthropometry. For example, bedside glucose screening rates for at-risk infants will likely change as there would be fewer babies being labelled as SGA.[32] Postnatal growth failure (PNGF), defined as a body weight below the 10th percentile or a temporal weight loss of more than 1–2 SD after birth, is seen commonly in preterm infants, which, in turn, is associated with their future neurodevelopment.[33 34] The use of appropriate growth charts is thus useful for timely identification of PNGF and applying early nutritional intervention.[35 36]

Strengths and limitations

The strength includes availability of a detailed database which allowed the examination of population data of three major Asian races. A comparatively uniform exposure to socioeconomic, cultural and healthcare influences of developed world standards allowed a level playing field for inter-racial comparisons. This model unmasked influences of genetic potential on fetal growth without being heavily confounded by external factors. We could study a wide range of prenatal and perinatal determinants of fetal growth, variables which are sometimes not accurately captured in big population-based studies.

The differences in birth anthropometrics among our racial groups, although small, reached statistical significance by virtue of the cohort size. These differences, however, were clinically not relevant (online supplemental figures 1 and 2). This allowed us to justify creation of a unified birth anthropometry chart for the entire cohort (online supplemental figures 3 and 4).

Although biological factors may not have changed much in the two decades that separate our 1991–1997 and 2010–2017 cohorts, SES, healthcare practices and maternal behaviour may have done so. Some studies have demonstrated improving SES, increased maternal body mass index, gestational weight gain, increased maternal height, less maternal smoking during pregnancy and higher maternal education to be responsible for a progressive increase in BW.[37 38] Contrary to this, several developed countries have reported a progressive decline in BW during the 21st century.[39 40] This is could be attributable to changes in obstetric practices, maternal comorbidities and maternal demographics resulting in earlier births and smaller babies. Babies in the 2010–2017 cohort were heavier by only 12g (95%CI 5 to 19) compared with the 1991–1997 cohort. This supports our decision to combine the cohorts and compare it with Fenton chart (of 1991–2007 and revised in 2013).[12]

We would like to highlight several limitations in our study. We did not study other SES-related factors such as maternal nutrition, psychosocial health, workload and perinatal care that might influence birth anthropometry. We also combined data from two different cohorts separated by two decades at inception. This study took place in one hospital in Singapore and generalisability to a larger population needs further validation.

CONCLUSION

This study of birth anthropometry and its contributing factors among three Asian racial groups in Singapore showed that maternal race among our population did not have a strong influence on birth anthropometry. We also detected slowing of intrauterine growth after 37 weeks on comparison with international standards (Fenton), and as such, the latter growth charts may not be appropriate for Singaporeans and perhaps Asians in general. Our data from a defined geopolitical area with stable racial demography exposed to relatively uniform and high-quality health, nutrition and socioeconomic factors form an important baseline for future studies on developmental origins of health and diseases as well as for studying intergenerational trends.

Contributors JL proposed the original concept and designed the study. JL, SS, CA and ZA acquired the data. YM and AC performed the statistical analysis. SS, AC, JL, AB, ZA and YM provided input on study design, analysed and interpreted the data. SS, AB, AC and JL drafted the manuscript. All authors approved the final version of the submitted manuscript. Author acting as guarantor: JL.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The National Healthcare Group Domain Specific Review Board (DSRB) approved the study (DSRB Reference: 2018/00389).The Review Board waived informed consent

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Dataset and programming code will be available on reasonable request.

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