

## Obesity/Pregnancy Outcomes

# Effects of maternal anthropometrics on pregnancy outcomes in South Asian women: a systematic review\*

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### Summary

**Aim:** This systematic review investigates associations between maternal pre-pregnancy/early-pregnancy anthropometrics (e.g. weight and body fat), anthropometric change and pregnancy outcomes in South Asian and White women.

**Methods:** Twelve electronic literature databases, reference lists and citations of all included studies were searched. Observational studies published in the English language were included. Descriptive synthesis was used to summarize the evidence base.

**Results:** Twenty-two studies met the inclusion criteria (403,609 births [351,856 White and 51,753 South Asian]). Nine were prospective cohort studies, nine were retrospective cohort studies and two were cross-sectional studies. Results suggested that in South Asian women, maternal pre-pregnancy/early-pregnancy anthropometrics were associated with anthropometric change, birthweight, mode of delivery and gestational diabetes mellitus (GDM). Gestational anthropometric change was found to be associated with GDM. There was limited evidence to suggest that there may be associations between maternal pre-anthropometrics/early anthropometrics and hypertensive disorders, stillbirth, congenital anomalies, post-natal weight retention and post-natal impaired glucose tolerance. The evidence suggested a combined effect of pre-pregnancy/early-pregnancy anthropometrics and gestational anthropometric change on both GDM and post-natal weight retention.

**Conclusion:** The increased risk of adverse pregnancy outcomes in South Asian women should be considered in guidelines for weight management before and during pregnancy.

**Keywords:** Ethnicity, gestational weight gain, maternal obesity, systematic review.

**Abbreviations:** AOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; GDM, gestational diabetes mellitus; GWG, gestational weight gain; IGT, impaired glucose tolerance; IoM, Institute of Medicine; NICE, National Institute for Health and Care Excellence; NICU, neonatal intensive care unit; OR, odds ratio; PAF, population attributable fraction; PPH, post-partum haemorrhage; SD, standard deviation; SFT, skin-fold thickness; WHO, World Health Organization.

### Introduction

Asian populations are at increased risk of obesity-related comorbidities, e.g. diabetes and hypertension, at a lower body mass index (BMI) than are White populations (1).

This is due, in part, to differences in body composition as BMI in some Asian populations reflects a higher body fat percentage than that in White populations does (2). The World Health Organization (WHO) BMI criteria reflect this difference in risk. For the general population, BMI criteria

are underweight ( $<18.5 \text{ kg m}^{-2}$ ), recommended weight ( $\geq 18.5$  to  $<25 \text{ kg m}^{-2}$ ), overweight ( $\geq 25$  to  $<30 \text{ kg m}^{-2}$ ) and obese ( $\geq 30 \text{ kg m}^{-2}$ ) (3). The obese group can then be further subdivided into class I ( $\geq 30$  to  $<35 \text{ kg m}^{-2}$ ), class II ( $\geq 35$  to  $<40 \text{ kg m}^{-2}$ ) and class III ( $\geq 40 \text{ kg m}^{-2}$ ) (3). However, the BMI criteria to indicate risk among Asian populations are reduced for recommended weight ( $\geq 18.5$  to  $<23 \text{ kg m}^{-2}$ ), overweight ( $\geq 23$  to  $<27.5 \text{ kg m}^{-2}$ ) and obese ( $\geq 27.5 \text{ kg m}^{-2}$ ) (3). The obese group can be further subdivided into class I ( $\geq 27.5$  to  $32.5 \text{ kg m}^{-2}$ ), class II ( $\geq 32.5$  to  $<37.5 \text{ kg m}^{-2}$ ) and class III ( $\geq 37.5 \text{ kg m}^{-2}$ ) (2). It is possible that the pattern of higher obesity-related risk may extend to pregnancy, resulting in increased risk of adverse pregnancy outcomes among Asian populations at a lower pre-pregnancy/early-pregnancy BMI and/or lower gestational weight gain (GWG).

Maternal obesity and both inadequate and excess GWG have been associated with adverse health outcomes for mother and infant (4). International research has highlighted that maternal obesity increases risks for both mother and child including gestational diabetes mellitus (GDM), pre-eclampsia, gestational hypertension, depression, instrumental and caesarean birth, pre-term and post-term birth, large-for-gestational-age babies, congenital anomalies and perinatal death (5–9). Maternal obesity has also been associated with longer-term outcomes for the infant, such as subsequent obesity development and the associated life course morbidities (10). Excess GWG has also been associated with increased birthweight and foetal growth, caesarean delivery, childhood overweight and post-natal weight retention (11–13), while inadequate GWG has been associated with decreased birthweight and foetal growth (11). The Institute of Medicine (IoM) in the USA have developed guidelines for GWG according to pre-pregnancy/early-pregnancy BMI category using the WHO general population BMI criteria (2). Recommended GWG ranges are 12.5–18 kg for women with an underweight BMI, 11.5–16 kg for recommended BMI, 7.5–11.5 kg for overweight and 5–9 kg for obese (14). The IoM guidelines are based on evidence of the weight gain-related risk of caesarean delivery, birthweight, preterm birth, childhood obesity and post-natal weight retention (14). This evidence is drawn from a variety of ethnic groups including White, African-American, East Asian (including Chinese, Filipino and Japanese) and Hispanic populations.

Internationally, some countries such as Canada and Finland and regions of Australia have adopted the IoM guidelines (15). However, there are currently no UK guidelines for GWG. The National Institute for Health and Care Excellence (NICE) has not incorporated the IoM recommendations into national guidelines for weight management during pregnancy owing to a lack of UK population evidence, particularly relating to ethnic diversity (16). NICE recommended that research was needed to

investigate weight gain in pregnancy and health outcomes among UK ethnic minority groups (16). In the UK, the largest ethnic group is White (86.0% of the population) followed by Asian (7.5% of the population) (17,18). The majority of the UK Asian population are South Asian, Indian (2.5%), Pakistani (2.0%) and Bangladeshi (0.8%) (17,18). NICE defines the UK South Asian population as ‘immigrants and descendants from Bangladesh, Bhutan, India, Indian-Caribbean (immigrants of South Asian family origin), Maldives, Nepal, Pakistan and Sri Lanka’ (19). The populations used to develop the IoM guidelines do not include South Asian populations, and, therefore, the IoM guidelines may not be appropriate for ethnic minority groups in the UK. Additionally, current UK guidelines for both weight management (16) and the clinical management of obesity-related risks in pregnancy (20) use the WHO general population BMI criteria rather than incorporating the BMI criteria specific to Asian populations. National data from England show that the incidence of maternal obesity in South Asian populations doubles when using ethnic group-specific BMI criteria rather than general population BMI criteria (21). Therefore, a large proportion of South Asian women are potentially being incorrectly assigned to low-risk care using current UK guidelines, which may widen the gap in health inequalities in access to health care (21).

Variations in obesity-related risk by ethnicity lead to health inequalities (22); addressing these inequalities requires an accurate account of epidemiology (23). There are existing reviews that consider associations between maternal BMI and pregnancy outcomes (6,24) as well as GWG and pregnancy outcomes (11,14). However, there is a lack of systematically reviewed evidence that relates to South Asian women or considers additional measures of body composition (anthropometrics) such as skin-fold thickness (SFT) and body fat percentage. These measures are especially important for Asian populations given the association between risk and body fat percentage and distribution. This systematic review aimed to synthesize the existing evidence base of associations between maternal pre-pregnancy/early-pregnancy anthropometrics (e.g. BMI and SFT). From this point forward exposures of pre-pregnancy/early-pregnancy BMI, SFT etc will be referred to as pre-pregnancy) and/or gestational change in anthropometrics (e.g. GWG and gestational change in SFT) on pregnancy outcomes among South Asian women and their offspring compared with White women.

## Methods

Electronic databases were searched using keywords. Search terms and subject headings were converted into the relevant format for 12 databases: MEDLINE (Fig. S1), Embase, Scopus, PsycINFO, British Nursing Index, the Cumulative Index to Nursing and Allied Health Literature, Allied and

Complementary Medicine Database, the Joanna Briggs Institute database, PROSPERO, Centre for Reviews and Dissemination database, Cochrane Database of Systematic Reviews and the federated search engine Epistemonikos, which provides access to systematic reviews, and primary studies included in these reviews (all searches shown in Fig. S1).

The search strategy for this review was designed to maximize the identification of relevant epidemiological studies. Additional searches included hand searching the reference lists of relevant studies or related reviews identified by the database searches to identify any relevant studies that had been cited. Each study that met the inclusion criteria was subjected to citation searches using all citations produced by Google Scholar to identify any published studies that had cited the included studies. Authors of any relevant published abstracts were contacted to identify any subsequent full publications of the research. Any studies identified by the supplementary searches were also subject to reference list and citation searches until no further eligible studies were identified. Authors of the final included studies were contacted for additional data to include in the analyses when required.

The comprehensive search strategy was carried out between December 2015 and July 2017. Inclusion criteria were peer-reviewed full studies, published in the English language at any date. Studies involving observational quantitative research methods including cross-sectional, case control and cohort study designs were included. Studies had to include data for both South Asian women and White women, and either

1. maternal pre-pregnancy or early-pregnancy anthropometric measures such as BMI or SFT, and pregnancy outcomes for mother or infant;
2. a measure of gestational anthropometric change (i.e. change from pre-pregnancy measures at specific time points in the pregnancy) such as GWG or gestational change in SFT, and pregnancy outcomes for mother or infant.

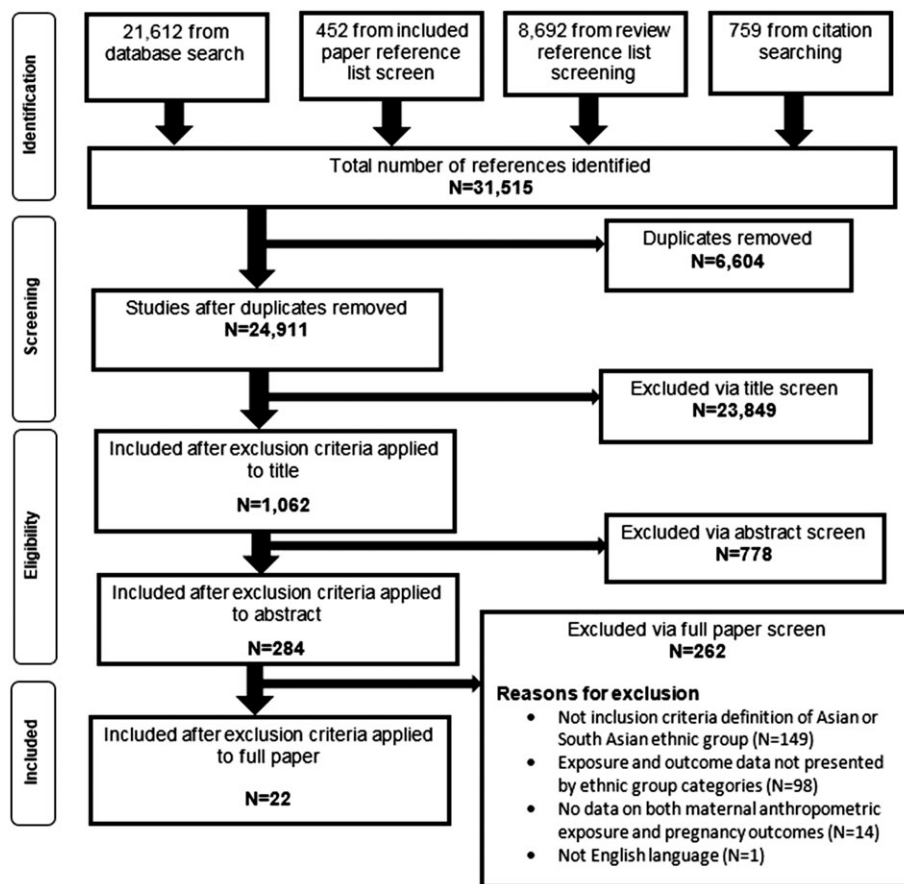
South Asian women were defined as per 2013 NICE guidelines to represent UK South Asian populations (19). Studies were also included if they were carried out in the UK and referred to an Asian population, because in the UK the term Asian is used to refer to people with ancestry in the Indian subcontinent, whereas in other countries, the meaning is much broader, particularly in the USA where the term is mainly used to describe East Asian populations (25). White populations were defined as White, White European, Caucasian or White British women. In studies that reported UK data and more than one White or European ethnic group, the data for White British or UK participants were included in this systematic review.

Two authors (E. S. and D. J.) independently screened titles, abstracts and full papers of potentially relevant studies for inclusion in the review. All four authors then carried out data extraction and quality assessments for all included studies (E. S., D. J., J. R. and N. H.). A standardized protocol was used for data extraction (Fig. S2). Quality assessment utilized an adapted version of the Newcastle–Ottawa scale for cohort studies (26). Full details of the exact questions used and reasons for amendments to the scale are given in Fig. S3. The Newcastle–Ottawa quality assessment scale is a tool for assessing the quality of non-randomized studies (where a score of 0 is lowest quality and a score of 8 is the highest possible quality) (26). It has previously been used for a systematic review considering the association between maternal BMI and pregnancy outcomes (7). Independent data extractions and quality assessments were combined and agreed upon. References were managed and recorded in ENDNOTE version 7 (1988–2016 Thompson Reuters, New York, USA).

Appropriateness of pooling the results of the individual studies identified for inclusion in the systematic review was assessed. Owing to the heterogeneity of pregnancy outcomes, anthropometric measures and comparisons made (i.e. South Asian women compared with White women of same BMI, and women of the same BMI compared within ethnic groups) in the primary studies, pooling of the data was not appropriate, and meta-analysis was not possible. A descriptive synthesis has been used to provide a narrative summary of pregnancy outcomes by weight-related exposure groups: group 1, maternal pre-pregnancy anthropometrics; group 2, gestational change in anthropometrics during pregnancy; and group 3, a combination of maternal pre-pregnancy anthropometrics and gestational change in anthropometrics. The systematic review was registered on the PROSPERO database (reference 42015024801).

## Results

A total of 31,515 studies were identified by the searches, of which 22 met the inclusion criteria (Fig. 1) and included a total of (403,609 births [351,856 White and 51,753 South Asian]). Thirteen studies were from the UK (27–39), three from Australia (40,41), two from Norway (42,43) and Canada (44,45), and one from USA (46) and Spain (47) (Table 1). Some studies used more than one exposure: 21 studies used maternal anthropometric measurements as the exposure (27–41,43–48) (group 1), three used gestational change in maternal anthropometrics as the exposure (31,42,47) (group 2) and two used a combination of pre-pregnancy anthropometrics and gestational change in anthropometrics (42, 43) (group 3). Of the studies that used maternal BMI as a categorical exposure ( $n = 7$ ), only three studies applied BMI criteria for South Asian populations (29,46,48). The quality scores of the studies ranged from 2



**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of searches, screening, and inclusion and exclusion of studies.

to 7 (out of a maximum of 8), with a mean score of 5 (Table 1). Detailed quality assessment results are presented in Table S4. In addition, there was one study carried out in Australia that defined South Asian women as per the NICE guidelines but also included women from Afghanistan and Iran. As the majority of the South Asian population met the NICE definition, and owing to the ambiguity of definitions used by other studies (e.g. 'from the Indian subcontinent' or 'any other Asian background'), a decision was made to include this study in the review.

Overall, results were inconsistent. Results have been presented narratively and grouped by pregnancy outcome and type of exposure. Included studies reported 17 pregnancy outcomes: three during pregnancy (GDM, hypertensive disorders and gestational change in anthropometrics<sup>1</sup>); 12 perinatal outcomes (mode of delivery, distance from skin to epidural space, post-partum haemorrhage [PPH], shoulder dystocia, foetal compromise, congenital anomaly,

preterm birth, stillbirth, admission to the neonatal intensive care unit [NICU] or special care nursery, perinatal death, birthweight and a composite category for any perinatal morbidity); and two post-natal outcomes (weight retention and impaired glucose tolerance IGT). Six of the outcomes were reported by more than three studies (GDM, anthropometric change during pregnancy, preterm birth, birthweight, mode of delivery and post-partum weight retention), and four of the outcomes were reported by two studies (stillbirth, hypertensive disorders, admission to NICU/special care nursery and PPH). The remaining eight outcomes were reported by one study only (distance from skin to epidural space, post-natal IGT, perinatal death, dystocia, foetal compromise, any perinatal morbidity, congenital anomalies and post-natal weight retention).

## Gestational diabetes

### *Exposure group 1: maternal pre-pregnancy anthropometrics*

Thirteen studies reported data for maternal pre-pregnancy weight, BMI, SFT and serum leptin levels (28,32,34,35,37–40,43,44,46–48). Nine reported an increased association

<sup>1</sup>Gestational change in anthropometrics is an exposure to investigate associations with pregnancy outcomes and also an identified pregnancy outcome associated with pre-pregnancy anthropometrics.

**Table 1** Summary of included studies [Colour table can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

Author, publication year, Region and country, Study design	Ethnic groups (Ethnic group terms and definitions used by included article, and sample size, n)	Data collection time period	Exposure	Outcome	Quality score (out of 8)
Anand <i>et al</i> 2015, Ontario, Canada, Prospective cohort (45)	White Caucasian, n=401 South Asian, n=389 Total n=790	White participants: 8 October 2002 and 8 July 2009, South Asian participants: 11 July 2011 and 20 September 2013	<ul style="list-style-type: none"> <li>Maternal weight (kg) and BMI (kg/m<sup>2</sup>)</li> </ul>	GWG (kg)	5
Bissenden <i>et al</i> , 1981, Birmingham, UK, Prospective cohort (31)	European n=28 Asian; Pakistani or Bangladeshi, n=11 Total n=39	Not specified	<ul style="list-style-type: none"> <li>Incremental changes per week in body measurements in the second trimester</li> <li>Maternal weight</li> <li>Mid upper arm circumference</li> <li>Triceps, biceps and subscapular skinfold thickness</li> </ul>	Well grown babies	2
Bissenden <i>et al</i> 1981 Birmingham, UK, Prospective cohort (30)	European, n=31 Asian; Pakistani or Bangladeshi, n=39 Total n=70	Not specified	<ul style="list-style-type: none"> <li>Maternal weight</li> <li>Triceps, biceps and subscapular skinfold thickness</li> <li>Incremental change from booking to 29 weeks was also calculated</li> </ul>	Anthropometric change; Incremental changes per week in body measurements in the second trimester; Maternal weight; Mid upper arm circumference; Triceps, biceps and subscapular skinfold thickness	2
Bryant <i>et al</i> , 2014, Bradford, UK, Prospective cohort (28)	White British n=4547 Pakistani n=4547 Total n=8478	March 2007 to December 2010	<ul style="list-style-type: none"> <li>Maternal BMI (Defined using WHO classification (BMI ≥30kg/m<sup>2</sup>) and South Asian specific category (BMI ≥27.5kg/m<sup>2</sup>))</li> </ul>	Mode of birth; Hypertensive disorders of pregnancy; GDM Macrosomia; Preterm births	5
Davies-Tuck <i>et al</i> 2016 Australia, Retrospective cohort (48)	White; Australian and New Zealand n=18768 South Asian; Bangladesh, Pakistan, Bhutan, India, Maldives, Nepal, Iran, Afghanistan, Sri Lanka n=8342 Total n=27110	2009 to 2013	<ul style="list-style-type: none"> <li>Maternal BMI (Obesity is BMI more than or equal to 30kg/m<sup>2</sup> (also did analysis on Asian population using BMI cut off of 26kg/m<sup>2</sup>. However, this did not change the results and so only a BMI cut off of 30kg/m<sup>2</sup> is presented))</li> </ul>	Gestational hypertension; GDM; Preterm birth; Shoulder dystocia; Postpartum Haemorrhage (1000ml); Mode of delivery (induced labour, instrumental vaginal, unplanned caesarean section); Birthweight (small for gestational age (<10 <sup>th</sup> centile) and macrosomia (>4kg)); Fetal compromise (pregnancy or labour); Admission to NICU/SCN; Any perinatal morbidity; Stillbirth	7
Dornhorst <i>et al</i> 1992 London, UK, Prospective cohort (35)	White; Northern European and Caucasian n=6109 Indian; from the Indian subcontinent n=1164 Total n=7273	1984 -1988	<ul style="list-style-type: none"> <li>Maternal BMI (kg/m<sup>2</sup>, &lt;27 and more than 27)</li> </ul>	GDM	5
Dunne <i>et al</i> 2000 Birmingham, UK, Retrospective cohort (38)	Caucasian n=312 Indo-Asian women; Pakistan, India, Bangladesh, n=128 Total n=440	1990-1998	<ul style="list-style-type: none"> <li>Maternal BMI (kg/m<sup>2</sup>)</li> </ul>	GDM and impaired glucose tolerance	3

(Continues)

Table 1 (Continued)

Author, publication year, Region and country, Study design	Ethnic groups (Ethnic group terms and definitions used by included article, and sample size, n)	Data collection time period	Exposure	Outcome	Quality score (out of 8)
Hernandez-Rivas et al 2013 Barcelona, Spain, Prospective cohort (47)	Caucasian n=190 South Central Asian; Pakistan, India, Bangladesh n=81 Total n=271	January 2004 to April 2011	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> <li>• Weight gain during pregnancy (kg)</li> </ul>	GDM	4
Nishikawa et al 2017 London, UK, Retrospective cohort (39)	White; British, English, European, White-Other, n=26433 South Asian; Asian, British-Asian, Asian-Other, Indian, Bangladeshi, Pakistani, Sri Lankan, n=2957 Total n=29390	2004-2012	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> </ul>	Presence or absence of diabetes during pregnancy	7
Makgoba et al 2011, London, UK, Retrospective cohort (33)	White woman, n=131201 South Asian women, n=2749 Total n=134150	1988 and 2000	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> </ul>	GDM	5
Makgoba et al 2012 London, UK, Retrospective cohort (34)	White woman, n=107901 South Asian women, n=15817 Total n=123718	1988 and 2000	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> </ul>	GDM; Birthweight	5
Oteng-Nim et al 2013 London, UK, Cross sectional (32)	White; White British, White Irish and Other White, n=12418 Asian; Bangladeshi, Indian, Pakistani, other Asian and Asian British, n=1162 Total n=13580	Jan 1 <sup>st</sup> , 2004 and Dec 31 <sup>st</sup> 2008	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> </ul>	GDM; Mode of delivery; Postpartum haemorrhage; Preterm delivery; Macrosomia; Low birthweight; Admission to NICU/SCN; Perinatal death	7
Penn et al 2014 London, UK, Retrospective cohort (29)	White; British, Irish, White Other, n=26390 Asian; Indian, Pakistani, Bangladeshi, Asian Other, n=2857 Total n=29347	January 2004 and May 2012	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> <li>• Also created a second BMI variable for South Asian women only.</li> </ul>	Stillbirth	6
Pu et al 2015 Northern California, Retrospective cohort (46)	White; Non-Hispanic White, n=9011 Asian Indian, n=5069 Total n=14080	Between 2007 and 2012	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>) (Also WHO categories relevant to South Asian women)</li> </ul>	GDM	7
Retnakaran et al 2006 Canada, Cross sectional (44)	Caucasian n=116 South Asian; India, Pakistan, Sri Lanka and Bangladesh, n=31 Total n=147	Not specified	<ul style="list-style-type: none"> <li>• Maternal BMI (kg/m<sup>2</sup>)</li> <li>• Weight gain in pregnancy (kg)</li> <li>• Adiponectin concentration (measure of hypoadiponectinemia)</li> </ul>	GDM; Impaired glucose tolerance; Normal glucose tolerance	3

(Continues)

Table 1 (Continued)

Author, publication year, Region and country, Study design	Ethnic groups (Ethnic group terms and definitions used by included article, and sample size, n)	Data collection time period	Exposure	Outcome	Quality score (out of 8)
Sharma <i>et al</i> 2011 Oxford, UK, Prospective cohort (36)	White; British, Irish and any other White Background, n=709 Asian or Asian British; Indian, Pakistani, Bangladeshi or any other Asian background, n=249 Total n=958	February 2009 to December 2009	• Maternal BMI (kg/m <sup>2</sup> )	Distance from Skin to lumbar epidural space	4
Sheridan <i>et al</i> 2013 Bradford, UK, Prospective cohort (27)	White British n=4488 Pakistani n=5127 Total n=9615	2007 and 2011	• Maternal BMI (kg/m <sup>2</sup> )	Congenital anomalies	5
Sinha <i>et al</i> 2002 Birmingham, UK, Retrospective cohort (37)	Caucasian n=91 Indo Asian; Predominantly Muslim women from the Punjab Region, n=89 Total n=180	Not specified	• Booking weight (kg) (Booking defined as 16 weeks gestation)	GDM; Postpartum impaired glucose tolerance	4
Sommer <i>et al</i> 2015 Goruddalen, Oslo, Norway, Prospective cohort (43)	European; Europeans of whom 82% were Norwegian (Three women born in North America were categorised as Europeans) n=353 South Asian; 63% Pakistani and 31% Sri Lankan n=190 Total n=543	May 2008 to May 2010	• Maternal BMI (kg/m <sup>2</sup> ) • Subcutaneous fat (mm, at 14 and 28 weeks gestation, and 14 weeks after delivery) • Serum Leptin level (ug/l at 14 and 28 weeks gestation, and 14 weeks after delivery)	GDM; Anthropometric change during pregnancy; PPWR	5
Sommer <i>et al</i> 2014 Goruddalen, Oslo, Norway, Prospective cohort (42)	European n=348 South Asian n=181 Total n=529	May 2008 and May 2010	• Maternal BMI (kg/m <sup>2</sup> ) • Body weight (kg) and truncal fat • Subcutaneous fat • Weight gain, and gain of total fat, truncal fat and mean skinfold gain	GDM	6
Wong <i>et al</i> 2011 New South Wales, Australia, Retrospective cohort (40)	Anglo-European n=215 South Asian; Indian, Pakistani, Sri Lankan and Fiji Indian n=160 Total n=375	July 2007 to July 2010	• Maternal BMI (kg/m <sup>2</sup> )	GDM	4
Yue <i>et al</i> 1996 Sydney, Australia, Retrospective cohort (41)	Anglo-Celtic n=2412 Indian n=114 Total n=2526	Not specified	• Maternal BMI (kg/m <sup>2</sup> )	GDM	4

Abbreviations: WHO=World Health Organization, BMI=Body mass index, GDM=Gestational diabetes mellitus, PPWR=Postpartum weight retention, NICU=Neonatal intensive care unit, SCN=Special care nursery

with GDM for South Asian women compared with White women (28,32,34,37–40,43,47). Three found a decreased association (35,44,46). One found an increased association for South Asian women in unadjusted results (48). However, following adjustment, this association decreased to less than that for White women (48).

Six studies found that mean weight (37) or mean BMI (34,38,40,43,47) was lower in South Asian women with GDM compared with White women with GDM. Two studies reported statistical significance: one found the difference to be significant (34) and the other did not (47). One study reported that although South Asian women with GDM had a lower mean BMI than did White women with GDM, they had higher mean values of SFT and serum leptin levels (43) (Table 2).

Six studies presented odds ratios (ORs) or relative risks for the association between maternal pre-pregnancy anthropometrics and GDM; three found an increased association between GDM and maternal BMI in South Asian women compared with White women (28,32,34), and two found a decreased association for South Asian women (35,46). Two studies only presented unadjusted results; both of these studies found that ORs of GDM were higher in South Asian women than in White women (28,34). Two studies presented unadjusted and adjusted results. One found that ORs of GDM were lower for South Asian women than were those for White women (35). The other found that South Asian women had a higher OR of GDM; however, following adjustment, the adjusted OR (AOR) decreased to less than that of White women (48). Two studies only presented

adjusted results: one found the AOR was higher in South Asian women (32), and the other found that South Asian women had a lower AOR of GDM than did White women at the same BMI (46) (Table 3).

One study found that South Asian women had lower insulin sensitivity relating to increasing BMI compared with White women (slope of  $-0.17$  [95% confidence interval {CI}  $-0.22$  to  $-0.13$ ] in White, slope of  $-0.04$  [95% CI  $-0.15$  to  $0.08$ ] in South Asians) (44). One study presented the performance parameters (sensitivity, specificity, positive predictive value and negative predictive value) of different BMI cut-offs (20, 21.5, 23, 25, 27.5 and 30  $\text{kg m}^{-2}$ ) for White and South Asian women (39). These parameters gave an indication of the proportion of the population with GDM in each ethnic group that was captured using each cut-off. A BMI of 20  $\text{kg m}^{-2}$  captured 95.2% of White women compared with 95.0% of South Asian women with GDM (39). All other BMI cut-offs investigated captured a higher percentage of South Asian women with GDM than White women (39). This ranged from 93.6% in South Asian women compared with 87.5% in White women at BMI 21.5  $\text{kg m}^{-2}$ , and 34.7% in South Asian women compared with 32.1% in White women at BMI 30  $\text{kg m}^{-2}$  (39). The prevalence of diabetes in pregnancy was also estimated for each BMI cut-off; results showed an increased risk of diabetes at all BMI points for South Asian women compared with White women (39). In addition, this study found that for South Asian women, the BMI with risk of GDM equivalent to 30  $\text{kg m}^{-2}$  in White women was approximately 21  $\text{kg m}^{-2}$  (39).

**Table 2** Pre-pregnancy anthropometric measurements of women in population of women with GDM

Author and study year	Ethnic group	Exposure	Exposure mean (standard deviation)		<i>p</i> value
			White ethnic group	South Asian ethnic group	
Dunne <i>et al.</i> , 2000 (38)	Caucasian women ( <i>n</i> = 312) Indo-Asian women: Pakistani, Indian, Bangladeshi ( <i>n</i> = 128)	BMI ( $\text{kg m}^{-2}$ )	29.2 (8.5)	29.1 (5.7)	—
Hernandez-Rivas <i>et al.</i> , 2013 (47)	Caucasian ( <i>n</i> = 190) South Central Asian: Pakistani, Indian, Bangladeshi ( <i>n</i> = 81)	BMI ( $\text{kg m}^{-2}$ )	27.4 (6.18)	27.0 (4.65)	0.630
Makgoba <i>et al.</i> , 2012 (34)	White European ( <i>n</i> = 707) South Asian ( <i>n</i> = 304)	BMI ( $\text{kg m}^{-2}$ )	26.7 (5.8)	25.3 (4.9)	<0.001
Wong <i>et al.</i> , 2011 (40)	Anglo-European women ( <i>n</i> = 215) South Asian women: Indian, Pakistani, Sri Lankan, Fiji Indian ( <i>n</i> = 160)	BMI ( $\text{kg m}^{-2}$ )	30.6 (8.1)	26.8 (5.2)	—
Sinha <i>et al.</i> , 2003 (37)	Caucasian women ( <i>n</i> = 91) Indo-Asian women: predominantly Muslim women from the Punjab Region ( <i>n</i> = 89)	Weight (kg)	69.8 (4.2)	68.3 (6.45)	—
Sommer <i>et al.</i> , 2015 (43)	European ( <i>n</i> = 353) South Asian: Pakistani and Sri Lankan ( <i>n</i> = 543)	BMI ( $\text{kg m}^{-2}$ ) Sum of SFT (mm) Serum leptin (ng)	27.3 (95% CI 25.9, 28.6) 76.1 (95% CI 71.1, 81.0) 1.73 (95% CI 1.45, 2.04)	25.5 (95% CI 24.3, 26.6) 78.0 (95% CI 73.3, 82.7) 1.94 (95% CI 1.70, 2.20)	— — —

BMI, body mass index; CI, confidence interval; GDM, gestational diabetes; SFT, skin-fold thickness.



**Table 3** Effects of maternal BMI on pregnancy outcomes in South Asian and White women

Pregnancy outcome	Author and study year	Exposure	Control group	OR (95%CI)			AOR (95%CI)	
				White ethnic group <sup>+</sup>	South Asian ethnic group <sup>+</sup>	White ethnic group <sup>+</sup>	South Asian ethnic group <sup>+</sup>	
<b>GDM</b>	Bryant <i>et al</i> 2014 (28)	5kg/m <sup>2</sup> increase in BMI	n/a	1.25 (1.12, 1.40)*	1.55 (1.43, 1.69)*	-	-	
	Davies-Tuck <i>et al</i> 2016 (48)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	3.20 (2.80, 3.65) <sup>***</sup>	3.48 (2.88, 4.21) <sup>***</sup>	3.21 (2.80, 3.67)* <sup>1</sup>	1.89 (1.57, 2.28)* <sup>1</sup>	
	Dornhorst <i>et al</i> 1992 (35)	BMI ≥27 kg/m <sup>2</sup>	BMI <27 kg/m <sup>2</sup>	4.6 (2.1, 10.4)*	3.5 (2.0, 4.2)*	4.3 (1.9, 9.8)* <sup>2</sup>	2.0 (0.9, 4.2) <sup>2</sup>	
	Makgoba <i>et al</i> 2011 (33)	25.0-29.9 kg/m <sup>2</sup>	15.5-24.9kg/m <sup>2</sup>	1.77 (1.50, 2.09)*	2.57 (2.02, 3.23) <sup>***</sup>	-	-	
		≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	4.70 (3.98, 5.55)*	5.80 (4.36, 7.71) <sup>***</sup>	-	-	
	Oteng-Ntlim 2013 (32) <sup>‡</sup>	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	4.97 (3.39, 7.28)* <sup>3</sup>	5.48 (2.43, 12.35)* <sup>3</sup>	
	Pu <i>et al</i> 2015 (46)	≥25kg/m <sup>2</sup>	<25kg/m <sup>2</sup>	-	-	<b>PAF</b> 20.3 (15.46, 24.53)	<b>PAF</b> 17.37 (13.07, 21.09)	
<b>Preterm delivery</b>	Bryant <i>et al</i> 2014 (28)	5kg/m <sup>2</sup> increase in BMI	n/a	0.87 (0.77, 0.98)*	0.98 (0.87, 1.11)	-	-	
	Davies-Tuck <i>et al</i> 2016 (48)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	1.06 (0.95, 1.18) <sup>°</sup>	1.07 (0.80, 1.43) <sup>°</sup>	1.04 (0.93, 1.16) <sup>5</sup>	1.08 (0.81, 1.45) <sup>5</sup>	
	Oteng-Ntlim 2013 (32)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	1.66 (1.30, 2.11)* <sup>3</sup>	1.25 (0.61, 2.56) <sup>3</sup>	
	Bryant <i>et al</i> 2014 (28)	5kg/m <sup>2</sup> increase in BMI	n/a	1.34 (1.26, 1.42)*	1.36 (1.27, 1.45)*	-	-	
	Davies-Tuck <i>et al</i> 2016 (48)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	1.49 (1.37, 1.62) <sup>***</sup>	1.37 (1.16, 1.62) <sup>***</sup>	1.35 (1.23, 1.49)* <sup>6</sup>	1.38 (1.15, 1.66)* <sup>6</sup>	
	Oteng-Ntlim 2013 (32)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	1.41 (1.08, 1.84)* <sup>3</sup>	1.52 (0.73, 3.14) <sup>3</sup>	
<b>Mode of delivery</b>	C-section	5kg/m <sup>2</sup> increase in BMI	n/a	1.34 (1.26, 1.42)*	1.36 (1.27, 1.45)*	-	-	
	Unplanned C-section	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	1.49 (1.37, 1.62) <sup>***</sup>	1.37 (1.16, 1.62) <sup>***</sup>	1.35 (1.23, 1.49)* <sup>6</sup>	1.38 (1.15, 1.66)* <sup>6</sup>	
	Elective LSCS	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	1.41 (1.08, 1.84)* <sup>3</sup>	1.52 (0.73, 3.14) <sup>3</sup>	
	Emergency LSCS	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	<b>PAF</b> 4.24 (2.43, 6.00)	<b>PAF</b> 4.02 (2.31, 5.70)	
	Induced labour	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	1.98 (1.69, 2.33)* <sup>3</sup>	0.65 (0.32, 1.31) <sup>3</sup>	
	Instrumental delivery	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	1.48 (1.37, 1.58) <sup>***</sup>	1.29 (1.10, 1.50) <sup>***</sup>	<b>PAF</b> 3.48 (2.65, 4.30)	<b>PAF</b> 2.93 (2.23, 3.63)	
Instrumental Delivery	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	0.65 (0.59, 0.72) <sup>***</sup>	0.60 (0.48, 0.74) <sup>***</sup>	0.73 (0.65, 0.82) <sup>7</sup>	0.76 (0.57, 1.01) <sup>7</sup>		
	Oteng-Ntlim 2013 (32)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	0.78 (0.63, 0.96)* <sup>3</sup>	1.04 (0.50, 2.16) <sup>3</sup>	
				-	-	<b>PAF</b> -1.84 (-2.71, -0.98)	<b>PAF</b> -1.57 (-2.30, -0.84)	

(Continues)

Table 3 (Continued)

Pregnancy outcome	Author and study year	Exposure	Control group	OR (95%CI)			AOR (95%CI)	
				White ethnic group <sup>+</sup>	South Asian ethnic group <sup>+</sup>	White ethnic group <sup>+</sup>	South Asian ethnic group <sup>+</sup>	
<b>Birthweight</b>	Macrosomia	5kg/m <sup>2</sup> increase in BMI	n/a	1.36 (1.27, 1.47) <sup>*</sup>	1.57 (1.41, 1.75) <sup>†</sup>	-	-	
	Bryant <i>et al</i> 2014 (28)							
	Davies-Tuck <i>et al</i> 2016 (48)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	1.43 (1.31, 1.56) <sup>**</sup>	2.22 (1.78, 2.77) <sup>**</sup>	1.90 (1.73, 2.08) <sup>‡§</sup>	2.24 (1.75, 2.83) <sup>‡§</sup>	
	Oteng-Ntiri 2013 (32)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	1.54 (1.27, 1.89) <sup>‡§</sup>	0.98 (0.30, 3.20)	
	Davies-Tuck <i>et al</i> 2016 (48)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	0.64 (0.57, 0.72) <sup>**</sup>	(0.56 (0.45, 0.71) <sup>**</sup>	<b>PAF</b> 5.15 (3.64, 6.64)	<b>PAF</b> 5.52 (3.84, 7.18)	
	Oteng-Ntiri 2013 (32)	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	0.64 (0.57, 0.72) <sup>‡§</sup>	0.64 (0.51, 0.81) <sup>‡§</sup>	
	LBW	≥30kg/m <sup>2</sup>	<30kg/m <sup>2</sup>	-	-	0.75 (0.58, 0.98) <sup>‡§</sup>	0.92 (0.47, 1.37) <sup>‡§</sup>	
						<b>PAF</b> -0.01 (-0.10, 0.08)	<b>PAF</b> -0.03 (-0.20, 0.14)	

OR=odds ratio AOR= adjusted odds ratio, GDM=gestational diabetes, SGA=small for gestational age, LSCS=lower section caesarean section, LBW=low birthweight

<sup>+</sup>For exact ethnic group definitions please refer to Table 1

<sup>‡</sup>GDM for this study includes GDM and pre-existing diabetes

<sup>\*</sup>Effect size calculated from data provided in published paper using STATA 14

<sup>\*\*</sup>Significant as 95% confidence interval does not cross 1.00

<sup>‡</sup>Relative risk

PAF: population attributable fraction % and 95%CI (PAF is the reduction in population disease risk or mortality that would occur if the exposure to a risk factor was eliminated or reduced to an ideal exposure scenario, where the distributions of other risk factors in the population remain unchanged (50,51))

<sup>1</sup>adjusted for age, parity and smoking status

<sup>2</sup>adjusted for age and parity

<sup>3</sup>adjusted for age parity and deprivation

<sup>4</sup>adjusting for maternal education, parity, smoking and insurance status

<sup>5</sup>adjusted for age, parity and smoking

<sup>6</sup>adjusted for maternal age, parity, account class, previous caesarean, onset of labour, gestation, birthweight, augmentation, epidural

<sup>7</sup>adjusted for maternal age, parity, onset of birth, epidural, baby birthweight, gestation, head position, augmentation and account class

<sup>8</sup>adjusted for parity, maternal age, account class, smoking, gestation and baby gender

<sup>9</sup>adjusted for maternal age, parity, smoking and account class

### *Exposure group 2: gestational anthropometric change*

Two studies presented results for the association between GDM and gestational change in weight, fat mass, truncal fat and mean skin-fold (42,47). Both studies found an increased association with GDM in South Asian women compared with White women (42,47). One identified a lower mean GWG among South Asian women with GDM (mean 8.3 kg, standard deviation [SD] 4.2) compared with White women with GDM (mean 9.4 kg, SD 4.96), although this was not significant ( $p = 0.163$ ) (47). One study found that, compared with White women, South Asian women had significantly increased association with GDM and GWG, fat mass gain, truncal fat gain and mean skin-fold gain, which remained significant following adjustment (43) (Table S5).

### *Exposure group 3: a combination of pre-pregnancy anthropometrics and gestational change in anthropometrics*

One study reported the combined influence of maternal pre-pregnancy BMI and gestational gain in truncal fat on GDM (42). South Asian women had an increased OR of GDM (OR 2.86, 95% CI 1.88, 4.34) compared with White women. Within the ethnic groups, the ORs of GDM increased with a 1 SD increase in pre-pregnancy BMI for both South Asian women (OR 4.75, 95% CI 2.96, 7.60) and White women (OR 1.66, 95% CI 1.4, 1.97). A similar pattern was observed for a 1 SD increase of truncal fat gain for South Asian (OR 3.8, 95% CI 2.4, 6.0) and White women (OR 1.3, 95% CI 1.1, 1.6), an increase in both truncal fat gain and pre-pregnancy BMI among South Asian (OR 6.3, 95% CI 3.74, 10.63) and White women (OR 2.21, 95% CI 1.68, 2.89) (42). For all levels of exposure, the ORs of GDM were higher for South Asian women than for White women (42).

## Anthropometric change during pregnancy (outcome)

### *Exposure: maternal pre-pregnancy anthropometrics*

Three studies provided results for the association between the exposure of pre-pregnancy BMI, weight, SFT and serum leptin levels and the outcome of gestational anthropometric change (30,43,45). One study presented GWG by pre-pregnancy weight (45). One study presented mean difference in gain of maternal weight and SFT (bicep, triceps and subscapular) and did not present data on statistical significance (30). One study presented the change in BMI, triceps, subscapular, suprailiac SFT measures and the sum of all these, and also serum leptin levels from 14 to 28 weeks' gestation (43).

All three studies (30,43,45) identified that South Asian women had a lower pre-pregnancy weight (or BMI) compared with White women ( $p = 0.015$  (43),  $p \leq 0.0001$  (45)). However, gestational change in weight or BMI was higher among South Asian women ( $p = 0.023$  (43),  $p = 0.17$  (45)). Two studies presented some conflicting

results relating to pre-pregnancy baseline SFTs and gestational change in SFTs. One study found that measures of SFT (bicep, tricep and subscapular) at 8–18 weeks' gestation were higher for South Asian women compared with White (30). Another study also reported significantly higher subscapular SFT ( $p = 0.002$ ) among South Asian women at 14 weeks, but no significant difference at 14 weeks for tricep ( $p = 0.83$ ), suprailiac ( $p = 0.96$ ) or the sum of SFTs ( $p = 0.20$ ) (43). Results relating to change in SFT during pregnancy were also conflicting. One study reported that both bicep and tricep SFT gains were higher for South Asian women than for White women at all time points (29, 32 and 37 weeks) (30), while another study found no significant difference in tricep ( $p = 0.085$ ) or suprailiac ( $p = 0.24$ ) SFT at 28 weeks (43). However, similar results were present for subscapular SFT gain, which both studies reported to be higher at 28 weeks ( $p < 0.001$ ) (43) and 29 weeks (30). One study further reported South Asian women had gained a significantly higher sum of triceps, subscapular and suprailiac SFTs ( $p = 0.001$ ) (43). This study also found that serum leptin levels were significantly higher at 14 and 28 weeks' gestation in South Asian women ( $p = 0.002$  and  $p \leq 0.001$  respectively) and that the change in serum leptin from 14 to 28 weeks' gestation was also significantly higher for South Asian women ( $p = 0.004$ ) (43).

## Preterm birth

### *Exposure: maternal pre-pregnancy anthropometrics*

Three studies presented results for the association between pre-pregnancy BMI and preterm birth (<37 weeks) (28,32,48). One reported unadjusted results, which suggested increased association between BMI and preterm birth among South Asian women (as the OR for preterm birth was significantly decreased for White women, but not for Pakistani women) (28). One reported adjusted results that suggested South Asian women have reduced OR of preterm birth with increased BMI compared with White women (32). One presented information for both unadjusted and adjusted results that suggested that with increased BMI, there was a marginally higher OR for preterm birth in South Asian women compared with White women (48). However, ORs (both unadjusted and adjusted) did not reach statistical significance for either ethnic group (48) (Table 3).

## Birthweight

### *Exposure: maternal pre-pregnancy anthropometrics*

Five studies reported results for the association between maternal pre-pregnancy BMI, weight, mid upper arm circumference and SFT and birthweight (28,31,32,34,48). One study reported the outcome of well-grown babies (above 10th centile (49)) (31), three reported macrosomia

(28,32,48), one low birthweight (32), one small for gestational age (48) and one birthweight  $z$  score (34).

South Asian women delivering well-grown babies had significantly higher mean triceps and SFT (mm) than did White women ( $p < 0.025$  and  $p < 0.005$ , respectively), but no difference in mean weight (kg), middle upper arm circumference (mm) and bicep SFT (mm) (31). Offspring of South Asian women had a higher AOR of low birthweight than did offspring of White women (32). White women with a BMI  $\geq 30$  kg m<sup>-2</sup> also had significantly reduced AOR of low birthweight, while the reduction in AOR for South Asian women did not reach statistical significance (32). One study found that with increased BMI, the odds of small for gestational age decreased significantly for both South Asian and White women; there was minimal difference in the decrease between the two ethnic groups, and this remained the same following adjustment (48) (Table 3).

Two studies found that with increased BMI, South Asian women had a higher OR for macrosomia than did White British women (28,48); for one study, this remained true following adjustment (48). However, the findings from one study refuted this association and reported South Asian women to have a lower AOR of macrosomia compared with White women (comparing maternal BMI  $\geq 30$  kg m<sup>-2</sup> with BMI  $< 30$  kg m<sup>-2</sup>) (32). One study found that in both women with and without GDM, BMI had a greater effect on birthweight  $z$  scores in South Asian women than in White women (34) (Table 3).

## Mode of delivery

### *Exposure: maternal pre-pregnancy anthropometrics*

Three studies reported results relating the association between maternal BMI and mode of delivery, including caesarean section and instrumental delivery (28,32,48). One found that South Asian women had a slightly higher OR of caesarean associated with an increase in BMI than did White women (28). One study found that the odds of unplanned caesarean were lower in South Asian women compared with White women (48); however, following adjustment, the odds in White women decreased below those of South Asian women (48). One study found that while there was a higher AOR of elective caesarean in South Asian women, the AOR of emergency caesarean was lower for South Asian women than for White women (32). Two studies presented results on instrumental delivery. Both studies found that South Asian women had a higher AOR of instrumental delivery associated with increased maternal BMI compared with White women (32,48) (Table 3).

## Pregnancy outcomes with evidence available from one or two studies

Two studies reported data for each of the following outcomes: stillbirth, hypertensive disorders, admission to

NICU/special care nursery and PPH. Single studies reported data for distance from skin to epidural space, post-natal IGT, perinatal death, congenital anomalies and post-natal weight retention. The results are presented in Table S5.

### *Exposure: maternal pre-pregnancy anthropometrics*

A significant positive association was identified between maternal BMI and stillbirth for South Asian infants but not for White infants in one study (29); the other study found a higher OR of stillbirth associated with maternal BMI for South Asian infants than for White (although this did not reach statistical significance) (48). Two studies found a significant positive association between maternal BMI and hypertensive disorders of pregnancy for both White and South Asian women, which was lower in South Asian women (28,48); this association remained following adjustment in one of the studies (48). The ORs and AORs of admission of infants to NICU/special care nursery and maternal PPH were lower in South Asian women compared with White women (32,48).

One study found that distance from skin to epidural space increased with increasing BMI; this was lower in South Asian women than in White women (36) (Table S5). In women with post-natal IGT, mean weight was lower for South Asian women (68.3 kg) than for White women (79.9 kg) (37). There were higher AORs for offspring perinatal mortality associated with maternal BMI among South Asian infants than White infants (32). South Asian infants also had a higher OR of congenital anomalies at BMI 25–29.9 kg m<sup>-2</sup> than did White infants, and a lower OR of congenital anomalies at BMI  $< 18.5$  and  $\geq 30$  kg m<sup>-2</sup> ((27)). South Asian infants had higher ORs and AORs for shoulder dystocia and ‘any perinatal morbidity’ compared with White infants (48). ORs of foetal compromise were lower for South Asian infants; however, following adjustment, AORs for South Asian infants increased to more than those for White infants (48).

Post-natal retention of anthropometric measures was found to be higher in South Asian women than in White women (43). At 14 weeks’ gestation, South Asian women had significantly lower BMI ( $p = 0.015$ ) and significantly higher subscapular SFT ( $p = 0.002$ ) and serum leptin levels ( $p = 0.002$ ) compared with White women (43). However, there was no significant difference in tricep SFT, suprailiac SFT or the sum of SFT ( $p = 0.83$ ,  $p = 0.96$  and  $p = 0.20$ , respectively) (43). Despite the differences at 14 weeks’ gestation, South Asian women had significantly higher change in all measures: BMI ( $p \leq 0.001$ ), tricep SFT ( $p \leq 0.001$ ), subscapular SFT ( $p = 0.022$ ), suprailiac SFT ( $p = 0.016$ ), sum of SFT ( $p \leq 0.001$ ) and serum leptin levels ( $p \leq 0.001$ ) (43). At 14 weeks’ gestation, BMI in South Asian women was not significantly different to that of White women ( $p = 0.83$ ), and all other measures were significantly higher for South Asian women than for White women; South

Asian women had significantly higher change in all measures: tricep SFT ( $p \leq 0.001$ ), subscapular SFT ( $p \leq 0.001$ ), suprailiac SFT ( $p = 0.001$ ), sum of SFT ( $p \leq 0.001$ ) and serum leptin levels ( $p \leq 0.001$ ) (43).

## Discussion

This systematic review included 22 studies and data from 403,609 births to compare the association between pregnancy anthropometrics and pregnancy outcomes in South Asian and White women. The strongest evidence from the included studies suggests that South Asian women have a higher risk of GDM associated with maternal pre-pregnancy anthropometrics and anthropometric change during pregnancy than do White women. There was also some evidence to suggest an increased association among South Asian women<sup>2</sup> with maternal pre-pregnancy anthropometrics and the outcomes anthropometric change during pregnancy, birthweight, mode of delivery and GDM. Gestational anthropometric change was also found to be associated with GDM. We found limited evidence to suggest that there may be associations between maternal pre-anthropometrics/early anthropometrics and hypertensive disorders, stillbirth, congenital anomalies, post-natal weight retention and post-natal IGT. The evidence also suggested that there may be a combined effect of pre-pregnancy anthropometrics and gestational anthropometric change on both GDM and post-natal weight retention. However, there was evidence that refuted some of these associations, and for many combinations of anthropometric exposure and pregnancy outcomes. Further evidence is required to explore these associations.

This review is the first to consider the association between maternal pre-pregnancy anthropometrics and anthropometric change during pregnancy on pregnancy outcomes in migrant and descendant South Asian women. Included studies allowed exploration of three levels of anthropometric exposure (maternal pre-pregnancy anthropometrics, gestational change in anthropometrics and a combination of maternal pre-pregnancy anthropometrics and gestational change in anthropometrics) on a number of different pregnancy outcomes. Consideration of different anthropometric measures is particularly important in the South Asian population as they better reflect fat distribution than does BMI alone. In the non-pregnant population, there is a wealth of evidence that the South Asian population is at an increased risk of diabetes at a lower BMI than the White population is (50).

It is hypothesized that these differences in body composition lower percentage of lean body mass and that a higher proportion of fat mass contributes to the increased risk of

type 2 diabetes in the South Asian population (50). Included studies have identified that South Asian women have a higher risk of GDM at a lower BMI or weight than do White women (28,32,34,37,38,40,43,47). A lower percentage of lean body mass and a higher proportion of fat mass may also play a role in the development of GDM at a lower BMI (or weight) than in White women. In addition to differences in body composition, many other factors may play a role in explaining the difference in risk of pregnancy outcomes observed between the White and South Asian populations, e.g. consanguinity (51), socioeconomic status (51), access to maternity care (52), maternal mental health (53), place of birth (51), maternal age (41) and marriage (or cohabiting status) (54).

A major strength of this review is the comprehensive search strategy used. We performed a search of 12 databases, piloting and refining the search strategy by the research team and an information scientist with expertise in database searching. We also searched citations and reference lists of included studies, and the reference lists of reviews that were related to the topic area. Of the 22 included studies, 20 were identified through database search alone (27–40,42–46,48), one from screening the reference lists of relevant reviews (41) and one from searching the citations of included studies (47). In their recent review and meta-analysis, Heslehurst *et al.* also found that in order to minimize bias, it was essential to include evidence from searches in addition to database searching (7).

The main limitation of this systematic review relates to data availability in the existing literature. Owing to the heterogeneity between populations (e.g. in relation to first-trimester maternal obesity (21), blood pressure (55) and risk factors for coronary heart disease (56)), we would have preferred to consider the risk for Pakistani, Indian and Bangladeshi women, etc. independently. However, the evidence identified did not allow for independent subgroup analysis, and all South Asian women had to be analysed together. This review was also unable to distinguish South Asian populations by place or birth and/or immigrant status. This has been shown to affect rates of GDM, as Asian and other immigrants to high-income countries typically have higher rates of GDM than do those born in high-income countries (57). Limited evidence was available for the following exposures: gestational anthropometric change and the combined effect of pre-pregnancy anthropometrics and gestational anthropometric change; for measures of anthropometrics other than BMI and weight (e.g. SFT and body fat percentage) and for a number of pregnancy outcomes, evidence was only available from one or two studies. Although this was useful as it highlights that this is an under-researched area, the lack of evidence available limited the ability for evidence synthesis and limits the conclusions that we can draw about these pregnancy outcomes.

<sup>2</sup>We are not comparing the results with White women here, just considering the association in South Asian women alone.

Among the included studies that compared maternal BMI categories ( $n = 7$ ), only three studies applied lower BMI cut-offs specific to Asian populations (29,46,48). Consequently, the results from the studies using general population BMI criteria for the South Asian population may have underestimated the effect size and the significance of the association. This is due to women of potentially increased obesity risk (pre-pregnancy BMI, 27.5–30 kg m<sup>-2</sup>) not being included in the obese category and women of potentially increased overweight risk (BMI, 23–25 kg m<sup>-2</sup>) included in the ‘low-risk’ comparison groups. This review has identified that South Asian women may have a higher risk of multiple-pregnancy outcomes at the same BMI than do White women. Had the BMI categories specific to the South Asian population been applied, it is possible that this risk may be even higher, and that some pregnancy outcomes that this review found to be non-significant for South Asian women may actually be higher and even reach statistical significance.

Of the three studies that did apply BMI cut-offs for the South Asian population, one reported that using the Asian-specific criteria did not make a difference to results, although it did not present the exact values (48). The other two studies both found a change in odds compared with the higher BMI cut-off. Penn *et al.* found that the odds of stillbirth decreased from 4.64 (1.84, 11.70) for BMI  $\geq 30$  kg m<sup>-2</sup> to 2.83 (1.17, 6.85) for BMI  $\geq 27.5$  kg m<sup>-2</sup> (29). Despite the decrease in odds, South Asian women still had higher odds of stillbirth than do White women: 1.32 (0.68, 2.57) (29). Pu *et al.* found that the odds of GDM increased from 1.17 (1.5, 2.0) at BMI  $\geq 25$  kg m<sup>-2</sup> to 1.9 (1.7, 2.2) at BMI  $\geq 23$  kg m<sup>-2</sup> (46). Of all the studies that considered GDM as an outcome where maternal BMI was categorized as the exposure, Pu *et al.* found the lowest odds of GDM (for both BMI cut-offs, Asian specific and general population) (46). One reason for this finding may be that women with overweight and obesity were grouped together in this study rather than examining the groups separately, or just looking at women with obesity.

This review has highlighted the lack of evidence available for the association between maternal pre-pregnancy anthropometrics, gestational anthropometric change and pregnancy outcomes in South Asian women. More research is needed that explores both the individual and combined effects of maternal pre-pregnancy anthropometrics and gestational anthropometric change on different pregnancy outcomes in South Asian women. No literature identified by this review considered the associations between maternal anthropometric exposures and childhood obesity among offspring. Childhood obesity was found to be an outcome associated with GWG in the 2009 IoM guidelines where the ethnic groups considered were White, African-American, East Asian and Hispanic populations (14). Future research should investigate the association between maternal

anthropometrics, both pre-pregnancy/early-pregnancy and the change during pregnancy, and childhood anthropometrics separately for boys and girls in the different South Asian subgroups. Future research investigating the association between maternal anthropometrics and pregnancy outcomes in South Asian women should present results separately for the different South Asian subgroups. Where possible, the risk associated with different anthropometric measures (as opposed to BMI alone) should be considered to inform the understanding of potential mechanisms relating to ethnic differences in body composition.

In addition, in this review, none of the included studies considered obesity subgroups using the Asian-specific BMI criteria (27.5 to  $<32.5$ ,  $\geq 32.5$  to  $<37.5$ , and  $\geq 37.5$  kg m<sup>-2</sup>(2)). It has been documented that within the pregnant population with obesity, levels of risk are not the same at all BMIs  $\geq 30$  kg m<sup>-2</sup>. For example, the risk of post-term birth in class I obesity is different to that in class III obesity (7). In order to explore whether this is the same for the pregnant South Asian population, future research should investigate the risk of pregnancy outcomes within each of the obesity subgroups of the Asian-specific BMI criteria, or ensure that BMI is investigated as a continuous exposure. It is recommended that wherever possible, BMI cut-offs are used that would facilitate international comparisons (18.5, 20, 23, 25, 27.5, 30, 32.5, 35, 37.5 and 40 kg m<sup>-2</sup>) (2).

This review has highlighted that there are differences in obesity-related risk in pregnancy for South Asian and White women. Results suggest that the risk of GDM is higher in South Asian women at a lower BMI than in White women, therefore supporting the use of ethnicity as independent criteria for GDM criteria in the NICE guidelines. Results also suggest that there are ethnic differences in risk for different pregnancy outcomes related to anthropometric measures. However, the lack of evidence available to explore these associations fully means that firm conclusions cannot be drawn. Therefore, before any recommendations can be made for policy and practice, more research is needed. In particular, the association between maternal anthropometrics and childhood obesity should be investigated in ethnic groups relevant to the UK population.

## Conclusion

This review found inconsistent results. However, evidence suggested that in South Asian women, maternal pre-pregnancy anthropometrics are associated with anthropometric change during pregnancy, birthweight, mode of delivery and GDM. Evidence also highlighted that gestational anthropometric change may be associated with GDM. However, the limited evidence available for these exposures and also other

pregnancy outcomes warrants further investigation to inform policy and practice to address health inequalities.

### Conflict of interest statement

No conflict of interest was declared.

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### Supporting information

Additional Supporting Information may be found online in the supporting information tab for this article. <https://doi.org/10.1111/obr.12636>

**Figure S1.** Search strategies

**Figure S2.** Data extraction form

**Figure S3.** Quality assessment

**Data S4** Quality assessment scores

**Data S5.** Effects of specified exposure on pregnancy outcomes in South Asian and White women

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