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Harvey, Louise; van Elburg, Ruurd; van der Beek, Eline M.

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Macrosomia and large for gestational age in Asia: One size does not fit all

Louise Harvey[1], Ruurd van Elburg[2] and Eline M. van der Beek[3]

[1]Nutricia Research, Danone Nutricia Research, Utrecht, The Netherlands
[2]Department of Pediatrics, Emma Children's Hospital, Amsterdam University Medical Centers, Amsterdam, The Netherlands
[3]Department of Pediatrics, University Medical Centre Groningen, Groningen, The Netherlands

Abstract

Macrosomia, usually defined as infant birth weight of ≥4000 g, does not consider gestational age, sex, or country/region-specific differences in mean birth weight and maternal body weight. This issue is particularly relevant for Asia, where 60% of the world's population lives, due to variations in maternal size and birth weights across populations. Large for gestational age (LGA), defined as birth weight > 90th centile, is a more sensitive measure as it considers gestational age and sex, though it is dependent on the choice of growth charts. We aimed to review reporting of macrosomia and LGA in Asia. We reviewed the literature on prevalence and risk of macrosomia and LGA in Asia over the last 29 years. Prevalence of macrosomia ranged from 0.5% (India) to 13.9% (China) while prevalence of LGA ranged from 4.3% (Korea) to 22.1% (China), indicating substantial variation in prevalence within and between Asian countries. High pre-pregnancy body mass index, excessive gestational weight gain, and impaired glucose tolerance conferred risk of macrosomia/LGA. Incidence of macrosomia and LGA varies substantially within and between Asian countries, as do the growth charts and definitions. The latter makes it impossible to make comparisons but suggests differences in intrauterine growth between populations. Reporting LGA, using standardized country/regional growth charts, would better capture the incidence of high birth weight and allow for comparison and identification of contributing factors. Better understanding of local drivers of excessive intrauterine growth could enable development of improved strategies for prevention and management of LGA.

Key words: Asia, large for gestational age, macrosomia, obesity, overweight.

Introduction

Macrosomia is arbitrarily defined as an infant birth weight of either ≥4000 g, ≥ 4500 g, or ≥ 5000 g, and even occasionally ≥3750 g. The weight cutoff varies not only between countries but also within countries, due to differences in medical and academic reporting, and there is insufficient consistency in application to allow for nuanced comparisons. A diagnosis of macrosomia does not consider gestational age, sex, or ethnicity. Large for gestational age (LGA), which is calculated from an infant's birth weight, gestational age, and sex, may better reflect fetal growth. In addition, LGA may also take into account ethnicity, depending on the population or growth charts used to calculate growth centiles. LGA usually refers to an infant born above the 90th/95th percentile for weight at gestational age. These definitions help to identify infants at risk for adverse outcomes, but the cutoffs used, particularly for macrosomia in countries with low average birth weights, have not been verified as conferring risk for these outcomes. Ideally, the definition of LGA allows for identification of infants who may have a higher risk for fast growth and excess

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Correspondence: Louise Harvey, Nutricia Research, Uppsalalaan 12, 3584 CT Utrecht, The Netherlands.
Email: louise.harvey@danone.com

adiposity development during childhood, increasing the risk of later overweight and obesity.[1]

Increases in average birth weight and rates of macrosomia/LGA, as well as in the prevalence of (childhood) obesity, have been reported in developed countries.[2,3] These increases coincided with increasing prevalence of maternal overweight and obesity, increased incidence of Type II diabetes, increasing maternal age, and reductions in rates of maternal cigarette smoking.[4,5] Recent data from the United States suggest that rates of macrosomia have peaked and are now stable; this may be related to improved education to control net gestational weight gain, but also to increased incidence of preterm birth, and increased use of labor induction simply resulting in shorter duration of gestation.[3,5]

Less is known about the situation in developing countries. Countries undergoing rapid economic growth, such as China and India, face a dual burden of malnutrition,[6] resulting in an increase of overweight/obesity in women of childbearing age, while maternal undernutrition is still prevalent. Indeed, over the last 20 years, reported rates of macrosomia in China have been steadily increasing.[7,8] Significant variations in macrosomia prevalence between Northern and Southern China have been described,[9] a reminder of the heterogeneity of large populations, particularly over environmentally diverse, large land masses. There is some evidence to suggest that rates of LGA in South East China have stabilized, and even decreased.[8] Given that Asia accounts for ~60% of the world's population and is undergoing rapid economic development, understanding the magnitude of the issue and the relationship between reported macrosomia and LGA incidence in this region is essential for prevention and management strategies and resource allocation.

There are many risk factors for macrosomia or LGA at birth: high parity; maternal age, height, and weight; post-term birth; male sex (risk factor for macrosomia only); maternal overweight and obesity; excessive gestational weight gain; pre-gestational diabetes; and gestational diabetes mellitus (GDM).[10,11] Understanding the drivers of macrosomic/LGA births is important as there are immediate and long-term risks for adverse outcomes for mother and infant. Short term, infants are at risk of perinatal asphyxia, birth trauma, hypoglycemia, and perinatal death, while mothers are at risk of Caesarean section, prolonged labor, hemorrhage, and perineal trauma.[11,12] Long-term effects for infants include increased risk of overweight/obesity during childhood[13] and developing type 1 or 2 diabetes in later life.[14,15] Mothers of a macrosomic infant have an increased risk of developing type 2 diabetes post-pregnancy.[16]

Much of the data on adverse outcomes are based on Caucasian populations in the United States and Europe. This is a concern, as there are country- and region-specific influences on maternal and neonatal characteristics, such as the nutritional environment, which influence the development of macrosomia/LGA. However, it is unclear whether risk factors described in Western/Caucasian populations confer the same magnitude of risk in Asian populations. For instance, recent data suggest that maternal short stature in developing countries could be a unique regional risk factor.[17] The risk of adverse outcomes may also differ due to ethnic backgrounds. The Born in Bradford study suggests that women of South Asian ethnicity have a lower threshold for glucose intolerance than British women; once this threshold has passed, the risk of an LGA birth for these women increases by 75%.[18] In addition, little is known about the social and economic consequences of macrosomia/LGA births; recent estimates suggest average short term direct costs for neonatal complications of a macrosomic birth are ~$US 3800.[19] Indirect costs and long-term consequences have not yet been estimated or modeled; indeed, in some Asian countries, the direct costs may still be unknown.

The primary aim of this review was to describe the prevalence of macrosomia and LGA in Asia and evaluate possible heterogeneity in reporting. To this end, we also aimed to determine: if there was a consistent definition of macrosomia; if LGA was used widely and appropriately (i.e., with appropriate/local growth charts and, if so, if cutoffs were specified); if the prevalence of each measure had changed over time; and if there were clear trends or country-specific changes for Asia. Finally, we aimed to describe the risk factors for macrosomia/LGA in Asia to understand which risk factor/s is/are most important and whether these might be different from what is known from data from Western countries.

Methods

We conducted our search strategy, study selection, and data extraction using a systematic and methodological approach to ensure we captured representative literature from all countries. However, this review is

not a systematic review as the heterogeneity of the studies, particularly the diversity in guidelines used to define LGA, meant that synthesis of data across studies/countries was not possible.

Search strategy and article selection

We identified 23 countries in Asia; Bangladesh, Bhutan, Cambodia, China, East Timor, Hong Kong, India, Indonesia, Japan, Korea, Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam. We searched PubMed on 16 February 2015 and 15 July 2019, using the following search string: (macrosomia OR "LGA" OR "high birth weight") AND (Bangladesh OR Bhutan OR Cambodia OR China OR East Timor OR India OR Indonesia OR Japan OR Laos OR Malaysia OR Maldives OR Mongolia OR Myanmar OR Nepal OR North Korea OR Pakistan OR Philippines OR Singapore OR South Korea OR Sri Lanka OR Taiwan OR Thailand OR Vietnam).

The original search resulted in 432 references; 33 duplicates were moved, leaving 399 articles. The updated search resulted in 452 new references, of which 69 were duplicates, leaving 383 articles.

Articles from both searches were scanned using a two-stage process. Articles were initially scanned on title and abstract using broadly defined inclusion criteria:

- human studies;
- studies must include people of Asian ethnicity, either living in Asia, or large Asian cohorts living in other countries;
- the study must measure prevalence of macrosomia or LGA;
- primarily large cohort studies but also include mid-size studies (e.g., focused on GDM or obese populations), which measure macrosomia/LGA;
- published between 1990 and date of search;
- written in English.

For the first search, screening on title/abstract eliminated 289, leaving 110 articles to be screened on full text. For the updated search, screening on title/abstract eliminated 253 articles, leaving 130 articles to be screened on full text.

When reviewing the full text (LH), we narrowed the inclusion criteria to the following requirements:

- study was conducted in one of the 23 identified Asian countries;
- study comprised >10 000 participants for studies based in China and >1000 participants for studies based in other Asian countries;
- studies that included data analysis of sub-populations based on risk factors were included, but studies that focused solely on disease or at-risk populations were excluded.
- studies that focused on pregnancies derived from assisted reproductive technology were excluded.

Data extraction

Data were extracted by a single researcher (LH). Where available, data extracted included: date of publication; time period of data collection; number of participants; definition of macrosomia used; source of centile/growth charts if LGA was assessed; overall/general prevalence of macrosomia and/or LGA, definition or normal birth weight, overall/general prevalence of normal birth weight; and risk factors of macrosomia/LGA identified by the authors. When an article split the study population according to risk factors, such as pre-pregnancy body mass index (BMI), gestational weight gain (GWG), or glucose intolerance/GDM, the prevalence of macrosomia/LGA in those sub-populations was extracted, along with any calculated odds ratios (OR)/adjusted odds ratios (aOR) and, importantly, the criteria used to define the populations.

Data analysis

We collated the data and compiled tables based on our research questions. If prevalence of macrosomia or LGA either overall or in specific sub-populations was only recorded as x number of cases/y number of participants, percentage prevalence was calculated as (x/y * 100). In these cases, the calculated data are always recorded as such when presented.

While we did not capture the specific growth charts used to calculate LGA in our initial summary of prevalence (Tables 1 and 2), we noted during our analysis that there was significant variation and sometime ambiguity in the definitions. We report specific definitions/growth chart references where specified in our analysis of prevalence and risk factors (Tables 3(a),(b), 4, and 5.)

Results

Screening on full text resulted in a total of 96 included articles. Two studies included data from multiple

TABLE 1 Prevalence of macrosomia and large for gestational age in Asia (excluding China)

Country	Date of data collection	*n*	% Macrosomia > 4000 g	% LGA > 90th percentile	References
Bangladesh	2001–2004	910		10.9	Fall et al.[20]/Margetts et al.[21,a]
Cambodia	2007–2008	5462	2.3		Koyanagi et al[17]
Hong Kong	1995–2005	29 303		8.7[b]	Leung et al[22]
Hong Kong	1995–2009	80 953	3.4		Cheng et al[23]
Hong Kong	2010–2016	61 807		5.4[b]	Chaemsaithong et al[24]
India	2007–2008	23 972	0.5		Koyanagi et al[17]
India	2009–2010	1463		9.8[c]	Balaji et al[25]
India	1996–2010	35 718		9.4	Jeyaseelan[26]
India	2010–2012	7280		11.5[b]	Aziz et al[111]
India	2011–2014	2728		12[d,b]	Bhavadharini[27]
India	2013–2015	1459		6.6[d,b]	Bhavadharini[28]
Indonesia	2001–2004	6177		9.7	Fall et al. [20]/Margetts et al.[21, a]
Japan	1990–2013	11 306	6.4		Kabeya et al[29]
Japan	2001–2002	46 659	0.9		Takimoto etal[30]
Japan	1997–2007	117 175	1.1		Yokomichi et al[31]
Japan	2007–2009	117 680	0.9		Morikawa et al[32]
Japan	ND	53 650		8.5	Matsuda et al[33]
Japan	2001–2012	7669	0.5[b]	6.2[b]	Toma et al[34]
Japan	2013	97 157	0.8[b]	10.1[b]	Enomoto et al[35]
Japan	2012–2014	6364	0.8	9.7	Takata et al[36]
Japan	2001–2015	5666	0.5[b]	8.8[b]	Oawada et al[37]
Japan	2011–2015	33 448		10.5/9.8[e]	Takagi et al[38]
Japan	2005–2017	21 642	1.1[b]		Shigemi et al[39]
Korea	2005–2010	2311	3.2[b]	8.2[b]	Park et al[40]
Korea	2000–2007	7843		9.6[b]	Wie et al[41]
Korea	2007	383 244	4.32		Cho et al[42]
Korea	2007–2009	2311		8.3[b]	Choi et al[43]
Korea	2007–2009	2789	3.9	4.3	Cho et al[44]
Korea	2010–2013	1 700 976	3.06		Song et al[45]
Korea	2007–2014	2 269 051	3.71		Cho et al[46]
Korea	2008–2016	38 049	3.7[b]		Lee et al[47]
Malaysia	1989	24 856	2.9		Boo[48]
Malaysia	2010–2012	88 837	2.5		Ganeshan et al[49]
Nepal	2007–2008	8308	1.5		Koyanagi et al[17]
Pakistan	1989–1993	6830	13.1		Ahkter et al[50]
Pakistan	1994–1996	6142	3.31		Najmi[51]
Philippines	2007–2008	13 037	1.1		Koyanagi et al[17]
Singapore	ND	1247		[f]	Aris et al[52]
Sri Lanka	2007–2008	9619	2.2		Koyanagi et al[17]
Taiwan	2001	250 079	2.8[g]		Weng et al[53]
Taiwan	2010	168 504	1.9[g]		Weng et al[53]
Taiwan	2001–2010	2 123 100	2.18[b]		Weng et al[54]
Taiwan	2009–2010	3056	2.3	7.8	Hung & Hsieh[55]
Taiwan	2006–2013	11 486	1.0		Lu[56]
Taiwan	2011–2013	5194	1.0		Ho[57]
Taiwan	2012–2013	3641	1.5	6.3	Hung & Hsieh[55]
Taiwan	2009–2014	9301	1.9[b]	8.8[b]	Hung et al[58]
Taiwan	2009–2015	12 064	1.8[b]	8.5[b]	Hung et al[59]
Taiwan	2006–2013	1 536 796		7.7	Sun et al[60]
Thailand	2007–2008	14 832	1.3		Koyanagi et al[17]
Thailand	2009	3715	1.7[b]		Saereeporncharenkul[61]
Thailand	2011–2012	5200		6.6	Sunsaneevithayakul et al[62]

(*Continues*)

TABLE 1 Continued

Country	Date of data collection	*n*	% Macrosomia > 4000 g	% LGA > 90th percentile	References
Thailand	2002–2012	21 771		14[b,h]	Srichumchit et al[63]
Vietnam	2007–2008	13 168	3.4		Koyanagi et al[17]
Vietnam	2007–2008	2989		9.9	Ota et al[64]
Vietnam	2010–2011	2772		11.8	Hirst et al[65]
Vietnam	2015–2016	1909	3.4	8.3[b]	Nguyen et al[66]

Abbreviations: LGA, large for gestational age; ND, not described.; [a]Fall et al' (2009)[20] was originally included in the review and reported LGA prevalence but it was necessary to refer to the partner publication[21] for information regarding the date of data collection.; [b]Calculated from data in the article.; [c]Article uses the term macrosomia however defines this as infant birth weight above 90th percentile (> 3.45 kg). No other definition or explanation was provided.; [d]Article uses definition of macrosomia as >3.5 kg (due to alignment with 90th percentile for birth weight in India).; [e]Males/females.; [f]General prevalence not described in paper, only in sub-divided populations.; [g]Values are approximate as they were determined from graph in Supplementary Material. [h]Article refers to measure as "fetal macrosomia" but definition given in Materials and Methods describes LGA; "defined as birth weight heavier than the 90th percentile for each gestational age."

countries and/or multiple cohorts within countries[17] while six studies (five in China and one in Taiwan) included data from multiple time periods in the same country.[7,8,53,55,67,69]

In Table 1, the prevalence of macrosomia (> 4000 g) and LGA (>90th percentile) is described for 57 individual country-time period data points across 16 Asian countries (Bangladesh,[20] Cambodia,[17] Hong Kong,[22–24] India,[17,25–28,111] Indonesia,[20] Japan,[29–39] Korea,[40–47] Malaysia,[48,49] Nepal,[17] Pakistan,[50,51] Philippines,[17] Singapore,[52] Sri Lanka,[17] Taiwan,[53–60] Thailand,[17,61–63] and Vietnam.[17,64–66] In Table 2, the prevalence of macrosomia (> 4000 g) and LGA (>90th percentile) is described for 47 individual data points across China.[7,9,17,67–99,112,124]

Of the 23 countries of interest, we found no studies that matched our inclusion criteria for Bhutan, East Timor, Laos, Maldives, Mongolia, and Myanmar. Data represent prevalence between 1989 and 2017. Though we originally wanted to capture data from 1990 to 2019, we did include a large 1989 study from Malaysia[48] as this was one of only two studies from Malaysia that our search detected. We also included a study with less than 1000 participants (n = 910) as it was the only study on Bangladesh that was identified.[20] Nearly 50% of the data on macrosomia/LGA in Asia was generated from Chinese populations (47/105 data points).

Two countries with prevalence of macrosomia over 10% were China and Pakistan (Tables 1 and 2). The countries with the highest prevalence of LGA (> 10%) were Bangladesh, China, India, Japan, Thailand, and Vietnam (Tables 1 and 2).

The majority of studies (61%, 64/105) reported only macrosomia, 18% (19/105) reported only LGA, and 21% (22/105) reported both macrosomia and LGA. In 20 of the 21 studies that reported both macrosomia and LGA, consistently higher prevalences were reported for LGA than for macrosomia; for example, prevalence of macrosomia 6.6% and LGA 22.1% in more than 14 000 infants China in 2012[79] and 0.8% (macrosomia) and 10.1% (LGA) in over 97 000 infants in Japan from 2013.[35]

Prevalence of macrosomia and LGA in at risk populations

Twenty-two studies assessed the prevalence of macrosomia/LGA in overweight and obese women and associated OR/aOR; 11 from Asia (excluding China) (Table 3(a)), and 11 from China (Table 3(b)). There were 13 different criteria used in the publications to classify pre-pregnancy or first visit BMI into overweight and obesity (or other sub-groups), including many modified versions of the World Health Organization (WHO) criteria. This was also true for the calculation of LGA using varying definitions or "somewhat defined" criterium. Within the last 12 years, in Asia (excluding China) the prevalence of infants with macrosomia from obese women was relatively low (under 5%), while the prevalence of LGA infants from obese women ranged from 2.25% in Vietnam in 2007–2008[64] to 22.6% in Japan in 2013[35] (Table 3(a)). In China, the prevalence of macrosomia in obese women ranged from 5.1%[94] to 22.9%,[82] while the prevalence of LGA in obese women ranged from 14.4%[82] to 39.7%[79] (Table 3(b)). While the studies reporting LGA in obese Chinese women are all reported within a 10 year time frame, the lack of information on specific growth charts referenced in these studies (e.g., "calculated using own study

TABLE 2 Prevalence of macrosomia and large for gestational age in China

Country	Date of data collection	*n*	% Macrosomia > 4000 g	% LGA > 90th percentile	References
China	1994	594 472	6	13.7	Lu et al[8]
China	1996	63 661	6.6		Shan et al[67]
China	2000	594 472	8.49		Lu et al[8]
China	2000	63 661	9.5		Shan et al[67]
China	2001	13 711	8.3		Bao et al[7]
China	2005	594 472	7.83	18.98	Lu et al[8]
China	2005	13 711	10.5		Bao et al[7]
China	2002–2005	21 315	11.67		Gu et al[68]
China	2006	27 322	9.1		Shi et al[69]
China	2007–2008	14 332	6.9		Koyanagi et al[17]
China	2006–2010	23 064	9.1		Wu et al[112]
China	2010	63 661	7		Shan et al[67]
China	2010	60 986	13.6		Sun et al[71]
China	2010	27 322	8		Shi et al[69]
China	2011	109 722	6.7		Hou et al[72]
China	2011	101 723	7.3		Li et al[9]
China	2011	113 597	7.1		Luo & Zhang[73]
China	2011	65 173	7.8[a]		Liu et al[74]
China	2009–2011	33 793	9.8[a]	10.4[a]	Li et al[75]
China	2010–2012	17 808	8.9[a]	9.9[a]	Pan et al[76]
China	2010–2012	133 232	5.8	11.8	Chen et al[77]
China	2010–2012	19 622	9.1	8.8	Yang et al[78]
China	2011–2012	89 171	5.2		Zhang et al[70]
China	2012	14 196	6.6	22.1	Zhang et al[79]
China	2010–2013	28 722	3.8		Pei et al[80]
China	2010–2013	213 461	8		Liu et al[81]
China	2010–2013	16 986	9.2	15.9	Hua et al[82]
China	2011–2013	85 765	6.5		Yang et al[83]
China	2013	14 168	7.86		Wang et al[84]
China	2013	14 451	7.8[a]		Wei et al[85]
China	2013	14 741	7.8[a]	6.6[a]	Feng et al[86]
China	2013	47 590	10[a]		Cai et al[87]
China	2013	49 357	10[a]		Tan et al[88]
China	2010–2014	178 709	6.4		Wang et al[89]
China	2010–2014	1313 169	8.7		Wang et al[90]
China	2014	10 366	6.1		Zheng et al[91]
China	2000–2015	227 359		7.9[a]	Zhang et al[70]
China	2001–2015	2 290 745		9.3	He et al[92]
China	2013–2015	43 086	6.5[a]		Yan et al 2020[124]
China	2015	59 189	13.9		Wang[90]
China	2015	15 615	3.4[a]		Wang[93]
China	2012–2016	14 984	2.62		Tu et al[94]
China	2013–2016	11 494		12.5[a]	Wu et al[95]
China	2016	16 780	6.1	11.8	Huang et al[96]
China	2005–2017	102 526	3.1		Rao et al[97]
China	2016–2017	11 581	7.37	15.5	Yuan et al[98]
China	2015–2017	506 000		7.23	Wang et al[99]

Abbreviations: LGA, large for gestational age; ND, not described.
[a]Calculated from data in the article.

population means and standard deviations") means comparisons between studies are difficult.

The prevalence of macrosomia/LGA in women with excessive GWG and the OR/aOR associated with this risk factor was described in 11 studies (Table 4). As with the BMI categorization, the reported data show differences with respect to the guidelines used to calculate adequate versus excessive

TABLE 3 Relationship between maternal body mass index and macrosomia/large for gestational age in (a) Asia (excluding China) and (b) China

References	Country	Time period	Type of study	*n*	BMI class.	M or LGA	Timing of weight measure	Overall study prevalence	Prevalence in normal category	Prevalence in overweight category	Prevalence in obese category	Overweight OR (aOR)	Obese OR/(aOR)
(a)													
Leung et al[22]	Hong Kong	1995–2005	Retro	29 303	WHO^{2008}	LGA[a]	First visit	8.7[b]	7.7[b]	16[b]	21	2.22-2.86	3.39
Aziz et al[111]	India	2010–2012	Retro	7284	WHO^{AI} versus WHO^{NIH}	LGA[c]	First visit	11.5[b]	10.81	14.9	20.1	(1.36 vs. 1.5)	(1.86 vs. 1.73)
Bhavadharani[27]	India	2011–2014	Retro	2728	WHO^{AI}	M/LGA[d]	First visit	12[b]	8.9	12.7	14.2	ND	ND
Toma et al[34]	Japan	2001–2012	Retro	7669	IOM^{2009}	M	Pre-preg SR	0.5[b]	0.4	1.2	2.4	2.79	6.54
						LGA	Pre-preg SR	6.2[b]	5.6	9.1	15.5	1.72	2.89
Enomoto et al[35]	Japan	2013	Retro	97 157	IOM^{2009}	LGA[e]	Pre-preg	10.1[b]	10.1	17.4	22.6	1.96	2.71
						M	Pre-preg	0.8[b]	0.7	1.8	3.1	2.61	4.60
Wie et al[41]	Korea	2000–2007	Retro	7843	IOM^{2009}	LGA	Pre-preg SR	9.6[b]	8.7	14	19.1	ND	ND
Choi et al[43]	Korea	2007–2009	Retro	2454	WHO^{AI}	LGA[f]	Pre-preg	8.3[b]	7.7	14	14.7	1.79	2.77
Park et al[40]	Korea	2005–2010	Retro	2311	WHO^{Asian}	M	Pre-preg	3.2[b]	2.7[b]	5.7[b]	ND		
						LGA[e]	Pre-preg	8.2[b]	7.3[b]	14.1[b]	ND	1.69	5.36
Hung et al[59]	Taiwan	2009–2015	Retro	12 064	GCOT	M	Pre-preg SR	1.8[b]	1.4	3.2	4.5	1.81	2.32
						LGA		8.5[b]	8.2	15.5	19.5	1.86	2.51
Sunsaneevithayakul et al[62]	Thailand	2011–2012	Retro	5200	WHO	LGA[e]	Pre-preg/ first visit	6.6	6.2	14.1	18.6	ND	ND
Ota et al[64]	Vietnam	2007–2008	Pro	2989	WHO^{Asian}	LGA[g]	Pre-preg SR	9.9	11.7	23	2.25	ND	ND
(b)													
Lu 2011[8]	China	2005	Retro	594 472	WHO^{AI}	M	First visit	7.83	7.31	12.09	16.71	(1.92)	(3.04)
Gu et al[68]	China	2002–2005	Pro	21 315	GCOT	M	First visit (<12 weeks)	11.67	11[b]	17[b]	15[b]	1.73	1.49
Shi et al[69]	China	2006–2010	Retro	27 322	WGOC + WHO	M	First visit (<20 weeks)	8.6	ND	ND	ND	1.8	ND
Li et al[75]	China	2009–2011	Retro	33 793	WGOC	M	First visit (<12 weeks)	9.8[b]	8.6	14.1	20	ND	ND
						LGA[h]	First visit (<12 weeks)	10.4[b]	9.1	14.9	22.6	ND	ND
Li et al[9]	China	2011	Cross-sectional	101 723	WGOC	M	ND	7.3	6.7	12	16.4	(4.1)	
Zhang et al[79]	China	2012	Retro	14 196	WGOC	M	Pre-preg SR	6.6	6.4	11.3	14.4	(1.9)	(2.3)
						LGA[i]	Pre-preg SR	22.1	21.9	31.4	39.7	(1.4)	
Yang et al[78]	China	2010–2012	Pro	19 622	Custom[j]	M	Pre-preg	9.1	7.8[b]	13.7[b]	18.4[b]	2.29	ND
						LGA	Pre-preg	8.8	7.4[b]	13.1[b]	19[b]	2.27	ND
Hua et al[82]	China	2010–2013	Pro	16 896	IOM^{2009}	M	Study visit	9.2	8.8[b]	13.8[b]	22.9[b]	(1.61)	(3.05)
						LGA[k]	Study visit	15.9	16.6[b]	15.9[b]	14.4[b]	ND	ND

(*Continues*)

TABLE 3 Continued

References	Country	Time period	Type of study	*n*	BMI class.	M or LGA	Timing of weight measure	Overall study prevalence	Prevalence in normal category	Prevalence in overweight category	Prevalence in obese category	Overweight OR (aOR)	Obese OR/(aOR)
Wei et al[85]	China	2013	Pro	14 451	WCOG[l]	M	Pre-preg SR	7.8[b]	7.55	11.16		12.35	
Tu et al[94]	China	2012–2016	Pro	14 984	Custom[m]	M	Pre-preg	2.62	2.9[b]	5.4[b]	5.1[b]	ND	ND
Wu et al[95]	China	2013–2016	Retro	11 494	Custom[n]	LGA	Pre-preg SR	12.5	17.2	22.7	24.7	2.14	2.42

Abbreviations: aOR, adjusted odds ratio (presented in brackets); GCOT, Group of China Obesity Task Force. Underweight <18.5 kg/m^2, Normal 18.5–24.9 kg/m^2, Overweight 25–29.9 kg/m^2, Obese ≥30 kg/m^2; GWG, gestational weight gain; IOM^{2009}: Underweight <18.5 kg/m^2, 18.5 ≤ Normal <25 kg/m^2, 25 ≤ Overweight <30 kg/m^2, Obese ≥30 kg/m^2; NC, not calculated; ND, not described; OR, odds ratio; Pro, prospective; Quintiles: Q1 < 22.6 kg/m^2, Q2 22.6–24.2 kg/m^2, Q3 24.2–26 kg/m^2, Q4 26–28.4 kg/m^2, Q5 > 28.4 kg/m^2 (used Q2 as reference); Retro, retrospective; WCOG, Working Group on Obesity in China. Underweight <18.5 kg/m^2, Normal 18.5–23.9 kg/m^2, Overweight 24–27.9 kg/m^2, Obese ≥28 kg/m^2; WHO^{2000}: Underweight <18.5 kg/m^2, Normal 18.5–24.9 kg/m^2, Overweight 25–29.9 kg/m^2, Obese ≥30 kg/m^2; WHO^{2008}: Underweight <18.5 kg/m^2, Lower normal 18.5–23 kg/m^2, Upper normal 23–25 kg/m^2, Pre-obese I 25–27.5 kg/m^2, Pre-obese II 27.5–30 kg/m^2, Obese ≥ 30 kg/m^2; WHO^{A1}, WHO Asian Indian: Underweight <18.5 kg/m^2, Normal 18.5–22.9 kg/m^2, Overweight 23–24.9 kg/m^2, Obese ≥25 kg/m^2; WHO^{NIH}: Underweight <19.9 kg/m^2, Normal 20–24.9 kg/m^2, Overweight 25–29.9 kg/m^2, Obese 30–34.9 kg/m^2, Morbidly obese ≥35 kg/m^2; WHO^{Asian}: Specifically for Asian populations, Low <18.5 kg/m^2, Normal 18.5–22.9 kg/m^2, High ≥23 kg/m^2.; [a]Local population standard charts[100] and "customized growth standards that adjust for gender and gestation as well as maternal size and pregnancy characteristics".[101]; [b]Calculated from data included in the paper, not explicitly stated.; [c]Used "appropriate neonatal growth charts developed for this population".[102]; [d]Based on definition of macrosomia as >3.5 kg (due to alignment with 90th percentile for birth weight in India).; [e]Growth charts or centiles used to calculate LGA were not described.; [f]Used "criterion derived from worldwide study".[103]; [g]Based on "gender-specific centiles for the Asian population".[104]; [h]Weight for gestational age "was calculated using own study population means and standard deviations".; [i]Birthweight above the 90th percentile of Chinese standard after adjusting for gender and gestational age (no other information given).; [j]National Health Commission of the People's Republic of China: Criteria for Weight of Adults 2013.; [k]LGA was defined as a birth weight greater than the sex and gestational age-specific 90th percentile.[105]; [l]Reported to use WHO recommendations for Asian populations but value ranges correspond to WCOG values.; [m]Chen et al. (2014).[106] [n]Custom: <19 kg/m^2, (reference) 19–22 kg/m^2, 22–25 kg/m^2, (used as overweight in table in above) 25–28 kg/m^2; (used as obese in table above) ≥ 28 kg/m^2.[110]

GWG and the formulas used to calculate GWG (e.g., delivery weight—pre-pregnancy weight vs. last prenatal weight measure vs. first prenatal weight measure) (Table 4). The prevalence of macrosomia in women who experienced excessive GWG during pregnancy (according to each study's criteria) ranged from 1.4% in Japan in 2001–2002[30] to 13% in China in 2009–2011,[75] while the prevalence of LGA ranged from 12.6% in Korea in 2005–2010[40] to 27.8% in China in 2012[79] (Table 4). The highest aOR associated with excessive GWG was 2.7, reported in a Japanese study.[35]

Fifteen studies described the prevalence of macrosomia/LGA in women with impaired glucose tolerance and/or GDM (Table 5). Again, a variety of growth and centile charts were used to calculate LGA (some charts were not defined or specified) and almost every study used different criteria to diagnose impaired glucose tolerance or GDM (Table 5), for example, 1 or 2 h glucose measures and a variety of cutoffs. Two Chinese studies[78,86] and one Vietnamese study[66] described both prevalence of macrosomia/LGA for women with GDM; the prevalence in the Chinese studies was similar but the prevalence of LGA was markedly higher compared to macrosomia in the Vietnamese study (again reflecting the difference between calculation of macrosomia and LGA). The highest prevalence of LGA (29.6%) in women with GDM was in the 1989 Malaysian study.[48] Many included studies did not calculate the OR/aOR for macrosomia/LGA following impaired glucose tolerance/GDM and did not include impaired glucose tolerance as a key group of interest.

The variability and lack of standardization in the growth charts used to calculate LGA is particularly striking in these "at risk" analyses. In almost all of the papers included in these sub-analyses, there is no way to accurately reference or source the growth chart that is used, meaning that the actual birth weight cut off that was used is unknown/unreported. While many papers use standardized or, at the least, well-defined criteria for categories of overweight and obesity, GWG and criteria for diagnosing GDM, the same cannot be said for the LGA classifications.

Discussion

We have captured the prevalence of macrosomia/LGA births in 16 countries in Asia from 1994 to 2017 (Tables 1 and 2). Variations in the measures reported

TABLE 4 Relationship between gestational weight gain and macrosomia/large for gestational age in Asia

References	Country	Time period	*n*	Type of study	GWG guideline	GWG calc	BMI calc	M or LGA	Overall study prevalence	Prevalence in adequate GWG	Prevalence in excessive GWG	Excessive OR (aOR)
Lu et al[8]	China	2005	594 472	Retro	IOM	Last PN—first PN	WHO^{AI}	M	7.83	6.82	10.66	(1.71)
Shi et al[69]	China	2006–2010	27 322	Retro	IOM	Last PN—first PN	WHO^{2000}	M	8.6	ND	ND	2.59
							WGOC	M	8.6	ND	ND	2.59
Li et al[75]	China	2009–2011	33 793	Retro	IOM	Delivery—pre-preg	WGOC	M	9.8[a]	5.8	13	2.28
								LGA[b]	10.4[a]	6.2	13.9	2.32
Zhang et al[79]	China	2012	14 196	Retro	IOM	Delivery—pre-preg	WGOC	M	6.6	4.5	9.6	(2.1)
								LGA[c]	22.1	18.1	27.8	(1.5)
Takimoto et al[30]	Japan	2001–2002	46 659	Retro	JSOG	ND	JSOG	M	0.9	0.7	1.4[a]	1.58 –2.26
Enomoto et al[35]	Japan	2013	97 157	Retro	IOM	ND	IOM^{2009}	M	0.8[a]	1[d]	2.7[d]	2.70
								LGA	10.1[a]	13.2[d]	21.2[d]	1.73
Wie et al[41]	Korea	2000–2007	7843	Retro	IOM	Delivery—pre-preg	IOM^{2009}	LGA	9.6[a]	7.6	15.4	ND
Park et al[40]	Korea	2005–2010	2311	Retro	custom	Delivery—pre-preg	WHO^{Asian}	M	3.2[a]	2.5[a]	5.2[a]	ND
								LGA[e]	8.2[a]	7.1[a]	12.6[a]	ND
Hung et al[58]	Taiwan	2009–2014	9301	Retro	IOM	Delivery—pre-preg	WHO^{2000}	M	1.9[a]	1.5	3.6	(2.2)
								LGA	8.8[a]	8.2	14	(1.8)
Sunsaneevithayakul et al[62]	Thailand	2011–2012	5200	Retro	IOM/ custom	Delivery—pre-preg or delivery—first visit	WHO	LGA[e]	6.6	ND	ND	ND
Ota et al[64]	Vietnam	2007–2008	2989	Pro		Delivery—pre-preg	WHO^{Asian}	LGA[f]	9.9	10.1	17.6	(1.93)

[a]OR, adjusted odds ratio; Calc, calculated; GWG, gestational weight gain; IOM: Adequate ranges 12.5–18 kg (pre-pregnancy BMI < 18.5 kg/m^2), 11.5–16 kg (BMI 18.5–23.9 kg/m^2), 7–11.5 kg (BMI 24.0–27.9 kg/m^2), and 5–9 kg (BMI ≥28 kg/m^2); JSOG, Japan Society of Obstetrics and Gynecology Perinatal Database; NC = not calculated; ND, not described; OR, odds ratio; PN, prenatal; WCOG, Working Group on Obesity in China. Underweight <18.5 kg/m^2, Normal 18.5–23.9 kg/m^2, Overweight 24–27.9 kg/m^2, Obese ≥28 kg/m^2; WHO^{2000}: Underweight <18.5 kg/m^2, Normal 18.5–24.9 kg/m^2, Overweight 25–29.9 kg/m^2, Obese ≥30 kg/m^2; WHO^{Asian}: Specifically for Asian populations, Low <18.5 kg/m^2, Normal 18.5–22.9 kg/m^2, High ≥23 kg/m^2; WHO^{AI} , WHO Asian Indian: Underweight <18.5 kg/m^2, Normal 18.5–22.9 kg/m^2, Overweight 23–24.9 kg/m^2, Obese ≥25 kg/m^2.; [a]Calculated from data included in the paper, not explicitly stated.; [b]Weight for gestational age "was calculated using own study population means and standard deviations".; [c]Birthweight above the 90th percentile of Chinese standard after adjusting for gender and gestational age (no other information given).; [d]Based only on normal weight women within the study population.; [e]Growth charts or centiles used to calculate LGA were not described. [f]Based on "gender-specific centiles for the Asian population".[104]

TABLE 5 Relationship between glucose tolerance/gestational diabetes mellitus and macrosomia/large for gestational age in Asia

References	Country	Time period	*n*	Type of study	M or LGA	Overall study prevalence	Prevalence in normal GT	Prevalence in impaired GT	Prevalence in GDM	Impaired GT OR (aOR)	GDM OR/ (aOR)
Pan et al[76]	China	2010–2012	17 808	Pro	M	8.9	8.6	NA	8/17.4/15[a]	ND	ND
					LGA[b]	9.9	9.5	NA	11.6/20.5/17.6[a]	ND	ND
Yang et al[78]	China	2010–2012	19 622	Pro	M	9.1	8.6[c]	ND	15.9[c]	ND	2.7
					LGA	8.1	8.2[c]	ND	16[c]	ND	2.57
Wang et al[84]	China	2013	14 168	Retro	M	7.86	7.36	ND	9.9[c]	ND	ND
Feng et al[86]	China	2013	14 741	Retro	M	7.8[c]	7.29	ND	9.67[d]	ND	1.36
					LGA	6.6[c]	5.87	ND	9.33[d]	ND	1.65
Yan 2020[126]	China	2013–2015	43 086	Pro	M	6.5[c]	6.22	ND	7.62[e]	ND	ND
Tu et al[94]	China	2012–2016	14 984	Pro	M	2.92	2.48	ND	3[c,f]	ND	ND
Balaji et al[25]	India	2009–2010	1463	Pro	LGA[g]	9.8	9.8	ND	9.9[h]	ND	0.75[i]
Bhavadharini[28]	India	2013–2015	1459	Pro	M/LGA[j]	6.6[c]	4.7	9.2[k]	ND	1.92	ND
Boo[48]	Malaysia	1989	24 856	Pro	LGA[l]	2.9	2.8	ND	29.6[m]	ND	ND
Ahkter et al[50]	Pakistan	1989–1993	6830	Retro	M	13.1	ND	10.5	23.5[n]	ND	ND
Aris et al[52]	Singapore	ND	1247	Pro	LGA[o]	ND	6.1	17.9[p]	NA	3.18	NA
Ho[57]	Taiwan	2011–2013	5194	Pro	M	1.0	0.8	2.0[q]	3.1[q]	2.5	3.6
Srichumchit et al[63]	Thailand	2002–2012	21 771	Retro	LGA[b]	14	13.6	NA	20.0[a]	NA	(1.48)
Hirst et al[65]	Vietnam	2010–2011	2772	Pro	LGA[r]	12.1[c]	11.76	16.06[s]	18.9[s]	(1.31)	(1.16)
Nguyen et al[66]	Vietnam	2015–2016	1909	Pro	M	3.4	1	ND	2.1	ND	ND
					LGA[t]	8.3[c]	5.7	ND	7.8[u]	ND	ND

aOR, adjusted odds ratio; CC, case–control; GDM, gestational diabetes mellitus; GT, glucose tolerance; NA, not applicable; ND, not described; OR, odds ratio; Pro, prospective; Retro, retrospective.; [a]National Diabetes Data Group criteria, 1979.; [b]Article refers to measure as "fetal macrosomia" but definition given in Materials and Methods describes LGA; "defined as birth weight heavier than the 90th percentile for each gestational age".; [c]Calculated from data included in the paper, not explicitly stated.; [d]Classified as GDM if any of the following OGTT values were met or exceeded: fasting ≥5.10 mmol/L, 1 h ≥ 10.0 mmol/L, or 2 h ≥ 8.5 mmol/L.; [e]IADPSG.[107]; [f]IADPSG.[108]; [g]Article uses the term macrosomia however defines this as infant birth weight above 90th percentile (> 3.45 kg). No other definition or explanation was provided.; [h]GDM 2 h glucose ≥7.8 mmol/L. Women with GDM received 2 weeks of medical nutrition therapy and, if unresponsive to this treatment, insulin. There was no untreated GDM group.; [i]Impaired 2 h glucose between 8.0–10.9 mmol/L; GDM > 11.0 mmol/L.; [j]Based on definition of macrosomia as >3.5 kg (due to alignment with 90th percentile for birth weight in India).; [k]Glycated hemoglobin ≥5.0%.; [l]90th percentile.[109]; [m]No definition or criteria for GDM included in paper.; [n]Impaired 1 h glucose between 7.8–9.7 nmol/L; GDM > 9.8 mmol/L. Diabetes in pregnancy population—16.5% has diabetes prior to pregnancy, 83.5% had GDM.; [o]90th percentile, based on centile charts determined for gender-ethnic groups (Chinese, Malay, Indian) in the cohort with gestational ages of 34–41 weeks.; [p]Impaired 2 h glucose ≥8.8 mmol/L.; [q]Carpenter and Coustan criteria. Two step testing: 50 g 1 h glucose challenge (threshold ≥140 mg/dL) then 100 g 3 h glucose challenge (threshold ≥140 mg/dL). Impaired glucose tolerance: positive first test, negative second test. GDM: two positive tests.; [r]90th percentile, based on local growth charts.; [s]Impaired glucose, International Association of the Diabetes and Pregnancy Study Groups (IADPSG) criterion positive but American Diabetes Association (ADA) criterion negative; GDM, positive on both IADPSG and ADA criterion.; [t]90th percentile with no further information given. [u]IADPSG/WHO criteria (prevalences as a result of other diagnostic critera were also included, refer to original manuscript).[110]

the growth charts and definitions used to calculate LGA, size of the studies, as well as the small number of studies/country (except China, Japan and Taiwan) make it more difficult to conclude if the prevalence of high birth weight babies is really changing. Nevertheless, LGA rates appear to be consistently higher than reported macrosomia, and studies that do allow for comparison within countries seem to suggest increases in prevalence over time. This unique data set provides an opportunity to illustrate the variability of growth charts used to calculate LGA, compare prevalence over time in the same country, to evaluate the relationship between macrosomia and LGA within countries, as well as the prevalence of macrosomia/LGA between geographically and ethnically similar countries in the region. Given the relationship between high birth weight and short- and long-term risks for mother and infant, adequate reporting is a necessary first step in understanding the magnitude of the issue.

The large number of studies from China, including studies which reported data over multiple time periods, suggests that the prevalence of macrosomia in China is still highly variable, and may likely depend on the region (urban or rural) in which the population is assessed. However, two prefecture level cities, only 1000 km apart, reported quite disparate levels of macrosomia in 2015; 13.9%[90] compared to 3.4%.[93] A more intensive regional analysis would be required to understand these differences. Interestingly, in 1995–2009 the rate of macrosomia appeared to be significantly lower in a Chinese population in Hong Kong,[55] highlighting the importance of environmental factors in determining outcomes in similar ethnic populations. In contrast, LGA prevalence did not seem to decrease over time, perhaps reflecting the appropriate use of local growth charts.

Maternal BMI, excessive GWG, and glucose intolerance/GDM were all shown to be risk factors for macrosomia/LGA in the Chinese populations, with the greatest risk conferred by being obese (aOR = 4.1).[9] The largest Chinese study (n = 594 472) attributed increases in prevalence of macrosomia from 1994 to 2000 to increasing GWG.[8] In this study, excessive GWG was recorded as weight gain >12.5 kg; the Institute of Medicine's guidelines indeed suggest that weight gain of 11.3–15.9 kg is excessive in women with normal pre-pregnancy BMI. Thus, efforts to monitor GWG in China may have helped attenuate the prevalence of macrosomia to current estimates of 6%–7%. Insufficient data from other countries in Asia lead to challenges in understanding temporal changes in the region and potential influencing (environmental) factors.

Surprisingly, the highest prevalence of macrosomia (>10%) was reported in China[68,71,90] and Pakistan,[50] while the highest prevalence of LGA (>10%) was in Bangladesh,[20] China,[8,77,79,82,95,96,98] India,[111] Japan,[35] Thailand,[63] and Vietnam.[65] The latter countries have traditionally low average birth weights and a high prevalence of low birth weight and term small for gestational age (SGA) births.[113] Many of these countries experience the dual burden of malnutrition, and it appears the consequences of this burden may be apparent from birth. These data highlight the discordance between reporting only macrosomia or only LGA, as well as the limiting assumption that a country with a low birth weight problem could not have a simultaneous high birth weight problem. It is essential that more studies report both measures. In addition, there is an urgent need to develop charts for birth weights by gestational age for these countries to allow for LGA calculations and for these charts to be used consistently and across different hospitals/facilities. It would be interesting to evaluate the applicability of the WHO Child Growth Standards in monitoring post-natal growth in countries with a high prevalence of extreme birth weights.

In studies that assess both macrosomia and LGA, we show that the majority report a marked disparity between prevalence of each. The largest disparity was found in Japan with macrosomia prevalence of 0.8% and LGA prevalence of 10.1% in almost 100 000 participants.[35] Similarly, a large Chinese study of ~600 000 participants reported macrosomia prevalence of 7.83% and LGA prevalence of 18.98%.[8] These discrepancies are clearly explained by the use of local birth weight charts, in which the 90th percentile for birth weight is substantially lower than 4000 g; however, they highlight two important points: the need for researchers to assess LGA in all study populations and the need to consider the meaningfulness of the 90th centile in populations where it correlates to an "average" birth weight in US/European populations. It is now clear that the growth charts being used may not adequately lead to a true reflection of birth weight distribution in a country. However, the confounding factor in our analysis is that, due to missing or unclear definitions of the growth charts used to calculate LGA, direct comparisons cannot be made even within countries. This is also a factor in reporting LGA in Europe, with many countries not using standardized

WHO guidelines/growth charts.[114,115] Therefore, the definition of LGA may lead to quite different cut offs between countries and thus the associated risk of unbalanced growth and/or adverse later life outcomes may be even more different than we expect.

Nevertheless, though we suggest that more studies should report prevalence of LGA using local/ethnically appropriate growth charts, the relevance and implications of being an LGA infant in countries that are known to have low mean birth weights are unclear. The 90th centile is relatively arbitrary and recent discussions have suggested that, in the USA, the 97th centile may be more appropriate, as it may identify infants at 2-fold risk of low 5 min Apgar scores.[116] Similar research has been published regarding cutoffs for macrosomia; in one study, macrosomia ≥4000 g indicated increased risk of birth and neonatal complications, whereas ≥4500 g appeared to be more predictive of neonatal morbidity and ≥5000 g predictive of neonatal mortality.[11] Similarly, a meta-analysis of 17 articles described risks of birth trauma increasing from 4% to 12% and 25% for birth weights of ≥4000, ≥ 4500, and ≥5000 g, respectively.[12] In addition, babies born ≥4000 g were three times more likely to experience respiratory distress syndrome, hyperbilirubinemia, or metabolic disturbances, such as hypoglycaemia.[12] These short-term, immediate consequences are relatively well described for the different categories; however, it is unclear whether there may be differing long term consequences for each. Much of these data are generated from US cohorts; different lower absolute birth weights (but >90th centile for local charts) in Asia populations may or may not confer the same risk. There are differing morbidities associated with birth weights ≥4500 g when comparing between ethnicities with different body compositions[116]; however, further research is required. Our analysis illustrates the variability in the data and the need for consistency and standardization.

The INTERGROWTH-21st Project has recently published international weight standards for newborn infants, to complement the WHO's growth charts for children under 5 years of age.[110] These standards have several important advantages; they are prescriptive, compared to current charts that use historical, potentially outdated data; they are "population-based, multi-ethnic, multi-country, and sex-specific"; and it has been shown that, once nutritional status was controlled, the eight populations that were used (including two from India and China) showed consistently similar birth weights, without ethnic or genetic variance.[110] While INTERGROWTH-21st was initially focused on understanding SGA, and local validation is required to avoid misclassification of SGA in certain ethnic groups,[118] we hope that the standards may also be used to classify LGA infants. Wide-spread adoption of the standards may generate meaningful, translatable, transferrable data about infants born macrosomic/LGA. A possible limitation of the charts is that they are based on a relatively small population of infants that are born late preterm or term, and do not consider the underlying morbidity that may contribute to earlier births. Given that new guidelines are often developed every 4–5 years,[110,119] consensus and inclusion of multiple assessments of prevalence and risk according to the most widely used guidelines may be required for a comprehensive assessment. Yet, even if the perfect guideline or growth chart existed, it loses its power if it is not applied broadly and consistently. Our overview suggests that this is an important point for communication to researchers in Asia.

We also evaluated the risk factors for macrosomia/LGA in Asia. A high pre-pregnancy or first pregnancy visit BMI conferred the highest risk for subsequent birth of a macrosomic/LGA infant. However, given that high pre-pregnancy BMI was the most studied risk factor, this could be due to reporting bias. The highest prevalence of macrosomia (23.5%)[50] and LGA (29.6%)[48] reported across our included studies were those in sub-populations with GDM (Table 5). However, only a few studies that assessed glucose intolerant/GDM sub-populations calculated risk. The reported OR/aORs for macrosomia and LGA in a GDM population were similar to the reported OR/aORs for macrosomia and LGA in a glucose intolerant population (Table 5). The relatively high rates of macrosomia/LGA in women with glucose intolerance (sometimes comparable to rates of women with GDM) could be due to late diagnosis and inadequate treatment in this (often neglected) population. These findings are interesting in light of a recent study that showed that South Central Asian and Chinese women with GDM living in New York had a relatively low risk of macrosomia (aOR 1.0–1.2) compared to Caribbean, Sub-Saharan African and African American women with GDM (aOR 2.4–2.6).[120] Additionally, changes in the guidelines for classification of GDM influence the reported prevalence of macrosomia; in Taiwan, the 2010 implementation of the new International Association of the Diabetes and Pregnancy Study Groups (IADPSG) guidelines for diagnosing GDM resulted in a reduction in the rates of

macrosomia (2.3%–1.5%) and LGA (7.8–6.3%) in the offspring of GDM mothers[55] whereas in China a shift from the 1999 WHO guidelines to the 2010 IADPSG guidelines resulted in rates of macrosomia/LGA almost doubling.[76] The fact that we excluded data from Asian populations living in countries other than Asia is a limitation of this review. The interaction between ethnicity, environment (country, latitude), glucose tolerance, and macrosomia/LGA is underexplored, though initial direct comparisons indicate that ethnic differences may result in significant underreporting of glucose intolerance/GDM.[18] Without this knowledge, there is an obvious gap in evidence-based recommendations for at-risk births in Asia.

There was a lack of reliable information about confounding factors in many of our included large population-based cohort studies. Some studies addressed this, noting lack of data on pre-existing diabetes or development of GDM in the study participants as a limitation[8] or variability of the data due to different sites.[121] Given that multiple factors contribute to the dynamic rates of macrosomia, addressing this issue in large-scale population studies will be a necessary step to reduce variability and increase translatable findings. For instance, the push-pull influence of decreasing gestational age (due to increasing elective Caesarian sections) on a background of rising maternal pre-pregnancy BMI and GWG is likely to influence reported rates.

Within our inclusion criteria, there were 38 papers identified by our 2015 search (1990–2015), and 58 papers included in our 2015–2018 search, indicating the rising interest in this subject. Our original search was surprising for the lack of meta-analyses assessing risk factors/development of macrosomia/LGA. However, our updated search showed progress, with multiple meta-analyses published assessing, separately, maternal obesity (OR 2.17, 95% CI: 1.92, 2.45),[122] excessive GWG (OR 2.35, 95% CI: 1.95, 2.85),[123] and GDM (OR 1.71, 95% CI: 1.52, 1.94)[10] as independent risk factors for macrosomia. The findings of these meta-analyses, focused on non-Asian populations, are in line with the data from Asia described in this review.

We have systematically collated data regarding the prevalence and associated risk factors for macrosomia and LGA in 17 countries in Asia. Macrosomia was widely reported, most often using the ≥4000 g definition; LGA was less widely reported, and studies often failed to define and describe the appropriateness of birth weight charts used for its calculation. China and Pakistan reported the highest prevalence of macrosomia while the highest prevalence of LGA was in China, Bangladesh, India, Japan, Thailand, and Vietnam. Prevalence of macrosomia appears to be stabilizing in China; however, rates of LGA were consistently higher than that of macrosomia. Pre-pregnancy BMI, GWG, and impaired glucose tolerance/GDM were consistent risk factors across Asia for the development of macrosomia/LGA. We propose that future studies report prevalence of both macrosomia and LGA but suggest that more research is required to understand the consequences of being born LGA according to country-specific growth charts, where mean birth weights are low compared to Western norms. Consistent use of growth charts could facilitate future comparisons and analyses.

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Author Contribution

LH, EMvdB and RvE conceived the idea for the manuscript, wrote the manuscript and contributed to all aspects of the interpretation of data and discussion. LH reviewed all included papers, extracted data, and prepared the summaries and tables.

Disclosure

All authors were employees of Danone Nutricia Research at the time of study conduct.

References

1. Druet C, Stettler N, Sharp S, Simmons RK, Cooper C, Davey Smith G, et al. Prediction of childhood obesity by infancy weight gain: an individual-level meta-analysis. *Paediatr Perinat Epidemiol*. 2012;**26**:19–26.
2. Leddy MA, Power ML, Schulkin J. The impact of maternal obesity on maternal and fetal health. *Rev Obstet Gynecol*. 2008;**1**:170–8.
3. Oken E. Secular trends in birthweight. *Nestle Nutr Inst Workshop Ser*. 2013;**71**:103–14.
4. Kramer MS, Morin I, Yang H, Platt RW, Usher R, McNamara H, et al. Why are babies getting bigger?

Temporal trends in fetal growth and its determinants. *J Pediatr*. 2002;**141**:538–42.
5. Surkan PJ, Hsieh CC, Johansson AL, Dickman PW, Cnattingius S. Reasons for increasing trends in large for gestational age births. *Obstet Gynecol*. 2004;**104**:720–6.
6. Kolcic I. Double burden of malnutrition: a silent driver of double burden of disease in low- and middle-income countries. *J Glob Health*. 2012;**2**:020303.
7. Bao C, Zhou Y, Jiang L, Sun C, Wang F, Xia W, et al. Reasons for the increasing incidence of macrosomia in Harbin, China. *BJOG*. 2011;**118**:93–8.
8. Lu Y, Zhang J, Lu X, Xi W, Li Z. Secular trends of macrosomia in Southeast China, 1994-2005. *BMC Public Health*. 2011;**11**:818.
9. Li G, Kong L, Li Z, Zhang L, Fan L, Zou L, et al. Prevalence of macrosomia and its risk factors in China: a multicentre survey based on birth data involving 101,723 singleton term infants. *Paediatr Perinat Epidemiol*. 2014;**28**:345–50.
10. He XJ, Qin FY, Hu CL, Zhu M, Tian CQ, Li L. Is gestational diabetes mellitus an independent risk factor for macrosomia: a meta-analysis? *Arch Gynecol Obstet*. 2015;**291**:729–35.
11. Boulet SL, Alexander GR, Salihu HM, Pass M. Macrosomic births in the United States: determinants, outcomes, and proposed grades of risk. *Am J Obstet Gynecol*. 2003;**188**:1372–8.
12. Rossi AC, Mullin P, Prefumo F. Prevention, management, and outcomes of macrosomia: a systematic review of literature and meta-analysis. *Obstet Gynecol Surv*. 2013;**68**:702–9.
13. Schellong K, Schulz S, Harder T, Plagemann A. Birth weight and long-term overweight risk: systematic review and a meta-analysis including 643,902 persons from 66 studies and 26 countries globally. *PLoS One*. 2012;**7**:e47776.
14. Harder T, Rodekamp E, Schellong K, Dudenhausen JW, Plagemann A. Birth weight and subsequent risk of type 2 diabetes: a meta-analysis. *Am J Epidemiol*. 2007;**165**:849–57.
15. Harder T, Roepke K, Diller N, Stechling Y, Dudenhausen JW, Plagemann A. Birth weight, early weight gain, and subsequent risk of type 1 diabetes: systematic review and meta-analysis. *Am J Epidemiol*. 2009;**169**:1428–36.
16. James-Todd TM, Karumanchi SA, Hibert EL, et al. Gestational age, infant birth weight, and subsequent risk of type 2 diabetes in mothers: Nurses' health study II. *Prev Chronic Dis*. 2013;**10**:E156.
17. Koyanagi A, Zhang J, Dagvadorj A, Hirayama F, Shibuya K, Souza JP, et al. Macrosomia in 23 developing countries: an analysis of a multicountry, facility-based, cross-sectional survey. *Lancet*. 2013;**381**:476–83.
18. Farrar D, Fairley L, Santorelli G, Tuffnell D, Sheldon TA, Wright J, et al. Association between hyperglycaemia and adverse perinatal outcomes in south Asian and white British women: analysis of data from the born in Bradford cohort. *Lancet Diabetes Endocrinol*. 2015;**3**:795–804.
19. Lenoir-Wijnkoop I, van der Beek EM, Garssen J, Nuijten MJ, Uauy RD. Health economic modeling to assess short-term costs of maternal overweight, gestational diabetes, and related macrosomia - a pilot evaluation. *Front Pharmacol*. 2015;**6**:103.
20. Fall CH, Fisher DJ, Osmond C, Margetts BM. Multiple micronutrient supplementation during pregnancy in low-income countries: a meta-analysis of effects on birth size and length of gestation. *Food Nutr Bull*. 2009;**30**(Suppl 4):S533–46.
21. Margetts BM, Fall CH, Ronsmans C, Allen LH, Fisher DJ. Multiple micronutrient supplementation during pregnancy in low-income countries: review of methods and characteristics of studies included in the meta-analyses. *Food Nutr Bull*. 2009;**30**(Suppl 4):S517–26.
22. Leung TY, Leung TN, Sahota DS, Chan OK, Chan LW, Fung TY, et al. Trends in maternal obesity and associated risks of adverse pregnancy outcomes in a population of Chinese women. *BJOG*. 2008;**115**:1529–37.
23. Cheng YK, Lao TT, Sahota DS, Leung VK, Leung TY. Use of birth weight threshold for macrosomia to identify fetuses at risk of shoulder dystocia among Chinese populations. *Int J Gynaecol Obstet*. 2013;**120**:249–53.
24. Chaemsaithong P, Leung TY, Sahota D, Cheng YKY, Leung WC, Lo TK, et al. Body mass index at 11-13 weeks' gestation and pregnancy complications in a southern Chinese population: a retrospective cohort study. *J Matern Fetal Neonatal Med*. 2019;**32**:2056–68.
25. Balaji V, Balaji M, Anjalakshi C, Cynthia A, Arthi T, Seshiah V. Diagnosis of gestational diabetes mellitus in Asian-Indian women. *Ind J Endocrinol Metab*. 2011;**15**:187–90.
26. Jeyaseelan L, Yadav B, Silambarasan V, Vijayaselvi R, Jose R. Large for gestational age births among south Indian women: temporal trend and risk factors from 1996 to 2010. *J Obstet Gynaecol India*. 2016;**66**(Suppl 1):42–50.
27. Bhavadharini B, Anjana RM, Deepa M, Jayashree G, Nrutya S, Shobana M, et al. Gestational weight gain and pregnancy outcomes in relation to body mass index in Asian Indian women. *Ind J Endocrinol Metab*. 2017;**21**:588–93.
28. Bhavadharini B, Mahalakshmi MM, Deepa M, Harish R, Malanda B, Kayal A, et al. Elevated glycated hemoglobin predicts macrosomia among Asian Indian pregnant women (WINGS-9). *Ind J Endocrinol Metab*. 2017;**21**:184–9.
29. Kabeya Y, Goto A, Kato M, Takahashi Y, Matsushita Y, Inoue M, et al. History of having a macrosomic infant and the risk of diabetes: the Japan public health center-based prospective diabetes study. *PLoS One*. 2013;**8**:e84542.
30. Takimoto H, Sugiyama T, Fukuoka H, Kato N, Yoshiike N. Maternal weight gain ranges for optimal fetal growth in Japanese women. *Int J Gynaecol Obstet*. 2006;**92**:272–8.
31. Yokomichi H, Tanaka T, Suzuki K, Akiyama T, Yamagata Z. Macrosomic neonates carry increased risk of dental caries in early childhood: findings from a cohort study, the Okinawa child health study, Japan. *PLoS One*. 2015;**10**:e0133872.
32. Morikawa M, Cho K, Yamada T, Sato S, Minakami H. Fetal macrosomia in Japanese women. *J Obstet Gynaecol Res*. 2013;**39**:960–5.
33. Matsuda Y, Ogawa M, Nakai A, Hayashi M, Satoh S, Matsubara S. Fetal/placental weight ratio in term Japanese pregnancy: its difference among gender, parity, and infant growth. *Int J Med Sci*. 2015;**12**:301–5.

34. Toma R, Aoki S, Fujiwara K, Hirahara F. Associations of pre-pregnancy obesity with adverse pregnancy outcomes and the optimal gestational weight gain in Japanese women. *Clin Exp Obstet Gynecol*. 2017;**44**:190–4.
35. Enomoto K, Aoki S, Toma R, Fujiwara K, Sakamaki K, Hirahara F. Pregnancy outcomes based on pre-pregnancy body mass index in Japanese women. *PLoS One*. 2016;**11**: e0157081.
36. Takata N, Tanaka K, Nagata C, Arakawa M, Miyake Y. Preterm birth is associated with higher prevalence of wheeze and asthma in a selected population of Japanese children aged three years. *Allergol Immunopathol*. 2019;**47**(5): 425–30.
37. Oawada N, Aoki S, Sakamaki K, Obata S, Seki K, Hirahara F. Clinical significance of low result of 1-h 50-g glucose-challenge test in pregnant women. *J Matern Fetal Neonatal Med*. 2019;**32**:58–61.
38. Takagi K, Iwama N, Metoki H, et al. Paternal height has an impact on birth weight of their offspring in a Japanese population: the Japan environment and children's study. *J Dev Orig Health Dis*. 2019;**10**(5):542–54.
39. Shigemi D, Yamaguchi S, Aso S, Yasunaga H. Predictive model for macrosomia using maternal parameters without sonography information. *J Matern Fetal Neonatal Med*. 2019; **32**(22):3859–63.
40. Park JH, Lee BE, Park HS, Ha EH, Lee SW, Kim YJ. Association between pre-pregnancy body mass index and socioeconomic status and impact on pregnancy outcomes in Korea. *J Obstet Gynaecol Res*. 2011;**37**:138–45.
41. Wie JH, Park IY, Namkung J, Seo HW, Jeong MJ, Kwon JY. Is it appropriate for Korean women to adopt the 2009 Institute of Medicine recommendations for gestational weight gain? *PLoS One*. 2017;**12**:e0181164.
42. Cho GJ, Kim SY, Lee HC, Lee KM, Han SW, Oh MJ, et al. Risk of adverse obstetric outcomes and the abnormal growth of offspring in women with a history of thyroid cancer. *Thyroid*. 2019;**29**:879–85.
43. Choi SK, Park IY, Shin JC. The effects of pre-pregnancy body mass index and gestational weight gain on perinatal outcomes in Korean women: a retrospective cohort study. *Reprod Biol Endocrinol*. 2011;**9**:6.
44. Cho EH, Hur J, Lee KJ. Early gestational weight gain rate and adverse pregnancy outcomes in Korean women. *PLoS One*. 2015;**10**:e0140376.
45. Song IG, Kim MS, Shin SH, Kim EK, Kim HS, Choi S, et al. Birth outcomes of immigrant women married to native men in the Republic of Korea: a population register-based study. *BMJ Open*. 2017;**7**:e017720.
46. Cho HW, Ouh YT, Lee KM, Han SW, Lee JK, Cho GJ, et al. Long-term effect of pregnancy-related factors on the development of endometrial neoplasia: a nationwide retrospective cohort study. *PLoS One*. 2019;**14**:e0214600.
47. Lee JW, Lee M, Lee J, Kim YJ, Ha E, Kim HS. The protective effect of exclusive breastfeeding on overweight/obesity in children with high birth weight. *J Korean Med Sci*. 2019; **34**:e85.
48. Boo NY. Morbidity and mortality of infants of diabetic mothers born at the maternity hospital, Kuala Lumpur. *Med J Malaysia*. 1992;**47**:56–9.
49. Ganeshan M, Bujang MA, Soelar SA, Karalasingam SD, Suharjono H, Jeganathan R. Importance of adopting BMI classifications using public health action points to delineate obstetric risk factors resulting in worsening obstetric outcomes among Asian population. *J Obstet Gynaecol India*. 2018;**68**:173–8.
50. Ahkter J, Qureshi R, Rahim F, Moosvi S, Rehman A, Jabbar A, et al. Diabetes in pregnancy in Pakistani women: prevalence and complications in an indigenous south Asian community. *Diabet Med*. 1996;**13**:189–91.
51. Najmi RS. Distribution of birthweights of hospital born Pakistani infants. *J Pak Med Assoc*. 2000;**50**:121–4.
52. Aris IM, Gandhi M, Cheung YB, et al. A new population-based reference for gestational age-specific size-at-birth of Singapore infants. *Ann Acad Med Singapore*. 2014;**43**:439–47.
53. Weng YH, Yang CY, Chiu YW. Risk assessment of adverse birth outcomes in relation to maternal age. *PLoS One*. 2014; **9**:e114843.
54. Weng YH, Yang CY, Chiu YW. Neonatal outcomes in relation to sex differences: a national cohort survey in Taiwan. *Biol Sex Differ*. 2015;**6**:30.
55. Hung TH, Hsieh TT. The effects of implementing the International Association of Diabetes and Pregnancy Study Groups criteria for diagnosing gestational diabetes on maternal and neonatal outcomes. *PLoS One*. 2015;**10**: e0122261.
56. Lu MC, Huang SS, Yan YH, Wang P. Use of the National Diabetes Data Group and the carpenter-Coustan criteria for assessing gestational diabetes mellitus and risk of adverse pregnancy outcome. *BMC Pregnancy Childbirth*. 2016;**16**:231.
57. Ho TC, Yan YH, Lu MC, Yu CW, Wang P. Influence of medical nutrition therapy on borderline glucose intolerance in pregnant Taiwanese women. *J Matern Fetal Neonatal Med*. 2016;**29**:1181–6.
58. Hung TH, Chen SF, Hsu JJ, Hsieh TT. Gestational weight gain and risks for adverse perinatal outcomes: a retrospective cohort study based on the 2009 Institute of Medicine guidelines. *Taiwan J Obstet Gynecol*. 2015;**54**:421–5.
59. Hung TH, Hsieh TT. Pregestational body mass index, gestational weight gain, and risks for adverse pregnancy outcomes among Taiwanese women: a retrospective cohort study. *Taiwan J Obstet Gynecol*. 2016;**55**:575–81.
60. Sun CC, Chou HH, Chuang LL. Trends and risk factors of stillbirth in Taiwan 2006-2013: a population-based study. *Arch Gynecol Obstet*. 2019;**299**:961–7.
61. Saereeporncharenkul K. Correlation of BMI to pregnancy outcomes in Thai women delivered in Rajavithi hospital. *J Med Assoc Thai*. 2011;**94** (Suppl 2):S52–8.
62. Sunsaneevithayakul P, Titapant V, Ruangvutilert P, Sutantawibul A, Phatihattakorn C, Wataganara T, et al. Relation between gestational weight gain and pregnancy outcomes. *J Obstet Gynaecol Res*. 2014;**40**:995–1001.
63. Srichumchit S, Luewan S, Tongsong T. Outcomes of pregnancy with gestational diabetes mellitus. *Int J Gynaecol Obstet*. 2015;**131**:251–4.
64. Ota E, Haruna M, Suzuki M, Anh DD, Tho LH, Tam NTT, et al. Maternal body mass index and gestational weight gain and their association with perinatal outcomes in Viet Nam. *Bull World Health Organ*. 2011;**89**:127–36.
65. Hirst JE, Tran TS, Do MA, Morris JM, Jeffery HE. Consequences of gestational diabetes in an urban hospital in Viet Nam: a prospective cohort study. *PLoS Med*. 2012;**9**: e1001272.

66. Nguyen CL, Lee AH, Minh Pham N, et al. Prevalence and pregnancy outcomes of gestational diabetes mellitus by different international diagnostic criteria: a prospective cohort study in Vietnam. *J Matern Fetal Neonatal Med*. 2020;**33**(21): 3706–12.
67. Shan X, Chen F, Wang W, et al. Secular trends of low birthweight and macrosomia and related maternal factors in Beijing, China: a longitudinal trend analysis. *BMC Preg Childbirth*. 2014;**14**:105.
68. Gu S, An X, Fang L, et al. Risk factors and long-term health consequences of macrosomia: a prospective study in Jiangsu Province, China. *J Biomed Res*. 2012;**26**:235–40.
69. Shi P, Yang W, Yu Q, Zhao Q, Li C, Ma X, et al. Overweight, gestational weight gain and elevated fasting plasma glucose and their association with macrosomia in chinese pregnant women. *Matern Child Health J*. 2014;**18**: 10–5.
70. Zhang L, Shen S, He J, Chan F, Lu J, Li W, et al. Effect of Interpregnancy interval on adverse perinatal outcomes in southern China: a retrospective cohort study, 2000-2015. *Paediatr Perinat Epidemiol*. 2018;**32**:131–40.
71. Sun L, Yue H, Sun B, Han L, Qi M, Tian Z, et al. Estimation of birth population-based perinatal-neonatal mortality and preterm rate in China from a regional survey in 2010. *J Matern Fetal Neonatal Med*. 2013;**26**:1641–8.
72. Hou L, Wang X, Li G, Zou L, Chen Y, Zhang W. Cross sectional study in China: fetal gender has adverse perinatal outcomes in mainland China. *BMC Pregnancy Childbirth*. 2014;**14**:372.
73. Luo XL, Zhang WY. Obstetrical disease spectrum in China: an epidemiological study of 111,767 cases in 2011. *Chin Med J (Engl)*. 2015;**128**:1137–46.
74. Liu H, Chen S, Zhu H, Yang H, Gong F, Wang L, et al. Correlation between preconception maternal non-occupational exposure to interior decoration or oil paint odour and average birth weight of neonates: findings from a nationwide cohort study in China's rural areas. *BMJ Open*. 2017;**7**: e013700.
75. Li N, Liu E, Guo J, Pan L, Li B, Wang P, et al. Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One*. 2013;**8**:e82310.
76. Pan L, Leng J, Liu G, Zhang C, Liu H, Li M, et al. Pregnancy outcomes of Chinese women with gestational diabetes mellitus defined by the IADPSG's but not by the 1999 WHO's criteria. *Clin Endocrinol (Oxf)*. 2015;**83**: 684–93.
77. Chen S, Zhou X, Zhu H, Yang H, Gong F, Wang L, et al. Preconception TSH and pregnancy outcomes: a population-based cohort study in 184 611 women. *Clin Endocrinol (Oxf)*. 2017;**86**:816–24.
78. Yang W, Liu J, Li J, Liu J, Liu H, Wang Y, et al. Interactive effects of prepregnancy overweight and gestational diabetes on macrosomia and large for gestational age: a population-based prospective cohort in Tianjin. *China Diabetes Res Clin Pract*. 2019;**154**:82–9.
79. Zhang CH, Liu XY, Zhan YW, Zhang L, Huang YJ, Zhou H. Effects of prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *Asia Pac J Public Health*. 2015;**27**:620–30.
80. Pei L, Kang Y, Zhao Y, Cheng Y, Yan H. Changes in socioeconomic inequality of low birth weight and Macrosomia in Shaanxi Province of Northwest China, 2010-2013: a cross-sectional study. *Medicine*. 2016;**95**:e2471.
81. Liu Y, Li G, Zhang W. Effect of fetal gender on pregnancy outcomes in northern China. *J Matern Fetal Neonatal Med*. 2017;**30**:858–63.
82. Hua XG, Jiang W, Hu R, Hu CY, Huang K, Li FL, et al. Large for gestational age and macrosomia in pregnancies without gestational diabetes mellitus. *J Matern Fetal Neonatal Med*. 2019;**33**:1–10.
83. Yang S, Peng A, Wei S, Wu J, Zhao J, Zhang Y, et al. Prepregnancy body mass index, gestational weight gain, and birth weight: a cohort study in China. *PLoS One*. 2015;**10**: e0130101.
84. Wang C, Zhu W, Wei Y, Feng H, Su R, Yang H. Exercise intervention during pregnancy can be used to manage weight gain and improve pregnancy outcomes in women with gestational diabetes mellitus. *BMC Pregnancy Childbirth*. 2015;**15**:255.
85. Wei YM, Yang HX, Zhu WW, Liu XY, Meng WY, Wang YQ, et al. Risk of adverse pregnancy outcomes stratified for pre-pregnancy body mass index. *J Matern Fetal Neonatal Med*. 2015;**29**:1–5.
86. Feng H, Zhu WW, Yang HX, Wei YM, Wang C, Su RN, et al. Relationship between oral glucose tolerance test characteristics and adverse pregnancy outcomes among women with gestational diabetes mellitus. *Chin Med J (Engl)*. 2017; **130**:1012–8.
87. Cai L, Tao J, Li X, Lin L, Ma J, Jing J, et al. Association between the full range of birth weight and childhood weight status: by gestational age. *Eur J Clin Nutr*. 2019;**73**: 1141–8.
88. Tan M, Cai L, Ma J, Jing J, Ma Y, Chen Y. The association of gestational age and birth weight with blood pressure among children: a Chinese national study. *J Hum Hypertens*. 2018;**32**:651–9.
89. Wang D, Zhu L, Zhang S, Wu X, Wang X, Lv Q, et al. Predictive macrosomia birthweight thresholds for adverse maternal and neonatal outcomes. *J Matern Fetal Neonatal Med*. 2016;**26**:1–6.
90. Wang H, Yue H, Sun B, Zhu X, Niu H, Qi T, et al. Birth population survey in Huai'an in 2015: perinatal-neonatal mortality and preterm birth rate in emerging regions in China. *J Matern Fetal Neonatal Med*. 2018;**33**:1–9.
91. Zheng W, Huang W, Zhang L, Tian Z, Wang T, Zhang T, et al. Changes in serum lipid levels during pregnancy and association with neonatal outcomes: a large cohort study. *Reprod Sci*. 2018;**25**:1406–12.
92. He JR, Li WD, Lu MS, Guo Y, Chan FF, Lu JH, et al. Birth weight changes in a major city under rapid socioeconomic transition in China. *Sci Rep*. 2017;**7**:1031.
93. Wang Y, He Y, Zhuang L, Li X, Chen T, Chen L, et al. Effect of maternal and neonatal factors on neonatal thyroid screening results. *Clin Lab*. 2018;**64**:1445–50.
94. Tu S, Wang AL, Tan MZ, Lu JH, He JR, Shen SY, et al. Family socioeconomic position and abnormal birth weight: evidence from a Chinese birth cohort. *World J Pediatr*. 2019; **15**:483–91.
95. Wu Y, Ming WK, Wang D, Chen H, Li Z, Wang Z. Using appropriate pre-pregnancy body mass index cut points for obesity in the Chinese population: a retrospective cohort study. *Reprod Biol Endocrinol*. 2018;**16**:77.

96. Huang X, Tan H, Cai M, Shi T, Mi C, Lei J. Gestational weight gain in Chinese women – results from a retrospective cohort in Changsha, China. *BMC Preg Childbirth*. 2018;**18**:185.
97. Rao J, Fan D, Wu S, Lin D, Zhang H, Ye S, et al. Trend and risk factors of low birth weight and macrosomia in South China, 2005-2017: a retrospective observational study. *Sci Rep*. 2018;**8**:3393.
98. Yuan X, Hu H, Zhang M, Long W, Liu J, Jiang J, et al. Iron deficiency in late pregnancy and its associations with birth outcomes in Chinese pregnant women: a retrospective cohort study. *Nutr Metab*. 2019;**16**:30.
99. Wang Q, Benmarhnia T, Li C, Knibbs LD, Bao J, Ren M, et al. Seasonal analyses of the association between prenatal ambient air pollution exposure and birth weight for gestational age in Guangzhou, China. *Sci Total Environ*. 2019; **649**:526–34.
100. Fok TF, So HK, Wong E, Ng PC, Chang A, Lau J, et al. Updated gestational age specific birth weight, crown-heel length, and head circumference of Chinese newborns. *Arch Dis Child Fetal Neonatal Ed*. 2003;**88**:F229–36.
101. Pang MW, Leung TN, Sahota DS, Lau TK, Chang AM. Development of a customised birthweight standard for ethnic Chinese subjects. *Aust N Z J Obstet Gynaecol*. 2000;**40**: 161–4.
102. Kandraju H, Agrawal S, Geetha K, Sujatha L, Subramanian S, Murki S. Gestational age-specific centile charts for anthropometry at birth for south Indian infants. *Indian Pediatr*. 2012;**49**:199–202.
103. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. *Obstet Gynecol*. 1996;**87**:163–8.
104. Hong JS, Yi SW, Han YJ, Park YW, Nam CM, Kang HC, et al. Fetal growth and neonatal mortality in Korea. *Paediatr Perinat Epidemiol*. 2007;**21**:397–410.
105. Dai L, Deng C, Li Y, Zhu J, Mu Y, Deng Y, et al. Birth weight reference percentiles for Chinese. *PLoS One*. 2014;**9**: e104779.
106. Chen C, Lu FC, People's Republic of China Department of Disease Control Ministry of Health. The guidelines for prevention and control of overweight and obesity in Chinese adults. *Biomed Environ Sci*. 2004;**17**:1–36.
107. Hod M, Kapur A, Sacks DA, Hadar E, Agarwal M, di Renzo GC, et al. The International Federation of Gynecology and Obstetrics (FIGO) initiative on gestational diabetes mellitus: a pragmatic guide for diagnosis, management, and care. *Int J Gynaecol Obstet*. 2015;**131** (Suppl 3):S173–211.
108. International Association of Diabetes and Pregnancy Study Groups Consensus Panel, Metzger BE, Gabbe SG, Persson B, Buchanan TA, Catalano PA, et al. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care*. 2010; **33**:676–82.
109. Gairdner D, Pearson J. A growth chart for premature and other infants. *Arch Dis Child*. 1971;**46**:783–7.
110. Villar J, Cheikh Ismail L, Victora CG, et al. International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21st Project. *Lancet*. 2014;**384**:857–68.
111. Aziz N, Kallur SD, Nirmalan PK. Implications of the revised consensus body mass indices for asian indians on clinical obstetric practice. *J Clin Diagn Res*. 2014;**8**:OC01–3.
112. Wu L, Ding Y, Rui XL, Mao CP. Seasonal variations in birth weight in Suzhou Industrial Park. *Biomed Environ Sci*. 2016;**29**:758–61.
113. Black RE. Global prevalence of small for gestational age births. *Nestle Nutr Inst Workshop Ser*. 2015;**81**:1–7.
114. Ott R, Stupin JH, Loui A, Eilers E, Melchior K, Rancourt RC, et al. Maternal overweight is not an independent risk factor for increased birth weight, leptin and insulin in newborns of gestational diabetic women: observations from the prospective 'EaCH' cohort study. *BMC Pregnancy Childbirth*. 2018;**18**:250.
115. Chattrapiban T, Smit HA, Wijga AH, Brunekreef B, Vonk JM, Gehring U, et al. The joint effect of maternal smoking during pregnancy and maternal pre-pregnancy overweight on infants' term birth weight. *BMC Pregnancy Childbirth*. 2020;**20**:132.
116. Xu H, Simonet F, Luo ZC. Optimal birth weight percentile cut-offs in defining small- or large-for-gestational-age. *Acta Paediatr*. 2010;**99**:550–5.
117. Sinclair BA, Rowan JA, Hainsworth OT. Macrosomic infants are not all equal. *Aust N Z J Obstet Gynaecol*. 2007; **47**:101–5.
118. Anderson NH, Sadler LC, McKinlay CJ, McCowan LM. INTERGROWTH 21st versus customized birthweight standards for identification of perinatal mortality and morbidity. *Am J Obstet Gynecol*. 2015;**214**:509.e1–7.
119. Mikolajczyk RT, Zhang J, Betran AP, Souza JP, Mori R, Gülmezoglu AM, et al. A global reference for fetal-weight and birthweight percentiles. *Lancet*. 2011;**377**:1855–61.
120. Mocarski M, Savitz DA. Ethnic differences in the association between gestational diabetes and pregnancy outcome. *Matern Child Health J*. 2012;**16**:364–73.
121. Ishihara O, Araki R, Kuwahara A, Itakura A, Saito H, Adamson GD. Impact of frozen-thawed single-blastocyst transfer on maternal and neonatal outcome: an analysis of 277,042 single-embryo transfer cycles from 2008 to 2010 in Japan. *Fertil Steril*. 2014;**101**:128–33.
122. Gaudet L, Ferraro ZM, Wen SW, Walker M. Maternal obesity and occurrence of fetal macrosomia: a systematic review and meta-analysis. *Biomed Res Int*. 2014;**2014**:640291.
123. Tian C, Hu C, He X, Zhu M, Qin F, Liu Y, et al. Excessive weight gain during pregnancy and risk of macrosomia: a meta-analysis. *Arch Gynecol Obstet*. 2016;**293**:29–35.
124. Yan J, Yang H, Meng W, Wang Y, Shang L, Cai Z. Abdominal circumference profiles of macrosomi infants born to mothers with or without hyperglycemia in China. *J Matern Fetal Neonatal Med*. 2020;**33**(1):149–56.