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Birth Weight Reference Percentiles for Chinese



 National Center for Birth Defects Monitoring, West China Second University Hospital of Sichuan University, Chengdu, People's Republic of China, 2 Key Laboratory of Obstetrics & Gynecology and Pediatric Diseases and Birth Defects of the Ministry of Education, West China Second University Hospital of Sichuan University, Chengdu, People's Republic of China, 3 Obstetric and Gynecologic Department, West China Second University Hospital of Sichuan University, Chengdu, People's Republic of China, 4 Yale School of Public Health, Yale University, New Haven, Connecticut, United States of America

Abstract

Objective: To develop a reference of population-based gestational age-specific birth weight percentiles for contemporary Chinese.

Methods: Birth weight data was collected by the China National Population-based Birth Defects Surveillance System. A total of 1,105,214 live singleton births aged \geq 28 weeks of gestation without birth defects during 2006–2010 were included. The lambda-mu-sigma method was utilized to generate percentiles and curves.

Results: Gestational age-specific birth weight percentiles for male and female infants were constructed separately. Significant differences were observed between the current reference and other references developed for Chinese or non-Chinese infants.

Conclusion: There have been moderate increases in birth weight percentiles for Chinese infants of both sexes and most gestational ages since 1980s, suggesting the importance of utilizing an updated national reference for both clinical and research purposes.

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Data Availability: The authors confirm that, for approved reasons, some access restrictions apply to the data underlying the findings. The original data for this study were abstracted from the National Center for Birth Defects Monitoring of China. In principle, the ownership of the data belongs to the Ministry of Health of China (MOH). Non-profit uses of the data in research are encouraged, but the data access needs an approval from the MOH. Researchers interested in the data can contact Li Dai at the National Center for Birth Defects, dail@scu.edu.cn. The principles of data sharing have been previously published (Liang J, et al. PLoS One. 2012;7(5):e37458. doi: 10.1371/journal.pone.0037458. Epub 2012 May 21).

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* Email: daili@scu.edu.cn (LD); yawei.zhang@yale.edu (YZ)

Introduction

Birth weight for gestational age is a commonly assessed perinatal outcome. Small for gestational age (SGA) is defined as weighing less than the 10th percentile of birth weight and is an important indicator of intrauterine fetal growth restriction (IUGR) [1,2]. Perinatal and infant morbidity and mortality as well as future adult chronic diseases have been linked to SGA [3,4], therefore it is important to identify SGA in both clinical and research settings.

Since gestational age-specific birth weight varies among racial groups [5–8], nation-specific birth weight references have been developed for several countries [1,9–13]. Although the population in China accounts for one fifth of the world population and each year approximately 16 million babies are born in China [14], no national population-based reference of birth weight currently exists. We used data from the largest National Population-Based Birth Defects Surveillance System (NPBDSS) [14] to construct a national reference of gestational age-specific birth weight percentiles for Chinese born between 2006–2010.

Methods and Materials

The NPBDSS was established in 2006, and data collected by the NPBDSS have been included in the official system of the National Bureau of Statistics of China since 2007 [14]. This surveillance system covers 64 counties and districts in thirty provinces, municipalities or municipal districts that fall under the central government. This database represents a wide array of geographical locations and socioeconomic status. Details on data collection and quality control of the NPBDSS were described elsewhere [14]. In brief, fetus and neonates of 28 gestational weeks or more born to women living in the surveillance areas for at least one year were recruited and followed. The time period for identifying birth defects was from 28 gestation weeks to 42 days after birth, during which major birth defects (i.e., external malformations and chromosomal aberrations coded according to the International Classification of Diseases 10th edition) diagnosed for the first time were required to be reported. Surveillance staffs at the community, township, or village levels were responsible for birth information collection, verification, and follow-up. By comparing the data with related data from other systems like





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Table 1. Characteristics of the study population.

| Groups | Boys | | Girls | | Total | |
|-----------------------|--------|-------|--------|-------|---------|-------|
| | n | % | n | % | n | % |
| Birth area | | | | | | |
| Urban | 270428 | 45.83 | 242612 | 47.10 | 513040 | 46.42 |
| Rural | 319596 | 54.17 | 272488 | 52.90 | 592084 | 53.58 |
| Geographic region | | | | | | |
| Coastal | 258534 | 43.82 | 227807 | 44.23 | 486341 | 44.01 |
| Inland | 178843 | 30.31 | 152087 | 29.53 | 330930 | 29.95 |
| Remote | 152647 | 25.87 | 135206 | 26.25 | 287853 | 26.05 |
| Maternal age (years)* | | | | | | |
| <20 | 7808 | 1.32 | 7061 | 1.37 | 14869 | 1.35 |
| 20–24 | 186177 | 31.59 | 169338 | 32.91 | 355515 | 32.21 |
| 25–29 | 247321 | 41.96 | 215344 | 41.85 | 462665 | 41.91 |
| 30-34 | 108333 | 18.38 | 89006 | 17.30 | 197339 | 17.88 |
| 35–39 | 34396 | 5.84 | 29154 | 5.67 | 63550 | 5.76 |
| ≥40 | 5364 | 0.91 | 4603 | 0.89 | 9967 | 0.90 |
| Maternal ethnicity | | | | | | |
| Han | 549866 | 93.19 | 480552 | 93.29 | 1030418 | 93.24 |
| Minority | 40158 | 6.81 | 34548 | 6.71 | 74706 | 6.76 |
| Parity [#] | | | | | | |
| 1 | 430681 | 73.01 | 396459 | 76.99 | 827140 | 74.87 |
| 2 | 148772 | 25.22 | 112149 | 21.78 | 260921 | 23.62 |
| ≥3 | 10412 | 1.77 | 6336 | 1.23 | 16748 | 1.52 |

*1219 births with unknown maternal age.

[#]315 births with unknown parity.

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Birth Certification, Perinatal Death Registry, etc., the information on reported cases or births are checked for accuracy and completeness. In addition, annual surveys are conducted to identify and correct errors and inaccuracies in the collected data. It is required that the under-reporting rate of live births or malformations should be no more than 1% and errors or missing values on the report form should also be no more than 1%.

The gestational age at delivery was calculated in completed weeks from the first day of the last menstrual period (LMP). In the surveillance areas, women with suspected pregnancy have an ultrasound examination for confirmation according to obstetric clinical guidelines. For women with irregular menses and/or bleeding during pregnancy as well as those who could not remember the LMP, gestational ages were estimated based on their ultrasound examination. Birth weight of each neonate was measured by a trained midwife within one hour after birth, recorded to the nearest 5 g, and included in hospital delivery records. The data were then abstracted by trained surveillance staff and entered into a web-based reporting system [14].

From October 2006 through September 2010, a total of 1,153,166 live and still births whose gestation age were equal to or greater than 28 weeks were identified by the NPBDSS. Stillbirth was defined as the delivery of a fetus that has died before birth for which there is no possibility of resuscitation. Figure 1 illustrates the records selection process for current study. Stillbirths (n = 5,337, 4.71‰), infants of foreign origin (n = 69), infants from multiple births (n = 19,914, 1.73%), and infants affected by congenital anomalies (n = 17,650, 1.56%), were first excluded from the analysis. Among the rest of 1,112,443 records, 6,608 (0.51%) with

missing gestational age or birth weight or gender, and 545 outliers (0.05%) according to previous inclusion criterion [1], were subsequently removed. Finally the procedure proposed by Alexander et al. [1] was adopted to screen records with implausible combinations of gestational age and birth weight. Specifically, gestational age distributions were examined for each 125 g interval of birth weight for preterm infants aged 28-32 weeks. Gestational age values of +/-2.5 standard deviations from the mean were used as cutoffs for implausible records. Under a normal distribution, the cutoffs roughly correspond to the 1st and 99th percentiles. In Alexander et al. [1], manual adjustments of the gestational age "by a week or more" were conducted for certain birth weight intervals. We did not perform such adjustments, due to the infrequent occurrence of abnormal observations. Following this procedure, a total of 7,319 newborns (0.66%) were removed from downstream analysis, yielding a final sample size of 1,105,214 for this study.

For statistical analysis, we first conducted a linear regression analysis and investigated maternal and infant characteristics that might affect birth weight. Since fitting smooth curves on sample quantiles of segmented age groups may demand a large sample size and lose information from nearby groups, we utilized the lambda-mu-sigma (LMS) method for the primary analysis of birth weight for specific gestational ages. The LMS method, which has been used in multiple reference curve studies, adopts a Box-Cox transformation based semiparametric technique and solves penalized likelihood equations. The centiles can be briefly summarized by the L (Box-Cox power), M (median) and S (coefficient variation), which are natural cubic splines with knots at each T_j





Figure 2. Percentile charts for Chinese newborns. P3, P5 to P97 denote the 3rd, 5th to 97th percentile curves, respectively. doi:10.1371/journal.pone.0104779.g002



Figure 3. Urban-rural variations of the 10th, 50th and 90th birth weight percentiles for Chinese infants irrespective of gender. doi:10.1371/journal.pone.0104779.g003

(gestation week) as described in Cole and Green's paper [15]. The aforementioned analysis was achieved using R package VGAM [16]. To evaluate the impact of employing previous percentiles for the current study cohort, we calculated the relative percentual differences for the 10^{th} , 50^{th} and 90^{th} percentiles between our data and those from other references as:

Relative percentual difference = $(Other_{perc} - China_{perc})/China_{perc} \times 100$. Here, the China_{perc} represents the percentiles calculated from our study, while Other_{perc} denotes the percentiles published previously.

Results

This study included 53.4% male and 46.6% female births. Urban and rural births accounted for 46.4% and 53.6% of the cohort, respectively, while newborns whose mothers lived in coastal regions, inland, and remote areas accounted for 44.0%, 29.9%, and 26.0% of all births respectively. The vast majority (93.2%) of the mothers were Han Chinese, and the rest (6.8%) were minorities. Most (74.0%) mothers aged 20–29 years at the time of delivery, with few (1.3%) aged \leq 20 years and 6.7% aged \geq 35 years. More than 70% of infants were born to primiparous women (73.0% for boys and 77.0% for girls). (Table 1) Both maternal (age, ethnicity, parity, and residence location/birth area) and infant (gestational age and gender) characteristics were associated with birth weight (Table S1).

Based on the smooth-estimated percentile values (Table 2), reference charts for male and female newborns were generated (Figure 2). As expected, the corrected median birthweights for boys at 28–44 weeks were 2.0–4.5% heavier than for girls. Notably, greater gender differences were observed in the $3^{\rm rd}$, $5^{\rm th}$, $10^{\rm th}$, $25^{\rm th}$ and $50^{\rm th}$ birthweight percentiles for preterm births (Figure 2), while for term births, male predominance in birth weight was found in all percentiles (Table 2). Significant urban-

Table 2. Smoothed birth weight percentiles for Chinese newborns during 2006–2010.

| Gestation (weeks) | Male | | | | | | | | | | | Female | | | | | | | | | | |
|----------------------|--------------|--------------|-----------|-----------|-----------|------------|-----------|-----------|-----------|------------|------------|-------------|-------------|------------|------------|-----------------------|----------|----------|-------------|------|------|------|
| | Number | Mean (SD) | ЪЗ | P5 | P10 | P25 | P50 | P75 | 06d | P95 | P97 | Number | Mean (SD) | ЪЗ | P5 | P10 | P25 | P50 | P75 | 06d | P95 | P97 |
| 28 | 168 | 1252(198) | 789 | 830 | 895 | 1011 | 1152 | 1307 | 1458 | 1553 | 1618 | 129 | 1166(210) | 721 | 763 | 830 | 952 | 1102 | 1268 | 1432 | 1537 | 1607 |
| 29 | 166 | 1374(224) | 934 | 981 | 1056 | 1191 | 1355 | 1533 | 1707 | 1818 | 1892 | 123 | 1336(225) | 864 | 913 | 992 | 1135 | 1309 | 1502 | 1692 | 1813 | 1895 |
| 30 | 251 | 1584(267) | 1081 | 1134 | 1220 | 1373 | 1558 | 1760 | 1957 | 2082 | 2166 | 192 | 1525(276) | 1011 | 1067 | 1157 | 1319 | 1517 | 1735 | 1950 | 2087 | 2180 |
| 31 | 366 | 1767(317) | 1233 | 1293 | 1388 | 1559 | 1765 | 1990 | 2208 | 2346 | 2439 | 265 | 1736(349) | 1162 | 1224 | 1325 | 1506 | 1726 | 1968 | 2206 | 2358 | 2460 |
| 32 | 693 | 1939(321) | 1392 | 1457 | 1563 | 1750 | 1977 | 2223 | 2462 | 2613 | 2714 | 465 | 1920(359) | 1320 | 1389 | 1499 | 1697 | 1937 | 2201 | 2459 | 2623 | 2734 |
| 33 | 837 | 2120(316) | 1560 | 1631 | 1746 | 1949 | 2194 | 2460 | 2717 | 2880 | 2989 | 574 | 2068(332) | 1487 | 1561 | 1680 | 1893 | 2150 | 2432 | 2707 | 2881 | 2998 |
| 34 | 1682 | 2359(385) | 1740 | 1816 | 1939 | 2156 | 2417 | 2699 | 2972 | 3144 | 3259 | 1232 | 2293(408) | 1667 | 1745 | 1871 | 2095 | 2365 | 2659 | 2945 | 3126 | 3248 |
| 35 | 3134 | 2591 (405) | 1934 | 2015 | 2143 | 2370 | 2642 | 2934 | 3215 | 3393 | 3511 | 2453 | 2535(417) | 1860 | 1942 | 2071 | 2302 | 2578 | 2877 | 3167 | 3349 | 3472 |
| 36 | 8602 | 2852(459) | 2143 | 2225 | 2356 | 2586 | 2860 | 3153 | 3434 | 3611 | 3729 | 6574 | 2784(461) | 2067 | 2149 | 2279 | 2509 | 2783 | 3077 | 3360 | 3538 | 3657 |
| 37 | 31949 | 3078(407) | 2355 | 2437 | 2565 | 2791 | 3058 | 3342 | 3613 | 3782 | 3895 | 24400 | 2989(404) | 2276 | 2356 | 2482 | 2704 | 2967 | 3247 | 3515 | 3683 | 3794 |
| 38 | 101207 | 3244(392) | 2534 | 2613 | 2739 | 2958 | 3215 | 3488 | 3746 | 3907 | 4014 | 82036 | 3140(381) | 2453 | 2530 | 2652 | 2865 | 3115 | 3380 | 3632 | 3789 | 3893 |
| 39 | 187452 | 3336(387) | 2647 | 2725 | 2849 | 3065 | 3317 | 3584 | 3836 | 3993 | 4098 | 163122 | 3234(374) | 2569 | 2645 | 2764 | 2972 | 3216 | 3473 | 3717 | 3869 | 3970 |
| 40 | 205506 | 3390(390) | 2704 | 2783 | 2908 | 3127 | 3382 | 3652 | 3907 | 4065 | 4171 | 183982 | 3291 (376) | 2627 | 2703 | 2824 | 3035 | 3281 | 3541 | 3787 | 3940 | 4042 |
| 41 | 40065 | 3473(416) | 2730 | 2812 | 2943 | 3170 | 3437 | 3719 | 3987 | 4153 | 4264 | 41272 | 3360(402) | 2648 | 2728 | 2854 | 3074 | 3332 | 3605 | 3863 | 4024 | 4131 |
| 42 | 6839 | 3461 (430) | 2739 | 2826 | 2963 | 3202 | 3483 | 3781 | 4064 | 4240 | 4357 | 7219 | 3358(416) | 2652 | 2735 | 2868 | 3099 | 3371 | 3659 | 3933 | 4104 | 4217 |
| 43 | 943 | 3447(444) | 2742 | 2832 | 2976 | 3228 | 3524 | 3839 | 4138 | 4325 | 4450 | 914 | 3307(421) | 2648 | 2736 | 2875 | 3118 | 3404 | 3709 | 3999 | 4181 | 4301 |
| 44 | 164 | 3462(489) | 2741 | 2836 | 2987 | 3252 | 3564 | 3897 | 4215 | 4413 | 4545 | 148 | 3368(476) | 2642 | 2733 | 2879 | 3135 | 3437 | 3759 | 4067 | 4260 | 4388 |
| Mean (SD) I | epresent the | e observed m | ean birth | n weights | for gesta | itional ag | je and co | hrrespond | ing stanc | lard devia | ations. P3 | , P5 to P97 | denote smoo | othed valu | ues for th | e 3 rd and | correspo | nding pe | ercentiles. | | | |

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Gestational age (weeks)

Figure 4. Comparison of the 10th birth weight percentiles for boys between the current study, USA, Norway, Kuwait and Brazil. doi:10.1371/journal.pone.0104779.g004

rural variations of smoothed birthweight percentiles were also identified (Figure 3). In brief, percentiles for urban term infants were larger than those for rural term births, but larger percentiles were found for rural early preterm babies (particularly ≤ 32 weeks of gestation). We constructed the smooth-estimated percentile values for Han infants only (Table S2), which showed no significant differences as compared to the percentiles based on all infants.

Using the values from the current study cohort as references, Table 3 showed relative differences for the 10th and 50th percentiles compared to previously published charts [1,9-13,17-20]. The general characteristics of these studies are presented in Table 4. Negative numbers are shown when the current percentiles are larger than the previous ones, suggesting that relative birth weight will likely be overestimated if older percentile references are used for the current population. On the other hand, positive numbers will likely result in underestimation if other references are used. For example, the SGA would be overestimated for the majority of newborns in our current study population except for very preterm infants (infants \leq 30 gestational weeks) if the China 1992 references [20] are used (Table 3). The degree of overestimation or underestimation from using previously published references could be as great as 24.5% for SGA and 14.4% for medium birth weight. Greater differences of the 10th percentiles were found at almost all gestation weeks between several national references. As illustrated in Figure 4, the values of 10^{th} percentiles at each gestation week in the current study were higher than those of Brazilian boys but lower than those of Norwegian male infants.

Discussion

This study represents the first national population-based, gestational age-specific reference of birth weight for Chinese singleton newborns based on a large and nationally representative database. The Chinese Ministry of Health developed a reference of birth weight for gestational age in 1975 based on data from a survey conducted in nine cities, and the reference has been updated every ten years since then [21]. However, this reference was only for term births. In the mid 1980s, the Chinese Ministry of Health conducted another cross-sectional survey in fifteen cities involving 24,150 live singleton births and developed gestational age-specific reference for birth weight in 1992 [20]. Although this reference included preterm births, the study population was not a nationally representative sample. In addition, during the past two decades there have been considerable changes in both maternal and infant characteristics, such as an increase in maternal age at delivery, improved education level of the mothers, increases in infant weight and length, as well as improvements in prenatal

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| 3. Relative p |
| Table |

| Gestation (weeks) | China 1 | 1992 [20] | USA 19 | 95* [17] | USA 19 | 96 [1] | Australia [18] | 1999 | Australia | 2012 [9] | Norway [11] | * 2000# | Canada [10] | 2001 | Kuwait 21 | 004 [19] | Scotland [13] | 2008* | Brazil 20 | 11 [12] |
|---|---|---|---|---|------------------------------|--|------------------------------|----------------------------|--------------------------|-----------------------------|--------------------------|--------------------------------|----------------|--------|-----------|----------|------------------|--------|-----------|---------|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| P10 | | | | | | | | | | | | | | | | | | | | |
| 28 | 19.11 | 7.59 | -7.26 | 7.59 | -7.49 | -3.86 | -5.03 | -8.43 | -5.70 | -7.95 | 7.26 | 2.41 | -4.69 | -3.37 | -10.95 | -11.57 | -6.93 | - 9.88 | -13.97 | - 11.45 |
| 29 | 5.59 | 1.61 | -7.67 | 1.61 | -9.47 | -6.75 | - 10.04 | -10.28 | -8.71 | -12.30 | 3.22 | 0.30 | -8.71 | -8.97 | -17.42 | -15.12 | -9.19 | -12.30 | - 19.32 | -17.74 |
| 30 | -4.26 | -2.51 | -6.15 | -2.51 | -8.44 | -6.22 | - 11.48 | -9.68 | -10.57 | -10.98 | 2.05 | 0.26 | -9.92 | -11.67 | -22.21 | -20.74 | - 10.16 | -11.58 | -21.31 | -20.66 |
| 31 | -8.50 | -5.21 | -3.46 | -5.21 | -5.76 | -3.55 | -5.62 | -13.96 | -8.50 | -10.19 | 2.31 | 0.75 | -9.29 | -11.85 | -24.50 | -24.45 | - 10.01 | -11.40 | - 19.02 | - 18.49 |
| 32 | - 9.60 | -6.74 | -0.83 | -6.74 | -2.69 | -0.27 | -10.43 | -10.61 | -8.51 | -10.07 | 3.33 | 1.73 | -7.61 | -10.21 | -22.46 | -23.02 | - 10.43 | -11.21 | -15.10 | - 14.54 |
| 33 | - 9.22 | -7.56 | 1.66 | -7.56 | 0.29 | 2.68 | -6.07 | -9.52 | -6.19 | -7.14 | 3.67 | 2.98 | -5.61 | -7.86 | -17.35 | -19.11 | -9.91 | -10.42 | - 11.63 | 1.01 |
| 34 | -8.25 | -7.96 | 3.66 | -7.96 | 2.37 | 4.22 | -5.11 | -5.93 | -4.07 | -5.72 | 4.18 | 3.96 | -3.76 | -5.51 | -12.58 | -15.82 | - 9.23 | -8.93 | -9.75 | -9.14 |
| 35 | - 7.47 | -8.21 | 4.53 | -8.21 | 2.89 | 4.25 | -1.54 | -1.98 | -2.94 | -4.39 | 3.36 | 3.57 | -2.43 | -3.52 | -9.10 | -12.55 | -8.49 | -7.44 | -8.26 | -7.77 |
| 36 | -7.09 | -8.38 | 4.63 | -8.38 | 2.16 | 3.29 | -1.53 | -2.59 | -2.59 | -3.55 | 2.29 | 2.24 | - 1.49 | -2.28 | -6.15 | -8.78 | -6.88 | -6.76 | -6.41 | -5.22 |
| 37 | -6.98 | -8.38 | 4.29 | -8.38 | 1.21 | 2.38 | -0.58 | -2.10 | -0.97 | -2.10 | 2.34 | 1.93 | -0.51 | -1.21 | -3.90 | -5.80 | -4.41 | -5.36 | -5.03 | -4.88 |
| 38 | -6.28 | -7.47 | 4.24 | -7.47 | 1.10 | 2.34 | 1.50 | 0.30 | 2.23 | 1.43 | 3.87 | 2.94 | 0.99 | 0.23 | -2.67 | -4.00 | -0.66 | -1.92 | -4.05 | -4.03 |
| 39 | -4.49 | -5.39 | 5.30 | -5.39 | 2.07 | 3.18 | 3.19 | 2.03 | 3.55 | 2.39 | 6.00 | 4.74 | 3.26 | 2.21 | -1.37 | -2.50 | 2.35 | 1.34 | -3.47 | -3.76 |
| 40 | -2.34 | -2.73 | 6.60 | -2.73 | 2.68 | 3.72 | 5.57 | 4.46 | 6.26 | 5.35 | 7.81 | 6.76 | 5.88 | 4.64 | 0.07 | -0.85 | 6.12 | 4.50 | -2.92 | -3.40 |
| 41 | -0.95 | -0.63 | 6.52 | -0.63 | 2.17 | 3.29 | 8.05 | 6.87 | 9.41 | 8.27 | 8.90 | 7.74 | 8.02 | 6.90 | 0.82 | 0.32 | 9.45 | 7.64 | -2.21 | -2.59 |
| 42 | -0.91 | -0.07 | 4.62 | -0.07 | 1.18 | 2.34 | 8.34 | 7.39 | 9.69 | 8.44 | 9.18 | 7.74 | 9.11 | 8.58 | 0.71 | 0.56 | 10.43 | 8.40 | -2.13 | -2.37 |
| P50 | | | | | | | | | | | | | | | | | | | | |
| 28 | 7.12 | 0.09 | 8.94 | 6.62 | 3.82 | 8.53 | 1.56 | -2.90 | 1.13 | -1.09 | 6.77 | 3.45 | 1.82 | 0.64 | -2.26 | -5.81 | -0.43 | -2.72 | 1.22 | 0.45 |
| 29 | 1.33 | -2.75 | 8.49 | 5.81 | 2.88 | 6.49 | -1.11 | -4.51 | -3.25 | -5.27 | 3.32 | 1.22 | -1.70 | -3.82 | -6.72 | -10.08 | -3.47 | -6.65 | -5.31 | -4.97 |
| 30 | - 2.05 | -4.81 | 8.79 | 6.46 | 5.07 | 7.91 | -4.36 | -6.39 | -3.85 | -7.71 | 2.05 | 0.86 | -3.27 | -5.93 | -8.60 | -13.32 | -4.81 | -7.32 | 6.10 | 6.26 |
| 31 | -4.02 | -6.20 | 9.35 | 7.76 | 8.67 | 11.12 | -5.38 | -7.88 | -4.82 | -7.88 | 2.55 | 1.39 | -3.80 | -6.55 | -9.35 | -14.37 | -5.04 | -8.46 | -3.85 | -4.06 |
| 32 | -5.26 | -7.12 | 9.76 | 8.67 | 11.43 | 13.73 | -4.40 | -8.11 | -4.91 | -8.11 | 3.69 | 2.22 | -3.59 | -6.20 | -9.76 | -12.49 | -5.97 | -9.19 | 0.25 | 0.21 |
| 33 | -6.06 | -7.67 | 9.62 | 9.07 | 12.03 | 14.33 | -3.37 | -5.12 | -4.01 | -6.47 | 4.38 | 3.02 | -3.05 | -5.35 | -9.07 | -9.58 | -5.88 | -9.02 | 3.24 | 3.35 |
| 34 | -6.70 | -7.95 | 9.23 | 8.46 | 10.34 | 12.77 | -2.77 | -4.44 | -3.19 | -5.29 | 5.09 | 3.81 | -2.36 | -4.19 | -7.20 | -7.65 | -5.50 | -7.48 | 3.43 | 3.59 |
| 35 | -7.23 | -8.07 | 8.25 | 7.45 | 7.15 | 9.81 | -1.97 | -3.41 | -2.42 | -3.80 | 5.41 | 4.34 | -1.59 | -2.79 | -4.81 | -6.13 | -4.50 | -5.28 | 2.12 | 2.29 |
| 36 | -7.59 | -7.98 | 7.17 | 6.36 | 3.99 | 6.86 | -1.40 | -2.26 | -1.40 | -2.62 | 5.59 | 4.74 | -0.52 | -1.40 | -2.69 | -4.13 | -2.38 | -3.45 | 0.98 | 1.19 |
| 37 | -7.52 | -7.45 | 6.44 | 5.49 | 1.93 | 5.06 | 0.72 | -0.24 | 0.72 | -0.07 | 5.79 | 5.16 | 0.72 | 0.03 | -1.50 | -2.26 | 0.16 | -1.18 | 0.07 | 0.30 |
| 38 | -6.72 | -6.32 | 6.22 | 5.30 | 1.49 | 4.75 | 2.95 | 1.77 | 3.58 | 2.73 | 6.69 | 6.10 | 2.33 | 1.73 | -0.84 | -1.28 | 3.05 | 1.96 | -0.40 | -0.32 |
| 39 | -5.03 | -4.60 | 7.02 | 5.88 | 2.50 | 5.72 | 4.31 | 3.23 | 4.61 | 3.86 | 8.38 | 7.43 | 4.46 | 3.67 | 0.21 | -0.65 | 4.91 | 4.23 | -0.51 | -0.81 |
| 40 | -3.22 | -2.90 | 8.07 | 6.52 | 3.34 | 6.52 | 6.45 | 5.15 | 7.04 | 6.07 | 10.14 | 8.96 | 6.83 | 5.76 | 1.21 | 0.21 | 7.89 | 6.61 | -0.38 | -1.01 |
| 41 | -2.21 | -1.98 | 8.23 | 6.69 | 2.62 | 5.85 | 8.52 | 6.84 | 9.25 | 8.19 | 10.85 | 9.69 | 8.61 | 7.32 | 0.93 | 0.69 | 10.36 | 8.79 | -0.41 | -1.20 |
| 42 | -2.24 | -2.34 | 7.52 | 5.90 | 1.12 | 4.48 | 8.53 | 7.09 | 9.68 | 8.28 | 10.54 | 9.46 | 9.53 | 8.42 | -0.34 | 0.53 | 10.71 | 8.96 | -0.95 | - 1.81 |
| Negative ni *Reference: #Presented doi:10.1371 | iumbers s for infa 1 mean v '/journal. | indicate the ants born to alues becat pone.01047 | e current 5 multipa use the 5 779.t003 | percentiles rous womei 0 th percenti | are large 1. les by ge | ir than the _f inder are no | orevious on ot available. | es, while pc Numbers ir | sitive num brackets ι | bers sugges represent th | st current ie referer | t ones are si rces in text. | maller. | | | | | | | |

Table 4. Selected published gestational-age-specific birth weight centiles for comparison.

| Country | Sample size | Population-based | Years | Method of assessing GA |
|---------------------|-------------|------------------|-----------|------------------------|
| China, current | 1,105,124 | Yes | 2006-2010 | LMP |
| China 1992 [20] | 24,150 | No | 1986–1987 | LMP |
| USA 1995 [17] | 3,427,009 | Yes | 1989 | LMP |
| USA 1996 [1] | 3,134,879 | Yes | 1991 | LMP |
| Australia 1999 [18] | 761,902 | Yes | 1991–1994 | LMP+ clinical estimate |
| Australia 2012 [9] | 2,528,641 | Yes | 1998–2007 | LMP+ ultrasound |
| Norway 2000 [11] | 1,800,000 | Yes | 1967–1998 | LMP |
| Canada 2001 [10] | 676,605 | Yes | 1994–1996 | Ultrasound |
| Kuwait 2004 [19] | 35,768 | No | 1998–2000 | Ultrasound |
| Scotland 2008 [13] | 100,133 | Yes | 1998-2003 | LMP+ ultrasound |
| Brazil 2011 [12] | 7,993,166 | Yes | 2003-2005 | LMP |

Numbers in brackets represent the references in text. GA is the abbreviation of gestational age. LMP represents the method that was used to calculate GA based on the last menstrual period.

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nutritional status [21,22]. Older references may be obsolete in evaluating contemporary Chinese newborns.

This newly developed reference shows that medium birth weight and 10th percentiles are larger for term and moderate preterm births but are smaller for very preterm births compared to the 1992 Chinese reference [20]. This phenomenon could be due to improved prenatal care, such as advances in neonatal intensive care during the past two decades, which has improved the survival of very preterm births with very low birth weight. In addition, improved nutritional status during the past two decades may have contributed to a heavier birth weight for term births.

When compared with the references from developed countries such as the United States [1], Australia [9], and Canada [10], the current Chinese median birth weights for gestational age were smaller particularly for term and moderate preterm newborns. Notably, the current 10th percentiles were smaller than those for Norwegians at all gestation weeks, but larger than such percentiles for Brazilians. Although mechanisms underlying the racial differences in birth weight patterns remain unclear, previous studies have suggested that environmental factors may be more important than genetic backgrounds [23,24]. It has also been suggested that racial disparities are more evident for birth weight than for other neonatal growth parameters [5,25–27].

Socioeconomic status [24,28,29] and other maternal characteristics [30,31] have been associated with birth weight. Consistent with earlier studies [13,24,28-33], the current study found that urban term infants who generally had better socioeconomic conditions had higher birth weights than rural term infants. The inverse urban-rural pattern in percentiles of very preterm babies strongly indicates the effects of environmental factors on birth weight. When compared to rural regions, better nutritional status and prenatal health care in urban areas may contribute to a higher live birth rate for fetuses prone to be premature and heavier birth weight for term babies. In our study, older women tended to give birth to heavier babies than younger women, and term newborns with a higher birth order weighed more than firstborns. Other factors such as delivery type (cesarean section) may affect birth weight distributions, but the effects on percentiles can't be assessed due to limits of data.

As noted previously, SGA is an important indicator of fetal growth restriction, and since there is a high rate of false-positive and false-negative diagnosis of IUGR, a customized chart of birth weight percentiles has been recommended [2]. However, evidence that customized birth weight percentiles are a better predictor of IUGR than population-based gestational-age specific birth weight percentiles is inconsistent [34–36]. Furthermore, although fetal weight estimation using the customized birth weight percentiles has led to more accurate predictions of adverse perinatal outcomes [2], fetal weights are not routinely assessed in clinical practice in China. Therefore, population-based birth weight percentiles for gestational age have important implications in both clinical and research settings.

A major strength of the current study is the quality of data, which were obtained from the NPBDSS, a large and welldocumented national registry designed to represent populations from a large number of geographic locations. Distributions of ethnic and urban-rural groups in the current study are highly comparable to those from the National Census 2010 (http://www. stats.gov.cn/tjgb/rkpcgb/). In our study, 6.8% of newborns were minorities, similar to the percentage observed in Census 2010 (8.5%). Urban births accounted for 46.4% of our overall study population, and the proportion from Census 2010 was 49.7%. Studies of birth registry data have the potential for error in the estimation of gestational age, measurement of birth weight, and data transcription. To reduce the possibility of error in our study, 0.66% of the records were removed from final analysis due to missing key variables or outlier values. Although variations in birth weight data collected at our various sites could influence the accuracy of percentiles, discrepancies in measurement were likely minimal due to the high quality of prenatal care and professionally trained midwives.

In summary, our novel gestational age-specific birth weight percentiles for contemporary Chinese singleton births are based on data from the largest national registry, making this version a more accurate and relevant resource for clinical practice, public health research, and health policy. It represents the first national reference for clinicians and researchers and may promote the recognition of SGA as a different concept from low birth weight. Although both conditions are associated with poor health outcomes and a higher incidence of future diseases such as diabetes, heart disease and even cognitive disabilities [4,37–40], identification of SGA in fetuses may provide an opportunity for early intervention.

Supporting Information

Table S1Linear regression analysis on the relationshipbetween birth weight and maternal/infant characteristics.

(DOCX)

Table S2Smoothed birth weight percentiles for HanChinese infants by gender during 2006–2010.(DOCX)

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Author Contributions

Conceived and designed the experiments: LD YZ. Analyzed the data: YL SM XM. Contributed to the writing of the manuscript: LD YZ. Supervised the birth defects surveillance program and provided access to data: JZ. Managed and verified the raw data: CD YM YD YW QL. Cleaned data and revised the draft: MM.

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