Australian national birthweight percentiles by sex and gestational age for twins, 2001–2010

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Abstract
Background: Birthweight remains one of the strongest predictors of perinatal mortality and disability. Birthweight percentiles form a reference that allows the detection of neonates at higher risk of neonatal and postneonatal morbidity. The aim of the study is to present updated national birthweight percentiles by gestational age for male and female twins born in Australia.

Methods: Population data were extracted from the Australian National Perinatal Data Collection for twins born in Australia between 2001 and 2010. A total of 43,833 women gave birth to 87,666 twins in Australia which were included in the study analysis. Implausible birthweights were excluded using Tukey's methodology based on the interquartile range. Univariate analysis was used to examine the birthweight percentiles for liveborn twins born between 20 and 42 weeks gestation.

Results: Birthweight percentiles by gestational age were calculated for 85,925 live births (43,153 males and 42,706 females). Of these infants, 53.6 % were born preterm (birth before 37 completed weeks of gestation) while 50.2 % were low birthweight (<2500 g) and 8.7 % were very low birthweight (<1500 g). The mean birthweight decreased from 2462 g in 2001 to 2440 g in 2010 for male twins, compared with 2485 g in 1991–94. For female twins, the mean birthweight decreased from 2375 g in 2001 to 2338 g in 2010, compared with 2382 g in 1991–94.

Conclusions: The birthweight percentiles provide clinicians and researchers with up-to-date population norms of birthweight percentiles for twins in Australia.

Keywords: Twins, Birth weight, Gestational age, Small for gestational age

Background
Birthweight remains one of the strongest predictors of perinatal mortality and disability [1, 2]. Birthweight percentiles form a reference that incorporates weight and gestational age of infants at birth and are used as an adjunct for detecting neonates with suspected intrauterine growth impairment and those at higher risk of neonatal and postneonatal morbidity. Twin births account for about 3 % of all births in Australia but make a significantly greater contribution to perinatal morbidity and mortality than singleton births [3]. Australia’s first birthweight percentiles for twin births based on national population data were published in 1999 using live twins born during 1991–94 [4]. Marked socio-demographic changes in maternal characteristics and clinical practice have occurred during the period since this publication including increased maternal age, reduced smoking rate, and increased usage of assisted reproductive technology [2]. The aim of the study is to present updated national birthweight percentiles for all male and female liveborn twins born in Australia over the 10-year period between 2001 and 2010.

Methods
Population-based data on twins born in Australia between January 2001 and December 2010 were obtained from Australian Institute of Health and Welfare National Perinatal Data Collection (NPDC). The NPDC is a national collation of jurisdictional population-based cross sectional data collections of pregnancy, childbirth and perinatal outcomes. Information is included in the NPDC on both...
live births and stillbirths of at least 400 g birthweight or at least 20 weeks gestation.

Records with missing birthweight, infant sex or gestational age values were excluded from calculating the birthweight-by-gestation percentiles. In addition, records with implausible birthweight were identified using Tukey’s methodology [5] based on the interquartile range. Birthweights for each sex and gestational age combination that fell below the first quartile minus twice the interquartile range (lower Tukey limit) or above the third quartile plus twice the interquartile range (higher Tukey limit) were considered outliers and were excluded from the analyses.

Level of remoteness was based on the geographical location of the usual residence of the mother, and was classified into five groups: major cities of Australia, inner regional Australia, outer regional Australia, remote Australia and very remote Australia.

Univariate analysis was used to examine the birthweight distributions and to determine the interquartile range for each gestational age for twins born in Australia. After removing outliers exact percentiles of birthweight in grams were calculated for each gestational week between 20 and 42 weeks. Results for the 5th and 95th percentile are presented only for gestational ages with a minimum of 100 records and the 10th and 90th percentile are plotted only for gestational ages with a minimum of 50 records, to be consistent with previously published Australian birthweight percentiles [2, 4]. Student t-test was used to examine the mean birthweight difference between twins born in 1991–94 and 2010. General linear model was used to investigate the trends for mean birthweight for male and female twins born between 2001 and 2010. All analyses were carried out using SAS for Windows, version 9.3 (SAS Inc, Cary, NC).

Ethics approval for this study was granted by the Human Research Ethics Advisory Panel of the University of New South Wales, Australia (Reference number: 2013-7-07) and Australian Institute of Health and Welfare Ethics Committee (Reference number: EO 2013/2/17). As secondary data analysis of de-identified data set, additional consent from participants was not required. Approval for use of data was provided by all states and territories.

**Results**

Between 2001 and 2010, a total of 43,833 women gave birth to 87,666 twins in Australia. Table 1 presents the maternal demographic and obstetric characteristics of these women. 1741 (2.0 %) births (1737 stillbirths and 4 births with unknown vital status at birth) were not considered further.

Among the 85,925 live births (43,153 males and 42,706 females), 53.6 % were born preterm (birth before 37 completed weeks of gestation) while 50.2 % were low birthweight (<2500 g) and 8.7 % were very low birthweight (<1500 g) (Table 2). More than half of liveborn twins were admitted to a special care nursery or neonatal intensive care unit (58.6 %) or required some type of active resuscitation measures (54.0 %) (Table 2). The median length of stay in hospital for twins was 6 days (interquartile range: 5 – 13 days). The 121 (0.1 %) records missing one or more of the key variables (sex, birthweight and gestational age), and 134 (0.2 %) lower Tukey limit and 207 (0.2 %) higher Tukey limit outliers were excluded. Percentiles were calculated for the remaining 85,436 infants.

Figure 1 shows birthweight percentiles by gestational age for liveborn twins by infant sex; exact birthweight percentiles are shown in Table 3 and Table 4. The mean birthweight slightly decreased from 2462 g in 2001 to 2440 g in 2010 for male twins ($p = 0.49$). For female twins,

| Maternal characteristics | Number & percentage |
|--------------------------|---------------------|
| Total                    | 43,833 (100.0 %)    |
| Maternal age (years)     |                     |
| < 20                     | 873 (2.0 %)         |
| 20-24                    | 4076 (9.3 %)        |
| 25-29                    | 10,468 (23.9 %)     |
| 30-34                    | 15,944 (36.4 %)     |
| 35-39                    | 10,412 (23.8 %)     |
| >=40                     | 2055 (4.7 %)        |
| Not stated               | 5 (0.0 %)           |
| Parity                   |                     |
| Primiparas               | 17,971 (43.3 %)     |
| Multiparas               | 23,466 (56.6 %)     |
| Not stated               | 37 (0.1 %)          |
| Country of birth         |                     |
| Australia                | 31,682 (72.3 %)     |
| Overseas                 | 11,944 (27.2 %)     |
| Not stated               | 207 (0.5 %)         |
| Smoking during pregnancy |                     |
| Yes                      | 4271 (13.9 %)       |
| No                       | 25,968 (84.7 %)     |
| Not stated               | 420 (1.4 %)         |
| Remoteness               |                     |
| Major Cities             | 30,579 (69.8 %)     |
| Inner Regional           | 8136 (18.6 %)       |
| Outer Regional           | 3959 (9.0 %)        |
| Remote                   | 738 (1.7 %)         |
| Very remote              | 367 (0.8 %)         |
| Not stated               | 17 (0.0 %)          |
the mean birthweight significantly decreased from 2375 g in 2001 to 2338 g in 2010 (< 0.001) (Fig. 2). Compared with twins born in Australian 1991–94, the mean birthweight was significantly lower for twins born in 2010 for both male (2485 g versus 2440 g, < 0.001) and female (2382 g versus 2338 g, <0.001).

Discussion

We developed the contemporary population-based birthweight percentile charts to provide an up-to-date reference for twins born in Australia.

Growth in twin pregnancies slows progressively from around 32 weeks until term [6]. When comparing the dataset in this study with a singleton population from a similar time period [2] this phenomenon is confirmed. The median gestation-specific birthweight for twins were remarkably similar to those for singletons from a similar era until around 32 weeks gestation. The difference then becomes progressively more pronounced, reaching 640 g for males and 480 g for females at 40 weeks. It has been postulated that this slowing of growth late in a multiple pregnancy is a physiologically adaptive process that favours developmental maturity at the expense of fetal size [6]. However, there is a limit to this physiological adaptation and eventually the growth restriction becomes a pathological process. This is evidenced by studies consistently highlighting the risks of late fetal death in twins, particularly in relation to growth restriction [7–9].

Twin pregnancies have an increased risk of adverse outcome compared to single pregnancies. The increase in perinatal mortality and morbidity is primarily related to preterm delivery, complications of monochorionicity, and fetal growth restriction. Accurate population data is required to accurately diagnose growth restriction in twin pregnancies.

Secular trends for a decrease in the overall mean birthweight for liveborn twins were observed for both male and females in Australia in the study period. In contrast the mean birthweight for liveborn singletons in Australia from a similar time period has been relatively stable [2]. The observed decline in the mean birthweight for twins over time was partially explained by the downward shift in the distribution of gestational age. The mean gestational age was 35.4 weeks for twins in 2001,
compared with 35.1 weeks in 2010 [10, 11]. Preterm birth occurred in 51.2 % of twins in 2001 and 56.7 % in 2010 [10, 11]. This decreased mean gestational age and increased pre-term births rate among twins might be attributed to improved intrapartum survival at earlier gestations, earlier obstetric interventions and increased usage of assisted reproductive technology [12, 13].

Population-based birthweight percentile charts for twins are scarce [14–17]. When comparing Australian birthweight percentile charts with others, significant differences in birth size are observed between populations. At 40 weeks gestation, the mean birthweight of Australian live born twins are markedly lower than Norwegian and Finnish counterparts [15, 17] but the median birthweight of Australian twins are heavier than Canadian and Japanese twins [14, 16]. Sanklampi et al. has stated that the differences in term birth size is largely associated with differences in genetic background rather than maternal nutrition or healthcare as this is comparable between these developed countries [17].

There is inherent appeal in the customisation of growth charts that incorporate maternal weight, height, ethnicity as well as plurality. The intent is to identify fetuses that are small as a consequence of growth restriction rather
than constitutionally small for clinical decision-making. Several large observational studies have suggested that customised charts improve the identification of infants with intrauterine growth restriction compared with population-based charts, although contrasting opinions exist [18–22]. Birthweight centiles provide a population reference describing fetal growth in the population rather than a standard for assessing individual growth [23]. They also provide the basis for characterising newborn size for longitudinal studies of childhood outcomes. The usefulness of customised birthweight percentiles has been debated. The value of plurality-specific centiles has been established but the literature remains divided on the benefits of customisation for other characteristics and the need for multiple reference charts [24]. Maternal height and weight have been included in the NPDC from 2010, but agreed national standards have not yet been implemented. Further studies are required to examine whether customised growth charts adjusted for maternal size and ethnicity contribute to improved prediction of adverse perinatal outcomes.

The provision of these updated birthweight percentile charts allows clinicians and researchers to re-evaluate the success of pregnancy management by determining the rate of detection of growth restriction. As previously described, growth restriction is the major cause of late fetal death in twin pregnancies and its accurate diagnosis is a focal point of good obstetric care.

One limitation of this study is that birthweight percentile charts do not measure intrauterine growth but rather size at birth. The birthweight of babies born prematurely is likely to be influenced by the pathological process leading to preterm birth and therefore likely to differ from those remaining in utero until term [25, 26]. It has been argued that the preterm births should be assessed using estimated fetal weight rather than birthweight percentile charts as preterm neonates are disproportionately affected by the fetal growth restriction [25]. However, the accuracy of estimated fetal weight is limited by the ability of obtaining accurate measurements included within the computation of estimated fetal weight and the formula used for computation [26, 27]. To date, there has been no Australian chart published for sono-graphic standards for estimated fetal weight and the Australasian Society for Ultrasound in Medicine's position is that ‘No formula for estimating fetal weight has

### Table 3 Birthweight percentiles for male liveborn twins, Australia, 2001-2010

| Gestation (weeks) | No. of births | Mean (g) | Standard deviation | Birthweight percentile (g) |
|-------------------|---------------|----------|--------------------|----------------------------|
|                   |               |          |                    | p3  | p5  | p10 | p25 | p50 | p75 | p90 | p95 | p97 |
| 20                | 42            | 338      | 50                 | .   | .   | .   | 300 | 340 | 369 | .   | .   | .   |
| 21                | 90            | 402      | 73                 | .   | .   | .   | 320 | 355 | 400 | 450 | 495 | .   |
| 22                | 131           | 495      | 72                 | 320 | 350 | 400 | 450 | 510 | 540 | 580 | 600 | 620 |
| 23                | 166           | 560      | 77                 | 400 | 440 | 470 | 505 | 560 | 610 | 650 | 695 | 718 |
| 24                | 216           | 666      | 96                 | 477 | 490 | 525 | 617 | 673 | 724 | 784 | 820 | 840 |
| 25                | 234           | 760      | 114                | 510 | 540 | 610 | 695 | 760 | 840 | 900 | 940 | 968 |
| 26                | 297           | 883      | 161                | 555 | 610 | 686 | 775 | 880 | 986 | 1080| 1156| 1205|
| 27                | 323           | 1010     | 161                | 616 | 716 | 804 | 912 | 1019| 1116| 1200| 1270| 1300|
| 28                | 478           | 1153     | 201                | 720 | 780 | 890 | 1030| 1160| 1290| 1410| 1450| 1505|
| 29                | 563           | 1297     | 219                | 757 | 875 | 1000| 1180| 1327| 1450| 1545| 1625| 1660|
| 30                | 720           | 1453     | 246                | 930 | 991 | 1128| 1314| 1477| 1600| 1755| 1850| 1928|
| 31                | 1059          | 1628     | 255                | 1120| 1172| 1285| 1470| 1632| 1790| 1942| 2060| 2120|
| 32                | 1638          | 1784     | 292                | 1180| 1275| 1400| 1596| 1799| 1972| 2155| 2245| 2316|
| 33                | 2040          | 1999     | 304                | 1410| 1469| 1590| 1815| 2010| 2200| 2370| 2486| 2555|
| 34                | 3408          | 2179     | 328                | 1530| 1618| 1760| 1970| 2180| 2400| 2600| 2704| 2780|
| 35                | 4503          | 2382     | 340                | 1755| 1830| 1950| 2155| 2380| 2600| 2810| 2950| 3040|
| 36                | 7319          | 2589     | 359                | 1910| 1995| 2135| 2350| 2595| 2820| 3044| 3185| 3280|
| 37                | 10665         | 2768     | 355                | 2100| 2190| 2315| 2530| 2765| 3000| 3215| 3356| 3470|
| 38                | 7601          | 2901     | 357                | 2240| 2320| 2450| 2665| 2894| 3130| 3365| 3510| 3620|
| 39                | 1129          | 2982     | 364                | 2260| 2415| 2538| 2730| 2980| 3220| 3460| 3600| 3695|
| 40                | 308           | 3031     | 427                | 2275| 2330| 2470| 2743| 3040| 3275| 3600| 3790| 3960|
| 41                | 25            | 3199     | 558                | .   | .   | .   | 2805| 3015| 3500| .   | .   | .   |
| 42                | 8             | 2969     | 459                | .   | .   | .   | 2500| 2980| 3400| .   | .   | .   |
### Table 4 Birthweight percentiles for female liveborn twins, Australia, 2001-2010

| Gestation (weeks) | No. of births | Mean (g) | Standard deviation | Birthweight percentile (g) |
|-------------------|---------------|----------|--------------------|---------------------------|
|                   |               |          |                    | p3  | p5  | p10 | p25 | p50 | p75 | p90 | p95 | p97 |
| 20                | 49            | 299      | 57                 | .   | .   | .   | 260 | 296 | 330 | -   | -   | -   |
| 21                | 94            | 374      | 58                 | .   | .   | .   | 300 | 340 | 370 | 415 | 450 | -   |
| 22                | 107           | 459      | 75                 | 300 | 330 | 350 | 420 | 460 | 508 | 545 | 570 | 580 |
| 23                | 143           | 517      | 83                 | 325 | 350 | 405 | 470 | 520 | 570 | 620 | 640 | 650 |
| 24                | 176           | 635      | 87                 | 425 | 480 | 530 | 589 | 638 | 700 | 731 | 751 | 780 |
| 25                | 167           | 728      | 113                | 520 | 547 | 580 | 656 | 730 | 800 | 878 | 907 | 920 |
| 26                | 241           | 845      | 141                | 525 | 580 | 660 | 760 | 864 | 930 | 1000| 1052| 1090|
| 27                | 308           | 951      | 186                | 550 | 598 | 710 | 840 | 983 | 1060| 1180| 1240| 1290|
| 28                | 384           | 1090     | 169                | 745 | 795 | 870 | 991 | 1112| 1200| 1280| 1345| 1365|
| 29                | 542           | 1219     | 211                | 750 | 808 | 930 | 1101| 1235| 1360| 1465| 1536| 1601|
| 30                | 697           | 1355     | 244                | 850 | 896 | 1010| 1210| 1375| 1530| 1655| 1725| 1760|
| 31                | 990           | 1551     | 239                | 1030| 1105| 1227| 1415| 1568| 1700| 1833| 1930| 1990|
| 32                | 1618          | 1713     | 262                | 1182| 1248| 1365| 1550| 1730| 1880| 2020| 2140| 2220|
| 33                | 2037          | 1895     | 288                | 1320| 1400| 1530| 1713| 1900| 2086| 2250| 2360| 2430|
| 34                | 3322          | 2085     | 308                | 1482| 1555| 1685| 1885| 2090| 2292| 2480| 2570| 2635|
| 35                | 4558          | 2267     | 324                | 1640| 1715| 1850| 2060| 2270| 2480| 2670| 2790| 2875|
| 36                | 7145          | 2464     | 339                | 1825| 1905| 2035| 2240| 2460| 2680| 2900| 3030| 3130|
| 37                | 10695         | 2656     | 340                | 2020| 2120| 2225| 2430| 2630| 2880| 3090| 3230| 3326|
| 38                | 7720          | 2774     | 339                | 2145| 2230| 2349| 2545| 2765| 2990| 3215| 3350| 3435|
| 39                | 1154          | 2884     | 373                | 2185| 2280| 2420| 2630| 2875| 3140| 3360| 3500| 3570|
| 40                | 320           | 2958     | 438                | 2110| 2180| 2368| 2668| 3000| 3240| 3518| 3653| 3800|
| 41                | 22            | 2976     | 322                | .   | .   | .   | 2795| 2933| 3220| .   | .   | .   |
| 42                | 11            | 3001     | 497                | .   | .   | .   | 2540| 2910| 3440| .   | .   | .   |

**Fig. 2** Mean birthweight of liveborn twins, by sex, Australia, 2001–2010.
achieved an accuracy which enables us to recommend its use’ [27, 28]. In such cases, the population-based birthweight percentile charts presented in this study provide a valuable reference for clinicians and researchers assessing the prognosis of twins in Australia.

Conclusions
This study presents the up-to-date national population-based birthweight percentile charts for male and female live born twins in Australia. These new charts provide a valuable reference for clinicians and researchers correctly identifying high-risk twins in Australia.

Abbreviations
AIHW: Australian Institute of Health and Welfare; NPDC: National Perinatal Data Collection.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
All authors participated in the study design and interpretation of data. ZL conducted the data analysis and drafted the manuscript. MPU participated in drafting the manuscript. LH participated in the data analysis and revised the manuscript critically. FX and EAS have revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Authors’ information
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