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ORIGINAL RESEARCH

Development of Local Birth Weight Reference Based on Gestational Age and Sex in South Kalimantan Province, Indonesia

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Purpose: Percentile reference of babies' birth weight is an effective reference tool for early detection of the risk of neonatal morbidity and impaired growth. However, the lack of minimum local and national perinatal data makes its development in Indonesia difficult. This study aims to develop a local birth weight percentile reference for babies based on gestational age and sex by utilizing local data in South Kalimantan Province which is one of the provinces with the highest neonatal mortality rate in Indonesia.

Patients and Methods: All single live newborns who were born and were recorded in 20 primary healthcare centers, between 1 June 2016 and 30 June 2017, were included in the study. Birth weight percentiles of infants were calculated using the weighted average method. The study focused on neonates born with gestational age from 36 to 40 weeks.

Results: A local birth weight reference for babies has been developed. According to our local reference, the proportion of male newborns with a birth weight < 10th percentile was higher (7.0%) than the existing Indonesian (4.2–4.3%) and international references (3.3–6.2%). Similarly, the proportion of female newborns with a birth weight <10th percentile was higher (6.5%) than the existing Indonesian references (3.6–4.4%) and the global reference (5.8%) but lower than the Intergrowth 21st project (7.2%). The differences suggest that relative birth weight will likely be underestimated (overestimated) if other percentile references are used for the local population.

Conclusion: A local birth weight percentile reference for babies in South Kalimantan Province based on gestational age (36–40 weeks) and sex has been developed. Access to the local data, as baseline information, will allow the compilation and comparison of pregnancy-related outcomes across provinces in Indonesia. Consequently, reliable national perinatal data can be strengthened to establish the national references for newborns' anthropometric measurements.

Keywords: percentile reference, birth weight, age, gender, Indonesia

Introduction

The complexity of prematurity is the most common cause of death among infants worldwide. This includes two-thirds premature birth (birth before 37 completed weeks of gestation) and one-third term birth but small-for-gestational-age (SGA) (< 10% of birth weight). However, birth weight is a primary measurement and significant indicator to ensure the optimal growth, survival, and future well-being of newborns. It is well documented that low birth weight (LBW) is associated with higher neonatal mortality and morbidity.[4] Birth weight percentiles that incorporate weight and gestational age (GA) of neonates at birth can be used as a reference for detecting the risk of having neonatal morbidity and growth impairment.[5] International standards for newborn's anthropometric measurements, such as birth weight, length, and head circumference, by GA (between 33 and 42 weeks) and sex have been developed.[3] However, heterogeneity of maternity population in different

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countries may inevitably impact the optimality of fetal and neonatal growth and size.[6] Currently, epidemiological data have highlighted four priorities to promote the Every Newborn Action Plan for delivering a healthy new generation, specifically to where (which countries) when (around birth), what (the leading causes of neonatal mortality), and who (small babies).[7] Therefore, nation-specific references for newborns' anthropometric measurements are required.

In Indonesia, a national reference is currently not available due to the lack of reliable national perinatal data. However, some efforts have been made to provide gestational age-specific reference percentiles for Indonesian newborns' anthropometric measurements. The first reference was developed in 1994 using a multicenter survey across 14 Indonesian teaching hospitals between 1990–1991 (n = 5844 live singleton newborns).[8] In 2016, the former references were then updated using the local maternal-perinatal database between 1998 and 2007 across 1 provincial (referral) hospital, 5 district hospitals, and 5 health centers in Yogyakarta (n = 54,599 live singleton births). However, none of these existing references compare the proportion of live births that are classified as SGA.

This study aims to develop local birth weight reference percentiles by GA and sex for all live singleton newborns in the province of South Kalimantan, Indonesia which is one of the five provinces recording the highest neonatal mortality rate.[9–11] The references are then used to compare the proportion of live births that are classified as SGA according to our local birth weight reference versus that of the existing Indonesian and international references to better understand the characteristics of maternity population across provinces and countries, respectively.

Materials and Methods

Study Population

This research was conducted in the South Kalimantan province between April 2016 and October 2017. The province consists of 2 municipalities (urban areas) and 11 districts (rural areas). In the capital of the province, public and private hospitals as tertiary health facilities are available. Each administrative area is served by hospitals as secondary health facilities that provide referral services in that area and health centers as primary health facilities. These primary healthcare (PHC) centers are the most locally recommended and cost-effective first level of healthcare systems in Indonesia.[9,12,13]

Our study population consisted of all newborns delivered in 20 primary healthcare (PHC) centers comprising: 14 public health centers (PKMs) and 6 private midwifery clinics (BPMs) which are proportionally distributed across the administrative areas of the province. These PHC centers were purposively selected by the provincial health department and midwifery association to be included in the study. The selection criteria were also based on the "large size of population" (5–18%) who live in the area and might seek and receive health care from the centers.

Research Design and Data Collection

A descriptive design using the quantitative method was used to conduct the research. Birth data collection was assisted by 20 trained and experienced midwives who were recommended by the provincial health department and midwifery association to participate in this study. The midwives represented the participating PHC centers. They had working experience in rendering antenatal and midwifery services with an average of 20 years: ranged from six to ten years (n =4; 20%), eleven to twenty years (n = 9; 45%), twenty-one to thirty years (n = 5; 25%), and thirty-one or longer (n = 2; 10%).

The data collection was carried out in two phases. A retrospective cohort study was used in Phase 1 while a prospective cohort study was used in Phase 2. During the retrospective phase, the participating midwives were asked to provide the manual local pregnancy registers (1 April 2007–31 May 2016) available at PHC centers to where they were assigned. These records were then entered into a spreadsheet for quantitative analysis by the local data collection team. To improve the quality of data processing tasks, the team in charge of data entry was trained to understand the content of the manual pregnancy registers. This was followed by face-to-face and online communication between the principal investigator, the data collection team, and the midwives to minimize data entry errors. Therefore, access to manually recorded antenatal care (ANC) information on 3181 women who enrolled, received care, and gave birth in the centers was granted.

A prospective cohort study was employed during the second phase of the study. The representative midwives agreed to participate in our prospective cohort study (1 June 2016–30 June 2017). By following the national standard operational procedures of ANC, the midwives were expected to longitudinally monitor and measure the recommended ANC examinations from the first trimester of pregnancy to delivery and timely record the results into our developed electronic pregnancy registers. Online communication between the principal investigator and the midwives was conducted to improve the quality of data processing tasks and minimize data entry errors. Therefore, access to electronically recorded ANC information on 435 women who enrolled, received care, and gave birth in the centers was granted.

Inclusion and Exclusion Criteria

All pregnant women who delivered live singleton newborns between 2007 and 2017 at the participating PHC centers and had complete key characteristic information of their newborns, such as gestational age, birth weight and sex were included in the study. Meanwhile, those with multiple pregnancies/births, abortion, stillbirths, premature births, and low birth weight were excluded from the study.

Statistical Analyses

Quantitative data analysis was used in this study. Birth weight was recorded in grams. Since ultrasound facilities are currently not available in the PHC centers, gestational age (GA) was calculated based on the first day of the last menstrual period (LMP) and recorded in completed weeks. Implausible birth weights were excluded using a method based on Tukey's box-and-whisker plots.[5] Birth weights below the first quartile minus one and a half times the interquartile range, or above the third quartile plus one and a half times the interquartile range were considered mild outliers. Meanwhile, birth weights below the first quartile minus three times the interquartile range, or above the third quartile plus three times the interquartile range, were considered extreme outliers. Both mild and extreme outliers were excluded from analyses. The relative percentile differences between our local (current) birth weight percentiles with the previously published percentiles were calculated using the following formula.[14]

$$Relative\ percentile\ difference = \frac{\left(Existing_{reference\ percentile} - Local\ (current)_{reference\ percentile}\right)}{Local\ (current)_{reference\ percentile}} \times 100 \quad (1)$$

Exact percentiles of birth weight for each gestational age between 22 and 44 weeks were calculated using the weighted average method. The means and standard deviations were also calculated. Weighted average accounts for uneven data, it is particularly useful in data dealing with demographics and population size. Percentiles were tabulated and plotted for each gestational age. Results for the 5th and 95th percentiles (and more extreme) are presented only for gestational ages with a minimum of 100 births[5] or 200 births.[15]

Results

Descriptive statistics on the baseline information of the study population between 2007 and 2017 (n = 3616) are presented in Table 1. Most mothers (47%) aged 23–32 years at the time of delivery, with few (22.8%) aged <22 years, 16.4% aged 33–42 years, 0.3% aged ≥42 years, and 13.5% with unrecorded age. Of these, 41.7% of mothers were well-nourished by considering the measurements of middle-upper arm circumference (≥23.5 cm) (41.7%) and body mass index (18.5–24.9 kg/m^2) (40%).

This study included 1123 (31.1%) male and 1094 (30.3%) female births and 1399 (38.7%) with unrecorded sex. Of these newborns, 362 (10%) were born preterm while 144 (4%) were LBW and 7 (0.2%) very low birth weight (<1500g). Most of the infants were delivered spontaneously (26.7%) with the assistance of health practitioners, midwives, and obstetricians (31.2%) and traditional birth attendance (0.4%).

We excluded from analysis 2413 births (66.73%) for which one or more of the key variables, such as sex, birth weight, and gestational age, were missing; among these were 5 (0.14%) with gestational age more than 44 weeks (Figure 1).

Table 1 Basic Characteristic of Mothers and All Live Singleton Newborns in South Kalimantan, Indonesia (2007–2017)

Characteristic	Number (%)
Total	**3616**
Maternal age (years)	
<22	825 (22.8)
23–32	1699 (47.0)
33–42	592 (16.4)
>42	11 (0.3)
Not stated	489 (13.5)
Maternal body mass index (kg/m^2)[18]	
Underweight (<18.5)	210 (5.8)
Normal (18.5–24.9)	1447 (40.0)
Overweight (25–29.9)	441 (12.2)
Obese (≥30)	96 (2.7)
Not stated	1422 (39.3)
Maternal nutritional status	
Chronic energy shortage (if middle upper arm circumference < 23.5 cm)	282 (7.8)
Normal (if middle upper arm circumference ≥ 23.5 cm)	1508 (41.7)
Not stated	1826 (50.5)
Birth order	
1st birth	639 (17.7)
2nd or greater	1270 (35.1)
Not stated	1707 (47.2)
Sex of neonate	
Male	1123 (31.1)
Female	1094 (30.3)
Not stated	1399 (38.7)
Birth weight (g)	
Very low birth weight (<1500g)	7 (0.2)
Low birth weight (1500–2499g)	144 (4.0)
Normal (2500–3999g)	3155 (87.3)
High birth weight (≥4000g)	32 (0.9)
Not stated	278 (7.7)

(*Continued*)

Table 1 (Continued).

Characteristic	Number (%)
Gestational age at delivery (weeks)	
Premature birth (<37 weeks)	362 (10.0)
Term birth (37–44 weeks)	1912 (52.9)
Post term birth (>44 weeks)	5 (0.1)
Not stated	1337 (37.0)
Mode of delivery	
Spontaneous	965 (26.7)
Sectio caesarean (SC)	103 (2.8)
Vacuum extraction (VE)	10 (0.3)
Not stated	2538 (70.2)
Birth attendance	
Health practitioner	678 (18.8)
Midwife	399 (11.0)
Specialist/obstetrician	50 (1.4)
Traditional birth attendance	14 (0.4)
Others	4 (0.1)
Not stated	2471 (68.3)

Birth Weight Percentiles by Gestational Age

Of the 1203 live singleton births with GA between 22 and 44 weeks and available data on birth weight, 15 (1.25%) were removed as mild outliers, with 13 (1.08%) being below the lower limit and 2 (0.17%) above the upper limit of the inner fence and none being extreme outliers. Percentiles were calculated for a total of 1188 births (Figure 1) and the basic characteristics of the study population after exclusion are described in Table 2.

Figure 2 shows the distribution of local birth weight data and its exact percentiles, using the weighted average method, by gestational age for all live singleton newborns. Exact 5th, 10th, 25th, 50th, 75th, 90th, and 95th birth weight percentiles between 36 and 40 weeks of GA are listed in Table 3.

Figure 3 shows the local mean of birth weight and GA at delivery recorded across urban and rural PHC centers between 2010 and 2017. The exact local mean of birth weight and GA and their corresponding ranges are presented in Table 4.

Overall, the mean birth weight was 3080 g. The trend fluctuated over the period with a significant decrease in 2012 (2932 g) (Figure 3 and Table 3). Meanwhile, the mean GA at delivery was 39 weeks. The trend remained stable over the period, except between 2013 and 2015 (38 and 37 weeks).

Birth Weight Percentiles by Sex and Gestational Age (GA)

Male Newborns

Of the 606 live singleton births with GA between 24 and 44 weeks and available data on birth weight, 5 (0.83%) were removed as mild outliers, with that being below the lower limit and none above the upper limit of the inner fence as well as being extreme outliers. Percentiles were calculated for a total of 601 births (Figure 1).

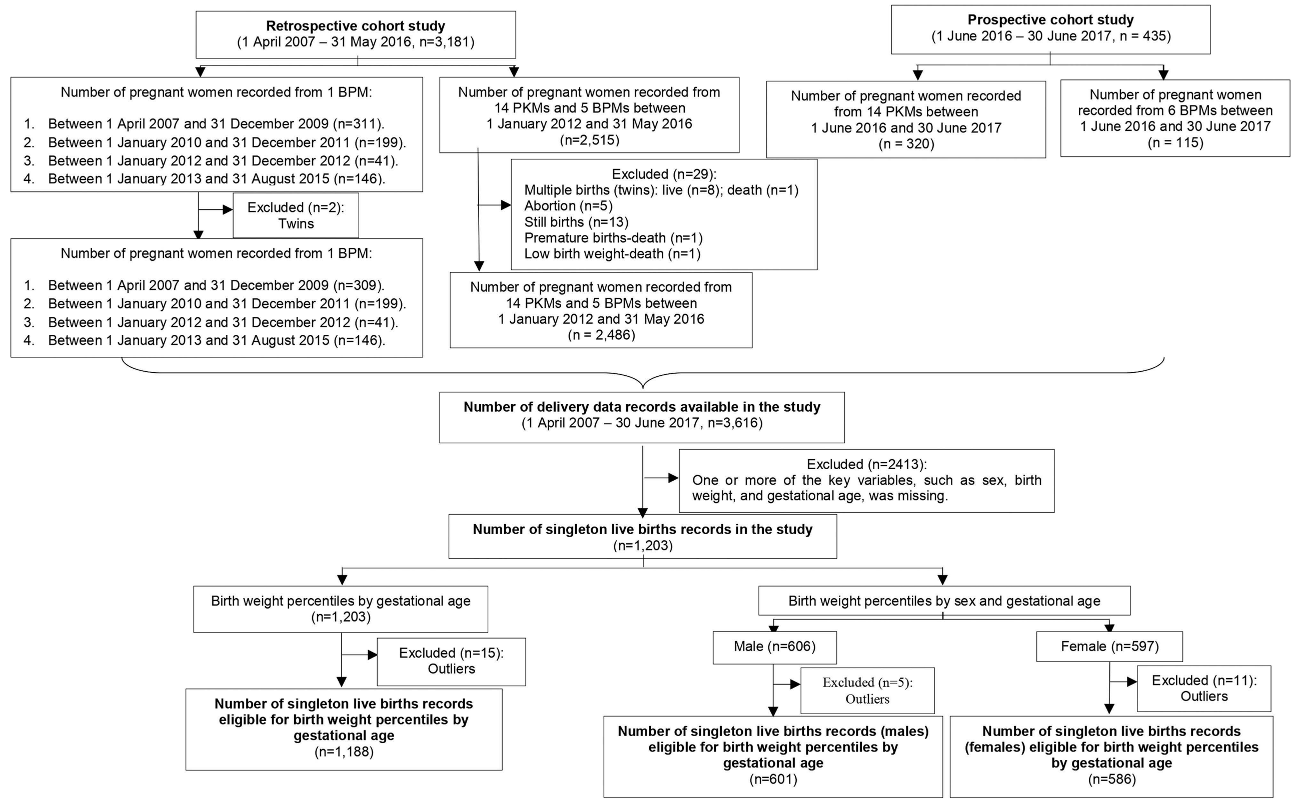

Figure 1 Flowchart of records selection process.

Figure 4 shows the distribution of local (current) birth weight data and its exact percentiles, using the weighted average method, by gestational age for male singleton live births. Exact 5th, 10th, 25th, 50th, 75th, 90th, and 95th local (current) birth weight percentiles between 36 and 40 weeks of GA are listed in Table 5.

Female Newborns

Of the 597 live singleton births with GA between 22 and 44 weeks and available data on birth weight, 11 (1.84%) were removed as mild outliers, with 10 (1.68%) being below the lower limit, 1 (0.17%) above the upper limit of the inner fence and none being extreme outliers. Percentiles were calculated for a total of 586 births (Figure 1).

Figure 5 shows the distribution of local (current) birth weight data and its exact percentiles, using the weighted average method, by gestational age for female singleton live births. Exact 5th, 10th, 25th, 50th, 75th, 90th, and 95th local (current) birth weight percentiles between 36 and 40 weeks of GA are listed in Table 6.

Figure 6 shows the local (current) mean of birth weight and GA at delivery for male and female newborns recorded across urban and rural PHC centers between 2010 and 2017. The exact local (current) mean birth weight and GA and their corresponding ranges for both male and female newborns are presented in Table 7.

Overall, the local (current) mean birth weight for males and females was 3110 g and 3055 g, respectively. The trend slightly increased between 2010 and 2017 for both sexes (Figure 6). The mean birth weights were higher for male newborns, except in 2011. This was followed by higher median birth weights for males than females between 36 and 40 weeks of GA (Tables 6 and 7). Meanwhile, the mean GA for female newborns was more stable than males over the period with a slight fluctuation between 2013 and 2015 (Figure 6 and Table 7).

Table 2 Basic Characteristic of Mothers and All Live Singleton Newborns in South Kalimantan, Indonesia (2007–2017) After Exclusion. This is the Data Set Used for the Analysis in This Paper

Characteristic	Number (%)
Total	**1186**
Maternal age (years)	
<22	311 (26.2)
23–32	656 (55.3)
33–42	217 (18.3)
>42	2 (0.2)
Maternal body mass index (kg/m^2)[14]	
Underweight (<18.5)	83 (7.0)
Normal (18.5–24.9)	566 (47.6)
Overweight (25–29.9)	214 ((18.0)
Obese (≥30)	29 (2.4)
Not stated	296 (24.9)
Maternal nutritional status	
Chronic energy shortage (if middle upper arm circumference < 23.5 cm)	56 (4.7)
Normal (if middle upper arm circumference ≥ 23.5 cm)	392 (33.0)
Not stated	740 (62.3)
Birth order	
1st birth	199 (16.8)
2nd or greater	600 (50.5)
Not stated	389 (32.7)
Sex of neonate	
Male	603 (50.8)
Female	585 (49.2)
Birth weight (g)	
Low birth weight (1500–2499g)	44 (3.7)
Normal (2500–3999g)	1144 (96.3)
Gestational age at delivery (weeks)	
Premature birth (<37 weeks)	215 (18.1)
Term birth (37–44 weeks)	973 (81.9)

Birth Reference Curves Comparison

Using the values from the local (current) study cohorts as references (Tables 3, 5, and 6), the mean and the 10th, 50th, and 90th percentiles of birth weight were compared to previously published Indonesian and international curves.[1–3,5,8,16] It should be noted that most international curves used ultrasound to estimate GA, therefore cannot be utilized in

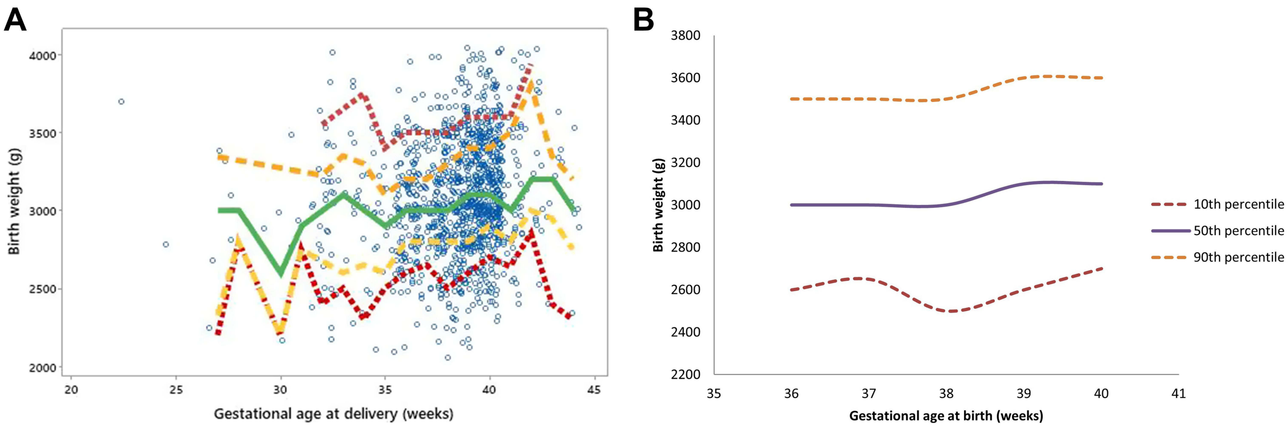

Figure 2 Local (current) birth weight percentiles by GA for all live singleton newborns, South Kalimantan, Indonesia, 2007–2017: (**A**) superimposed observed data between 22 and 44 weeks of GA with the 10th, 25th, 50th, 75th, and 90th percentile limits and (**B**) between 36 and 40 weeks of GA.

Indonesia due to the lack of ultrasound facilities in most PHC centers. The general characteristics of these studies are presented in Table 8. The comparison of mean birth weight is illustrated in Figures 7–10.

The mean birth weight for GA < 37 weeks was higher in our study (solid black line) than those in the previously published Indonesia's (dotted blue and red lines) and UK's studies (dotted green line). Meanwhile, GA between 37 and 40 weeks presented the highest mean birth weight in Britain's population but the lowest in one of the Indonesian study populations (Figure 7).

The comparison between the local (current) birth weight percentiles and the previously published curves[1,2,8] are illustrated in Figure 8. Overall, the non-Indonesian birth weight percentiles[1] was higher than the existing Indonesian references, particularly after 38 weeks of GA. The values of 10th percentiles between 36 and 38 weeks of GA in the local (current) study were higher than those of Britain and Indonesian infants but lower than that of Britain infants after 38 gestation weeks.

Figure 7 shows that while the local (current) trend of birth weight percentiles is similar to the ones constructed in 1994 based on the Indonesian population,[8] the local (current) birth weight percentiles have decreased (Figure 8). Also, the generic reference tool developed by Mikolajczyk et al in 2011[2] does not fit our local data, except in the 10th percentiles between 38 and 40 weeks of GA.

The mean birth weight for GA <37 weeks was higher in the local (current) study than those in the previously published Indonesia's, Australia's, and China's studies. Meanwhile, GA between 37 and 40 weeks presented the highest mean birth weight in the Australian population followed by the Chinese population but the lowest in the Indonesian population (Figure 9).

Table 3 Local (Current) Birth Weight Percentiles by GA for All Live Singleton Newborns, South Kalimantan, Indonesia, 2007–2017

Gestational Age at Delivery (Weeks)	Number of Births	Mean (SD) Birth Weight (g)	Birth Weight Percentile (g)						
			5th	10th	25th	50th	75th	90th	95th
36	117	3012 (328)	2500	2600	2800	3000	3200	3500	3600
37	94	3027 (323)	2500	2650	2800	3000	3200	3500	3550
38	179	3020 (376)	2400	2500	2800	3000	3300	3500	3600
39	259	3102 (373)	2500	2600	2800	3100	3400	3600	3700
40	338	3143 (347)	2595	2700	2900	3100	3400	3600	3800

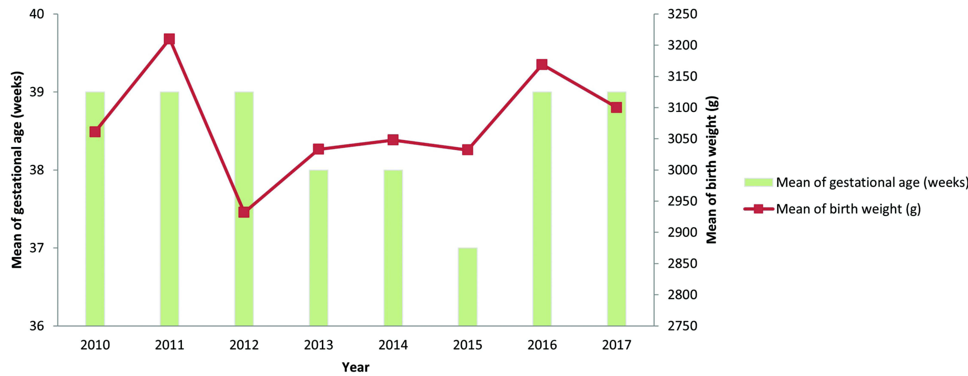

Figure 3 Mean of local (current) birth weight and GA by year for all live singleton newborns, South Kalimantan, Indonesia, 2010–2017.

The comparison between the local (current) birth weight percentiles by GA and sex with the previously published references[2,3,5,8,14,16] were shown in Figure 10. In general, the birth weight percentiles both for male and female newborns based on non-Indonesian population[3,5,14] were higher than those in the local (current) and previously published references[2,8,16] based on the Indonesian population. There was consistent evidence that the local (current) characteristics of birth weight percentiles for males and females have close similarity with the ones constructed in 1994[8] and 2016[16] based on the Indonesian maternity population, particularly after 38 weeks of GA. Also, the generic reference tool developed by Mikolajczyk et al in 2011[2] does not fit our local (current) population for both sexes, except in the 10th percentiles between 38 and 40 weeks of GA.

Overall, the mean birth weight between 36 and 40 weeks of GA was higher in our local (current) study than those in the previously published Indonesia's studies (Figure 11).

The relative differences for the 10th, 50th, and 90th percentiles between our local (current) reference and those from other references are listed in Tables 9 and 10. Overall, greater differences were found at almost all gestation weeks among the existing references, particularly at or before 37 gestation weeks.

The positive values in both (Tables 9 and 10) indicate that the local (current) percentiles were smaller than the existing ones, suggesting that relative birth weight will likely be overestimated if other percentile references are used for the local (current) population. On the other hand, negative numbers will likely result in underestimation if other references are used.

As per the definition of SGA, the comparison of the proportion of live births with a birth weight < 10th percentile between our local (current) reference and the existing Indonesian and international references is given in Table 11.

Table 4 Mean and Range of Local (Current) Birth Weight and GA for All Live Singleton Newborns (n=1123), South Kalimantan, 2010–2017

	2010	2011	2012	2013	2014	2015	2016	2017
Birth weight (g)								
Mean	3061	3210	2932	3033	3048	3032	3169	3100
Range	2100–3700	2400–4000	2400–3700	2100–4000	2100–4000	2200–4000	2270–4000	2100–4000
GA (weeks)								
Mean	39	39	39	38	38	37	39	39
Range	35–43	34–43	34–40	32–44	24–44	28–44	32–41	32–43

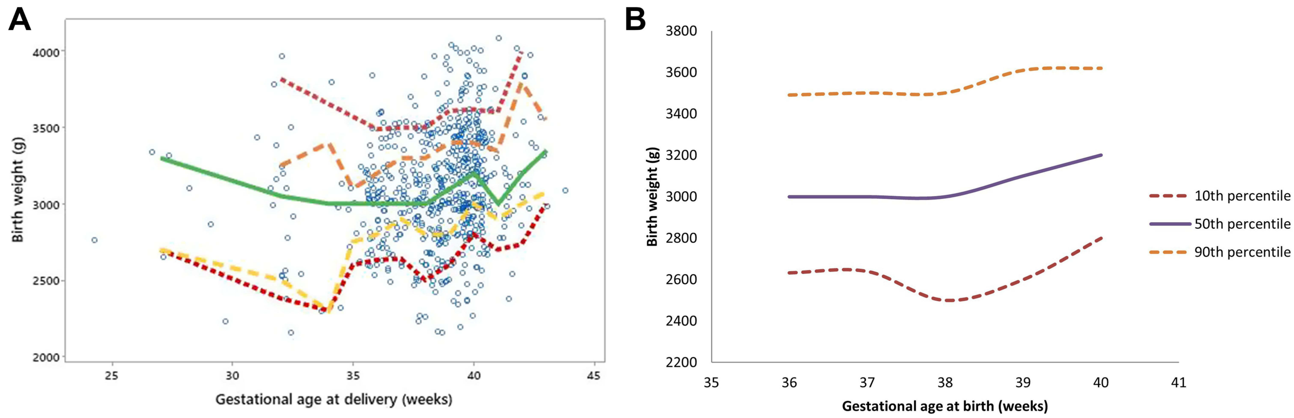

Figure 4 Local (current) birth weight percentiles by GA for male live singleton newborns, South Kalimantan, Indonesia, 2007–2017: (**A**) superimposed observed data between 24 and 44 weeks of GA with the 10th, 25th, 50th, 75th, and 90th percentile limits and (**B**) between 36 and 40 weeks of GA.

Regardless of the sexes, overall, the proportion of live births with a birth weight < 10th percentile according to our local (current) reference (5.9%) was higher than the existing Indonesian reference (4.7%) but lower than the existing global reference (6.7%). This trend was similar to newborns who were delivered at term pregnancy (between 37 and 40 weeks). Meanwhile, preterm birth (< 37 weeks) presented the highest proportion in our local (current) population.

For male newborns, the proportion of live births with a birth weight < 10th percentile according to our local (current) reference (7.0%) was higher than the existing Indonesian (4.2–4.3%) and international references (3.3–6.2%). This trend was similar to those delivered at preterm pregnancy. At term birth, however, our local (current) population presented a higher proportion of SGA babies (1.2%) than the existing Indonesian and international standard references (0%) but lower than the existing global reference (6.2%).

For female newborns, the proportion of live births with a birth weight < 10th percentile according to our local (current) reference (6.5%) was higher than the existing Indonesian references (3.6–4.4%) and the global reference (5.8%) but lower than the Intergrowth 21st project (7.2%). This trend was similar to those delivered at term pregnancy. Nevertheless, at preterm birth, our local (current) population presented a higher proportion of SGA newborns (0.7%) than the existing Indonesian and international references (0%).

Discussion

Main Findings of the Study

This study has locally presented the first gestational age-specific reference of birth weight between 36 and 40 weeks of GA for live singleton newborns in the South Kalimantan province which is one of the five provinces recording the

Table 5 Local (Current) Birth Weight Percentiles by GA for Male Live Singleton Newborns, South Kalimantan, Indonesia, 2007–2017

Gestational Age at Delivery (Weeks)	Number of Births	Mean (SD) Birth Weight (g)	Birth Weight Percentile (g)						
			5th	10th	25th	50th	75th	90th	95th
36	70	3040 (296)	2600	2633	2800	3000	3200	3490	3600
37	43	3070 (296)	2520	2640	2900	3000	3300	3500	3500
38	94	3028 (363)	2375	2500	2800	3000	3300	3500	3500
39	127	3141 (399)	2500	2600	2800	3100	3400	3610	3860
40	177	3182 (351)	2600	2800	3000	3200	3400	3620	3800

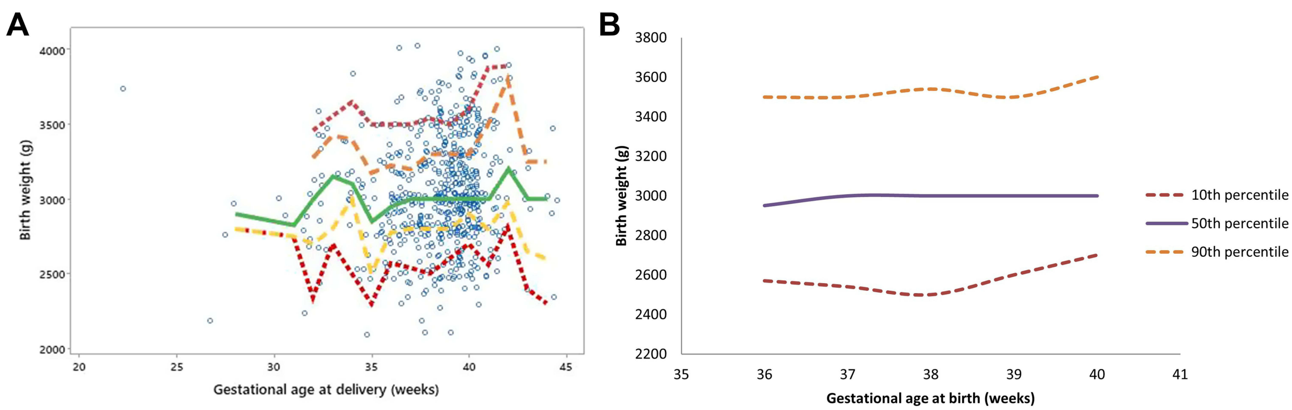

Figure 5 Local (current) birth weight percentiles by GA for female live singleton newborns, South Kalimantan, Indonesia, 2007–2017: (**A**) superimposed observed data between 22 and 44 weeks of GA with the 10th, 25th, 50th, 75th, and 90th percentile limits and (**B**) between 36 and 40 weeks of GA.

highest neonatal mortality rate in Indonesia[9–11] 7. The birth weight reference was developed based on available complete local perinatal data between 2010 and 2017 across 20 primary healthcare centers in the province. The reference can be used as an effective tool to describe the characteristics of the local newborn population and compare them (in terms of GA) with the previously Indonesian published references (1994[8] and 2016[16]). The provision of the local birth weight percentiles also enables the comparison of the proportion of live births that are classified as SGA according to our local reference versus that of the existing Indonesian and international references. Consequently, the characteristics of the newborn population or pregnancy-related outcomes, specifically across provinces in Indonesia, can be better reflected.

The local newborn population was overall delivered at term pregnancy (37–39 weeks of GA) with a normal range of mean birth weight (3080 g) as it is mostly expected. The trend of the mean GA at delivery for the total population, males, and females was fairly steady over time, with an equal maximum variation of 2 weeks. Meanwhile, the mean birth weight was similar to that of the Indonesian newborns recorded between 1990 and 1991 (3085 g)[8] even though the study population was different. The previous study was based on a multicenter survey across 14 Indonesian teaching hospitals regarded as tertiary healthcare centers which tend to have a more at-risk maternity population than the present study which was based on retrospective and prospective cohort studies conducted across 20 primary healthcare centers. However, the present mean birth weight was higher than that of the newborn population in Yogyakarta between 1998 and 2007 (2964 g) which was based on local maternal and perinatal data recorded across primary, secondary, and tertiary healthcare facilities.[16]

It is noteworthy that the mean birth weight of newborns in the present study had experienced a slight increase between 2010 and 2017, with a maximum variation of 278 g. Though, the trend was relatively stable over time for both

Table 6 Local (Current) Birth Weight Percentiles by GA for Female Live Singleton Newborns, South Kalimantan, Indonesia, 2007–2017

Gestational Age at Delivery (Weeks)	Number of Births	Mean (SD) Birth Weight (g)	Birth Weight Percentile (g)						
			5th	10th	25th	50th	75th	90th	95th
36	46	2990 (350)	2468	2570	2775	2950	3225	3500	3630
37	51	2991 (342)	2400	2540	2800	3000	3200	3500	3700
38	85	3012 (392)	2400	2500	2800	3000	3300	3540	3700
39	132	3066 (343)	2500	2600	2800	3000	3300	3500	3600
40	161	3100 (339)	2500	2700	2900	3000	3300	3600	3700

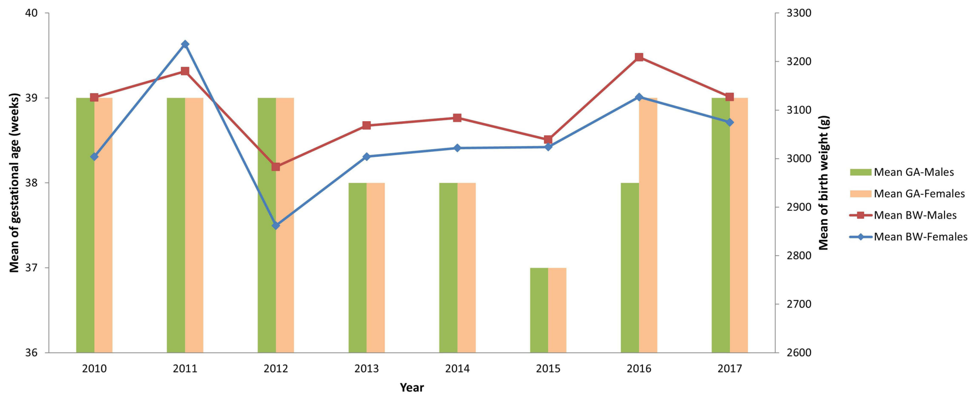

Figure 6 Local (current) mean birth weight and GA by year and sex live singleton newborns, South Kalimantan, Indonesia, 2010–2017.

male and female newborns, with a higher maximum variation in the females (374 g) than the males (226 g). The present trend of mean birth weight based on newborn's gender was similar to that of the Australian newborns[5] but with a reverse trend in the maximum variation. Such comparison could not be made with that in the previous Indonesian studies,[8,16] since there was no information available on such trends on the mean and variance of birth weight. In addition, the mean birth weight in the present study was 55 g higher in male newborns than the females, except in 2011. This result was in agreement with both the Indonesian[8,16] and Australian[5] studies.

When compared with the existing international birth weight references, the current Indonesian median birth weights for gestational age were smaller than those in the UK,[1] Australia,[5] and China[14] and larger than those based on the Intergrowth 21st project,[3] particularly after 38 weeks of GA. However, when compared with the existing Indonesian birth weight percentiles,[8,16] the current 50th percentiles were relatively equal, specifically after 38 weeks of GA. This suggested that the current and previous birth weight references have reflected similar characteristics of Indonesian newborns.

Early detection of the risk of having neonatal morbidity and growth impairment, such as prematurity and SGA is crucial in providing appropriate interventions promptly. As demonstrated in this study, the proportion of live births, both males and females, with a birth weight < 10th percentile classified as SGA according to our locally derived birth weight reference for GA was higher than the existing Indonesian and international references,[2,3,8,16] particularly at preterm births. This implies that the use of local reference had a higher threshold for SGA, particularly before 37 weeks of

Table 7 Local (Current) Mean and Range Birth Weight and GA for Live Singleton Newborns by Sex, South Kalimantan, 2010–2017

Sex	Statistics	2010	2011	2012	2013	2014	2015	2016	2017
Birth Weight (g)									
Male (n=574)	Mean	3126	3180	2983	3068	3084	3039	3209	3127
	Range	2200–3700	2400–4000	2500–3700	2300–4000	2200–4000	2200–3800	2270–4000	2200–4000
Female (n=547)	Mean	3004	3236	2862	3004	3022	3024	3127	3075
	Range	2100–3600	2500–3900	2400–3700	2100–4000	2300–4000	2400–4000	2500–3900	2200–4000
GA (weeks)									
Male (n=574)	Mean	39	39	39	38	38	37	38	39
	Range	36–43	36–42	36–40	32–42	24–42	28–44	32–41	34–42
Female (n=547)	Mean	39	39	39	38	38	37	39	39
	Range	35–41	34–43	34–40	32–44	31–44	28–43	34–41	32–43

Table 8 List of the Selected Previously Published Studies Together with the Information on Their Settings That is Used to Compare with the Local (Current) Study

Country	Sample Size	Population-Based	Settings	Years	GA (Weeks)	Method of Assessing GA	Method of Developing Curves
Indonesia, 1994[8]	5844	No	14 Indonesian teaching hospitals	1st July 1990–30th June 1991	34–44	LMP	Arithmetic percentiles
Global reference, 2011[2]	237,025	No (WHO Global Survey)	24 countries in Africa, Latin America, and Asia	2004–2008	24–41	Ultrasound	Based on the concept of foetal weight reference,[19] and individualized growth chart / proportionality[20]
Australia, 2012[5]	2,528,641	Yes	Australia	1998–2007	20–44	LMP or Ultrasound	Exact percentiles
China, 2014[14]	1,105,214	Yes	64 counties and districts in 30 provinces, municipalities, or municipal districts of China	October 2006–September 2010	28–44	LMP and ultrasound	Lambda-mu-sigma (LMS) method
International standards, 2014[3]	20,486	Yes	8 countries (Brazil, Italy, Oman, UK, USA, China, India, Kenya)	27th April 2009–2nd March 2014	33–42	Ultrasound	GAMLSS framework
Yogyakarta, Indonesia, 2016[16]	54,599	No	1 referral hospital, 5 district hospital, and 5 health centres in Yogyakarta, Indonesia	1st January 1998–31st December 2007	26–42	Dubowitz score and LMP	A third-order polynomial equation
UK, 2016[1]	92,018	No	1 hospital in London and 1 hospital in Kent, UK	March 2006–October 2015	24–43	Ultrasound	Linear regression analysis, Based on the Intergrowth-21st standard[3,21]
South Kalimantan, Indonesia-Our Local (Current) Study, 2017	1188	No	20 primary healthcare (PHC) centres comprising: 14 public health centres (PKMs) and 6 private midwifery clinics (BPMs) which are proportionally distributed across the administrative areas of the province.	1 April 2007–30 June 2017	36–40	LMP	Exact percentiles (weighted average method)

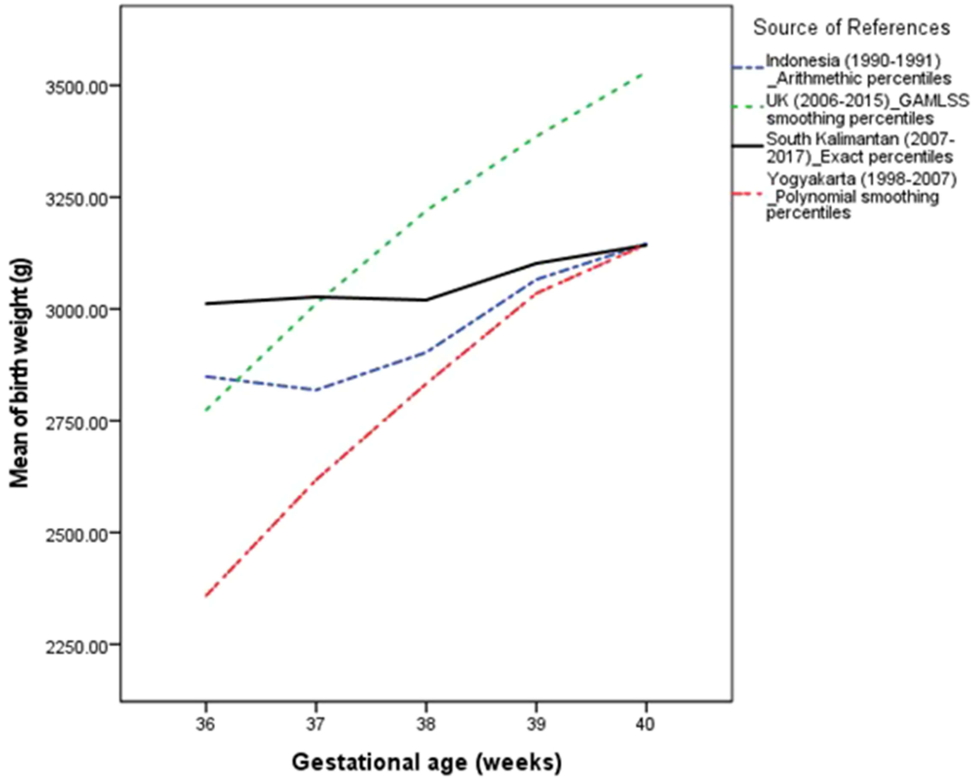

Figure 7 Mean birth weight by GA for all live singleton newborns.

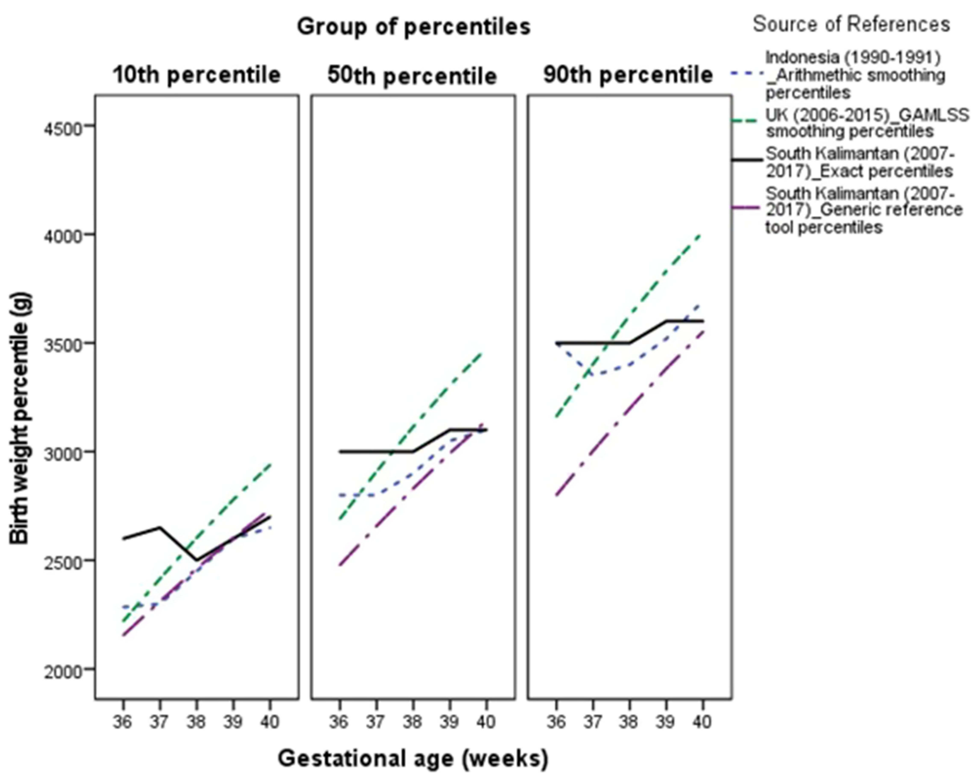

Figure 8 Birth weight percentiles by GA for all live singleton newborns.

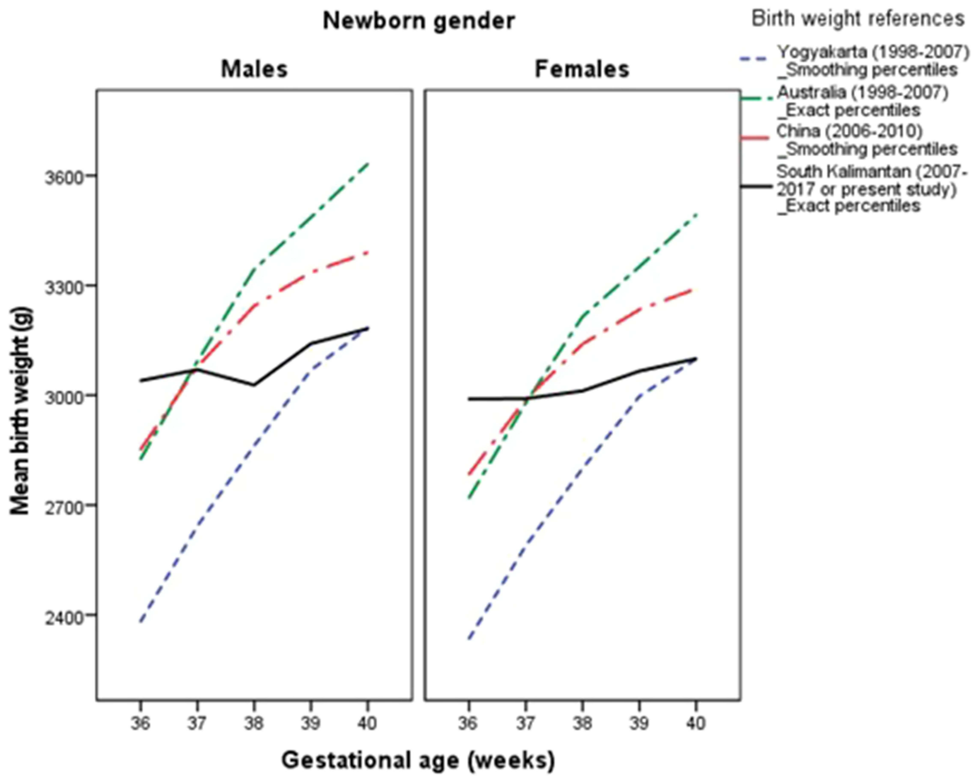

Figure 9 Mean birth weight by GA for male and female singleton newborns.

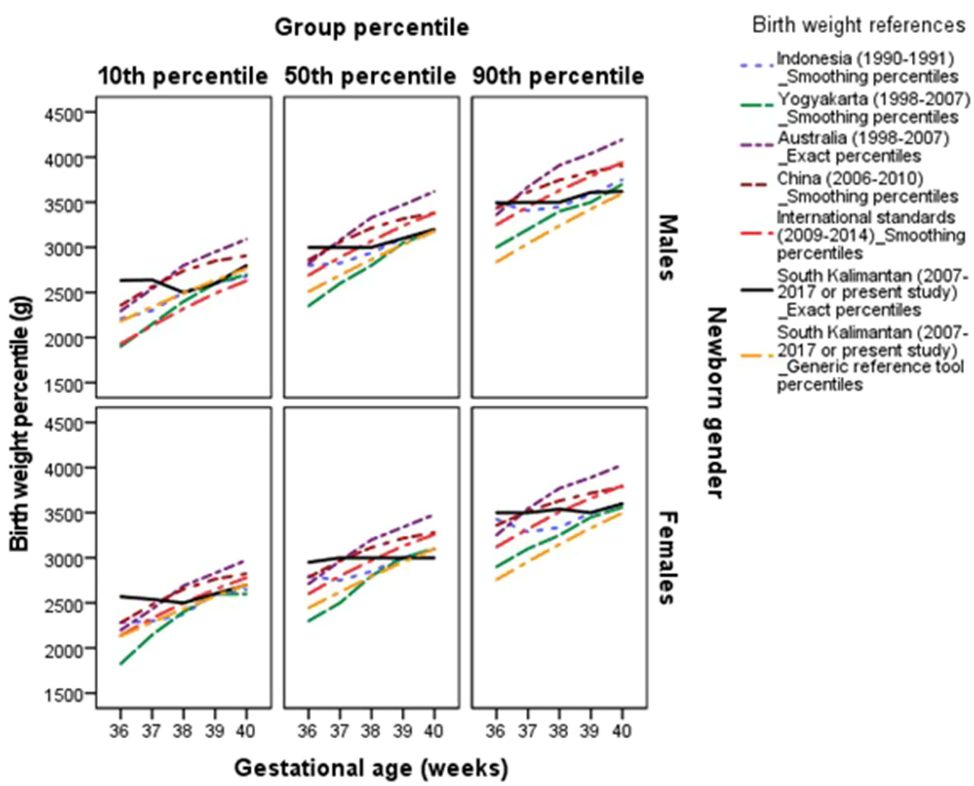

Figure 10 Birth weight percentiles by GA for males and females live singleton newborns.

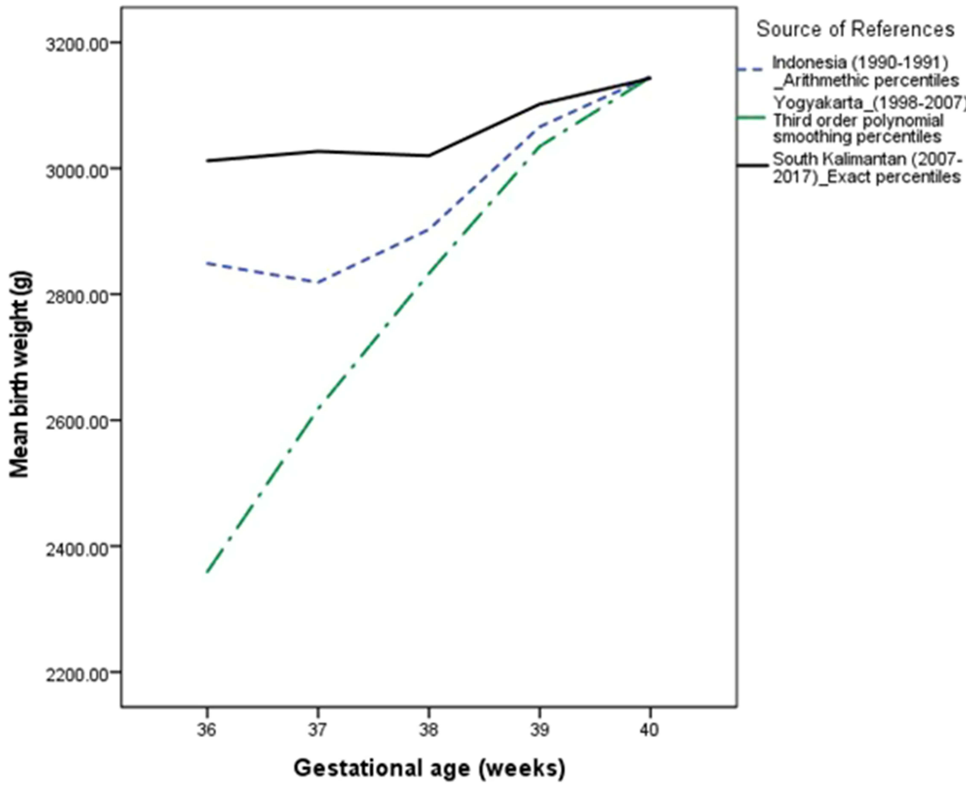

Figure 11 Mean birth weight by GA for all Indonesian live singleton newborns.

pregnancy. In our study, the 10th percentile of birth weight for 38th weeks is lower than that of 37th week based on recorded data. This could be due to fact that the available data for 37 weeks (94 births) was less than a minimum of 100 births[5] or 200 births.[15]

Since Indonesia has diverse geographical areas across 34 provinces and adopted a decentralization policy in 2001,[13] routine collection of local perinatal data is urgently required to promote the provision of a reliable national database in a timely manner. The utility of local health registers rather than periodic demographic or household surveys are recommended to obtain significant figures of maternal, fetal, and neonatal health in rural Indonesia or close to where people live.[13,17] Access to the local collection of perinatal data, as baseline information, will allow the comparison of pregnancy-related outcomes across provinces. Such comparison enables monitoring and evaluation of the performance of health service providers and the impact of planning programs or interventions, allocating resources and policy progress to improve pregnancy outcomes.[13]

Strengths and Limitation

A major strength of the current study was the proportional selection of participating primary healthcare (PHC) centers which represented each area of 11 districts and 2 municipalities in the South Kalimantan province. Our selection of PHC centers rather than secondary or tertiary/referral health facilities, such as hospitals ensured the inclusion of pregnant women with lower maternity and delivery risks in the study. However, this leads to the weakness of our study which did not have enough individuals with low gestational age (< 36 weeks) and high gestational age (> 40 weeks). The calculation of GA which was only based on the first day of the last menstrual period (LMP) should also be acknowledged as the limitation of this study. Due to the lack of ultrasound facilities in most PHC centers, LMP is the only alternative way of estimating GA. The lack of complete recorded data particularly in rural settings led to a high

Table 9 Relative Differences in the 10th, 50th, and 90th Percentiles of Birth Weight by GA Between Previously Published References and the Local (Current) Reference (Table 3)

Gestational Age at Delivery (Weeks)	Indonesia, 1994[8]	Global Reference, 2011[2]	UK, 2016[1]
10th percentile			
36	−12.12	−17.08	−14.58
37	−13.21	−12.74	−8.83
38	−2.00	−1.50	4.16
39	0.00	0.16	6.92
40	−1.85	1.27	8.85
50th percentile			
36	−6.67	−17.39	−10.30
37	−6.67	−11.40	−3.03
38	−3.33	−5.64	3.83
39	−1.61	−3.44	6.65
40	0.00	1.39	12.13
90th percentile			
36	0.00	−19.99	−9.66
37	−4.29	−14.18	−2.77
38	−2.86	−8.60	3.63
39	−2.22	−6.04	6.44
40	2.61	−1.34	11.44

percentage of data exclusion, however, the sample size was statistically acceptable to carry out the analysis presented in this paper.

Exact percentiles by excluding implausible birth weights were used in constructing our birth weight percentiles. This approach has been used in Australia which has a high quality of national birth weight data.[5] Although our local data were not as high quality as the Australian data, as a preliminary study, the use of exact percentiles rather than smooth-estimated percentiles is more useful in describing the true characteristics of the study population.

Conclusion

Early detection of the risk of having neonatal morbidity and growth impairment, such as prematurity and SGA is crucial in providing appropriate interventions in a timely manner. The national reference is currently not available in Indonesia. Therefore, our locally derived gestational age-specific reference percentiles can be used as a reference to assist medical practitioners, particularly in rural areas to detect the risk of having neonatal morbidity and growth impairment at birth. This reference is appropriate for studies on populations with similar demographic characteristics, particularly in Indonesia. This reference chart is best for 36–40 weeks of gestation.

The utility of local reference based on local perinatal data is recommended since it provides significant figures of maternal, fetal, and neonatal health close to where people live. Access to the local collection of perinatal data, as baseline information, will allow the compilation and comparison of pregnancy-related outcomes across provinces in Indonesia. Consequently, reliable national perinatal data can be strengthened to establish the national references for newborns'

Table 10 Relative Differences in the 10th, 50th, and 90th Percentiles of Birth Weight by GA and Sex Between the Local (Current) Reference (Table 2) and Previously Published References

Gestational Age at Delivery (Weeks)	Indonesia, 1994[8]		Global Reference, 2011[2]		Australia, 2012[5]		International Standards, 2014[3]		China, 2014[14]		Yogyakarta (Indonesia), 2016[16]	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
10th percentile												
36	−16.07	−11.09	−17.15	−17.05	−12.84	−14.47	−26.70	−16.73	−10.52	−11.32	−27.84	−29.07
37	−12.88	−9.53	−11.38	−9.99	−3.79	−4.33	−19.32	−8.27	−2.84	−2.28	−18.56	−15.55
38	0.00	−5.08	−0.33	−2.60	12.00	7.60	−7.20	0.00	9.56	6.08	−4.00	−4.00
39	0.00	0.00	1.34	−0.97	13.46	8.85	−4.23	1.92	9.58	6.31	0.00	0.00
40	−4.29	−1.85	−1.19	0.13	10.36	10.19	−6.07	2.96	3.86	4.59	−3.57	−3.70
50th percentile												
36	−6.67	−5.08	−16.37	−17.14	−6.00	−8.14	−10.33	−11.86	−4.67	−5.66	−21.67	−22.03
37	−5.83	−8.33	−10.30	−12.61	2.67	−1.17	−3.67	−6.67	1.93	−1.10	−13.33	−16.67
38	−2.00	−5.00	−4.47	−6.93	11.00	6.67	2.33	−1.00	7.17	3.83	−6.67	−6.67
39	0.00	0.00	−2.24	−1.58	11.94	11.33	4.52	4.33	7.00	7.20	−1.61	0.00
40	−1.56	3.33	−0.56	3.34	13.13	16.00	5.63	8.67	5.69	9.37	−0.63	3.33
90th percentile												
36	0.29	−2.00	−18.72	−21.23	−3.72	−7.14	−6.88	−10.86	−1.60	−4.00	−14.04	−17.14
37	−2.63	−6.06	−13.08	−15.51	4.86	1.29	−1.43	−5.14	3.23	0.43	−8.57	−11.43
38	−1.43	−5.76	−7.43	−11.04	11.71	6.50	3.71	−0.85	7.03	2.60	−2.86	−8.19
39	−0.64	0.00	−5.09	−4.85	11.91	11.14	4.99	4.57	6.26	6.20	−3.05	−1.43
40	3.59	0.00	−0.62	−2.87	15.88	11.94	8.84	5.56	7.93	5.19	2.21	−1.11

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Table 11 Proportion of Live Births with Birth Weight <10th Percentile for GA Using Local (Current) Reference and the Existing Indonesian and International References

Cut Off for < 10th Percentile	Live Singleton Births [in Number or (%)]															
	All Sexes				Males						Females					
	Total	Local (Current) Reference	Indonesian Reference (1994)[8]	Global Reference (2011)[2]	Total	Local (Current) Reference	Indonesian Reference (1994)[8]	Global Reference (2011)[2]	Intergrowth 21st Project (2014)[3]	Indonesian Reference (2016)[16]	Total	Local (Current) Reference	Indonesian Reference (1994)[8]	Global Reference (2011)[2]	Intergrowth 21st Project (2014)[3]	Indonesian Reference (2016)[16]
All cases	1188	70 (5.9%)	56 (4.7%)	80 (6.7%)	601	42 (7.0%)	26 (4.3%)	37 (6.2%)	20 (3.3%)	25 (4.2%)	586	38 (6.5%)	26 (4.4%)	34 (5.8%)	42 (7.2%)	21 (3.6%)
Preterm delivery (< 37 weeks)	215	6 (0.5%)	1 (0.1%)	1 (0.1%)	111	7 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	102	4 (0.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Term delivery (37–40 weeks)	870	64 (5.4%)	55 (4.6%)	79 (6.7%)	441	35 (5.8%)	26 (4.3%)	37 (6.2%)	20 (3.3%)	25 (4.2%)	429	34 (5.8%)	26 (4.4%)	34 (5.8%)	42 (7.2%)	21 (3.6%)
Late and post term delivery (> 40 weeks)	103	Not included			49	Not included					55	Not included				

anthropometric measurements and to monitor and evaluate the performance of health development programs and policies to improve pregnancy outcomes.

Abbreviations

LBW, low birth weight; SGA, small for gestational age; GA, gestational age; PHC, primary healthcare; PKM, public health centers; BPMs, private midwifery clinics; ANC, antenatal care; LMP, last menstrual period.

Data Sharing Statement

Data underlying the findings of this study are included in the manuscript.

Ethics Approval and Informed Consent

This study has complied with the Declaration of Helsinki and obtained research permissions from the Indonesian national, provincial, and local governments and two ethics' clearances from the Lambung Mangkurat University Medical Research Ethics Committee, Indonesia (reference: 018/KEPK-FK UNLAM/EC/III/2016) and the RMIT College Human Ethics Advisory Network (CHEAN), Australia (reference: ASEHAPP 19-16/RM No: 19974). All participants provided informed consent to take part in this study. Data about the private idea of the task and a consent form (written in both Bahasa Indonesia and English) for enrollment to the examination were given to the chosen midwives and pregnant women (prospective study), who all consented to take an interest.

Consent for Publication

The manuscript does not contain any individual person's data; hence consent for publication is not applicable.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas. They also took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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