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Percentile Distributions of Birth Weight according to Gestational Ages in Korea (2010-2012)

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The Pediatric Growth Chart (2007) is used as a standard reference to evaluate weight and height percentiles of Korean children and adolescents. Although several previous studies provided a useful reference range of newborn birth weight (BW) by gestational age (GA), the BW reference analyzed by sex and plurality is not currently available. Therefore, we aimed to establish a national reference range of neonatal BW percentiles considering GA, sex, and plurality of newborns in Korea. The raw data of all newborns (470,171 in 2010, 471,265 in 2011, and 484,550 in 2012) were analyzed. Using the Korean Statistical Information Service data (2010-2012), smoothed percentile curves (3rd-97th) by GA were created using the lambda-mu-sigma method after exclusion and the data were distinguished by all live births, singleton births, and multiple births. In the entire cohort, male newborns were heavier than female newborns and singletons were heavier than twins. As GA increased, the difference in BW between singleton and multiples increased. Compared to the previous data published 10 years ago in Korea, the BW of newborns 22-23 gestational weeks old was increased, whereas that of others was smaller. Other countries' data were also compared and showed differences in BW of both singleton and multiple newborns. We expect this updated data to be utilized as a reference to improve clinical assessments of newborn growth.

Keywords: Birth Weight; Singleton; Multiple Birth; Newborn; Gestational Age

INTRODUCTION

Worldwide data of the significance of newborn birth weight (BW) have been studied since the 1970s (1). By analyzing newborn BW by gestational age (GA), we can evaluate fetal growth, intrauterine growth restriction (which has high perinatal mortality), and epidemiologic data comparing fetal growth and chronic adulthood disease. The newborn's condition immediately after birth can be predicted accordingly. From the long-term perspective, a nation's public health system could be established (2,3). Since 2000, several studies have provided a reference range of newborn BW by GA in Korea. However, some have limitations, including: an insufficient sample size based on 18,427 newborns in 2003; the Korean Statistical Information Service data (2001-2003, 1,509,763 persons; 2000-2004, 2,585,516 persons) were based on the previous 10 years; and recent data based on Korean Statistical Information Service data (2008-2012) did not exclude the common error showing the double humped curve that appears most frequently in the big data analysis and made only singleton references (4-7).

It has recently become popular in Korea to marry at a later age, which could increase the number of elderly gravida and high-risk pregnancies, eventually increasing premature birth rates. In addition, in vitro fertilization is associated with an increase in multiple pregnancies. There has been a recent increase in inter-racial infants in Korea (8-10). These changes have a strong influence on BW. Therefore, in this study, we aimed to establish a new national reference range of neonatal BW percentiles considering the GA, sex, and plurality of newborns in Korea.

MATERIALS AND METHODS

For this study, we used the Korean Statistical Information Service data (2010.01-2012.12) of a total of 1,425,986 newborns. The raw data of all newborns (470,171 in 2010, 471,265 in 2011, and 484,550 in 2012) were analyzed. Our results were based on 1,422,890 births after exclusions. Newborns with unknown BW (n = 2,100), unknown GA (n = 2,514), or a GA < 22 weeks (n = 73) or > 42 weeks (n = 297) were excluded. Some of the exclusions (n = 1,888) are duplicated. The GA referred to the interval, in completed weeks, between the first day of the mother's last menstrual period and the delivery date. Therefore, the GA of 40 weeks means 40 weeks plus 0-6 days. BW was measured to the nearest 10 g.

Fig. 1 represented the percentile curves of BW for GA based on the Korean Statistical Information Service's raw data after

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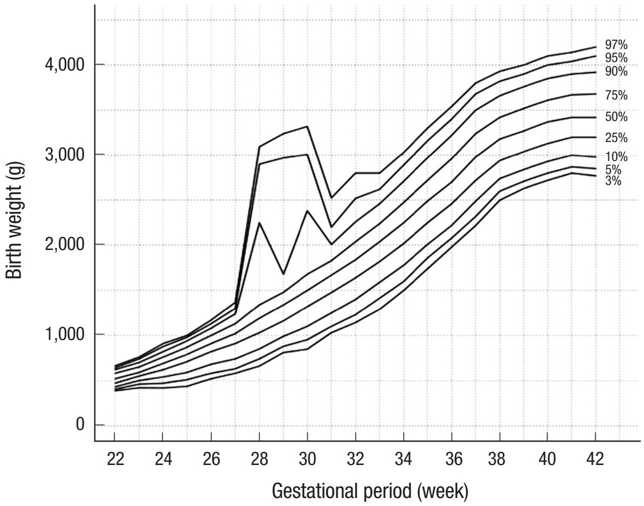

Fig. 1. Percentile curves [3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th] of birth weight for gestational age based on the raw data. %, percentile.

exclusions. It included the estimated error data of 28-32 weeks' gestation. The histogram of BW of 28-32 weeks' gestation before smoothing showed a double humped curve as reported by Lee (6). Both humps are normal distributions with the estimated truth (left) and error values (right).

This report used the Finite Gaussian mixture model, which is a convex combination of two or more probability density functions that was enabled to correct the error and represent the normal distribution curve (11,12). The lambda-mu-sigma (LMS) method, a way of obtaining normalized growth curves, was developed by Cole and Green (13), and it was expected that the data could be normalized using a powerful transformation that changes raw data into a standard deviation Z-score. The LMS method calculates asymmetrical parameters by the Box-Cox transformation to be normal. Here it estimated the three parameters of the Box-Cox transformation of the measurement distribution (14). The three parameters are constrained to change smoothly as the covariate changes.

The LMS methods were analyzed by Stata version 12.0 (StataCorp, College Station, TX, USA). Moreover, all graphs were made using GraphPad Prism software (ver. 6.05, GraphPad Software Inc., La Jolla, CA, USA). The SPSS for Windows (version 18.0; SPSS, Chicago, IL, USA) was used for the data input, processing, and analysis. The smoothed data were represented by the BW percentile curves. The curves appeared at intervals of one week by gestation and separated into all live births, singlet births, and multiple births. We also constructed separate curves and tables for male and female newborns for the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th percentiles from 22 to 42 completed weeks based on smoothed estimated curves.

Classification according to BW are as follows: extremely low birth weight (ELBW, BWs < 1,000 g) infants, very low birth weight (VLBW, BWs < 1,500 g) infants, low birth weight (LBW, BWs < 2,500 g) infants, normal birth weight (NBW, 2,500 ≤ BWs ≤ 3,999 g) infants, high birth weight (HBW, BWs > 4,000 g) infants.

Table 1. Number of infants divided by infant sex and multiplicity before exclusions, 2010-2012

Demography parameters	Year			
	2010	2011	2012	Total
Sex				
Male	242,901	242,121	248,958	733,980
Female	227,270	229,144	235,592	692,006
Male/female ratio	1.07	1.06	1.06	1.06
Multiplicity*				
Singlet	455,309	457,171	468,608	1,381,088
Multiple	12,841	13,852	15,621	42,314
Multiple birth rate†	27.3	29.4	32.2	29.7

*Except unknown multiplicity; †Per 1,000 live births.

Table 2. Distribution of births by birth weight and gestational period before exclusions, 2010-2012

Birth parameters	No. (%) of birth
By birth weight	
ELBW infants	3,394 (0.24)
VLBW infants	8,789 (0.62)
LBW infants	74,054 (5.19)
NBW infants	1,300,902 (91.23)
HBW infants	48,930 (3.43)
Unknown	2,100 (0.15)
Total	1,425,986 (100)
By gestational period	
Preterm infants	86,365 (6.06)
Term infants	1,333,242 (93.5)
Post-term infants	3,865 (0.27)
Unknown	2,514 (0.18)
Total	1,425,986 (100)

ELBW, extremely low birth weight; VLBW, very low birth weight; LBW, low birth weight; NBW, normal birth weight; HBW, high birth weight.

RESULTS

Of all infants born between 2010 and 2012, there were 733,980 and 692,006 boys and girls, respectively, showing a gender ratio of 1.06, and there were 1,381,088 and 42,314 singleton and multiple births, respectively (Table 1). After assessing BW and GA for the 3-year period, extremely low BW infants and very low BW infants accounted for 0.24% and 0.62%, respectively, while premature birth infants born at < 37 weeks' gestation accounted for 6% of the total infant population (Table 2). Initially, data on 2,726 infants whose BW and GAs were unclear as well as those of 370 infants whose GA was ≤ 21 weeks or ≥ 43 weeks were excluded from the raw data of the National Statistical Office of South Korea. Subsequently, error data of 28-32 weeks' gestation were removed, followed by smoothing with the LMS method.

All infants were classified according to gestation regardless of singleton or multiple birth, and data on the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th percentiles are presented in Tables 3 (male) and 4 (female). Data on boys and girls born by sin-

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Table 3. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentiles of birth weight (g) for 22-42 weeks' gestational age for all male infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	65	356	374	402	448	499	550	596	623	641
23	157	418	441	476	535	602	669	730	767	791
24	285	479	507	550	624	707	793	871	918	949
25	325	541	575	628	717	819	923	1,017	1,074	1,112
26	434	606	647	712	819	940	1,061	1,171	1,236	1,279
27	547	677	728	805	932	1,072	1,210	1,334	1,407	1,454
28	744	758	819	909	1,057	1,216	1,371	1,507	1,587	1,638
29	793	857	926	1,030	1,197	1,374	1,544	1,692	1,779	1,835
30	1,032	974	1,052	1,167	1,351	1,545	1,730	1,891	1,985	2,045
31	1,325	1,114	1,197	1,321	1,518	1,728	1,929	2,103	2,205	2,271
32	1,944	1,273	1,359	1,488	1,697	1,922	2,139	2,330	2,442	2,514
33	2,728	1,448	1,535	1,668	1,888	2,127	2,362	2,571	2,695	2,775
34	5,236	1,637	1,725	1,861	2,087	2,339	2,591	2,817	2,952	3,040
35	9,516	1,836	1,924	2,060	2,292	2,552	2,816	3,057	3,202	3,297
36	22,408	2,038	2,126	2,262	2,494	2,759	3,030	3,280	3,431	3,530
37	67,989	2,237	2,323	2,458	2,688	2,953	3,226	3,479	3,633	3,735
38	188,256	2,422	2,506	2,638	2,864	3,125	3,395	3,647	3,801	3,902
39	210,907	2,588	2,670	2,798	3,018	3,273	3,538	3,785	3,937	4,038
40	174,916	2,735	2,814	2,938	3,152	3,400	3,659	3,901	4,051	4,150
41	40,834	2,867	2,943	3,063	3,270	3,511	3,763	4,001	4,147	4,244
42	1,677	2,992	3,066	3,181	3,381	3,614	3,859	4,091	4,234	4,329

GP, gestational period.

Table 4. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentile birth weight (g) for 22-42 weeks' gestation for all female infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	62	349	361	381	419	467	523	582	622	650
23	123	409	425	452	500	563	635	710	760	795
24	240	467	488	521	583	661	750	841	901	943
25	328	523	549	592	668	764	871	978	1,047	1,095
26	379	582	614	667	761	875	1,000	1,122	1,200	1,252
27	493	646	686	751	864	998	1,140	1,275	1,359	1,415
28	674	720	770	848	981	1,134	1,291	1,437	1,525	1,583
29	643	810	869	961	1,114	1,285	1,457	1,612	1,705	1,766
30	892	919	987	1,090	1,261	1,449	1,635	1,801	1,900	1,964
31	1,013	1,051	1,125	1,238	1,423	1,627	1,828	2,008	2,114	2,183
32	1,561	1,204	1,281	1,400	1,598	1,817	2,035	2,231	2,348	2,423
33	2,198	1,371	1,451	1,575	1,784	2,018	2,254	2,469	2,598	2,682
34	4,213	1,553	1,635	1,762	1,979	2,226	2,479	2,711	2,851	2,943
35	7,659	1,746	1,828	1,958	2,181	2,437	2,702	2,948	3,098	3,197
36	18,226	1,943	2,026	2,156	2,381	2,642	2,914	3,167	3,323	3,426
37	56,714	2,137	2,220	2,350	2,574	2,835	3,108	3,363	3,520	3,624
38	163,877	2,319	2,400	2,528	2,749	3,006	3,274	3,526	3,681	3,784
39	197,141	2,484	2,563	2,688	2,904	3,155	3,417	3,662	3,813	3,913
40	184,907	2,627	2,705	2,827	3,038	3,282	3,536	3,774	3,921	4,017
41	47,541	2,756	2,832	2,951	3,157	3,394	3,641	3,871	4,012	4,106
42	1,888	2,878	2,952	3,068	3,269	3,499	3,738	3,961	4,097	4,188

GP, gestational period.

gleton and multiple births are presented in Tables 5-8. The BW percentile curves after smoothing singleton births are presented in Fig. 2A and B, while the BW percentile curves of multiple births are presented in Fig. 3A and B. In the 10th, 50th, and 90th percentile graphs of singleton births, boys showed higher BW than those of girls in the total infant graphs at each GA (Fig. 2C). Multiple-birth infants also showed a pattern similar to that of singleton-birth infants. However, BW of boys and girls close to 40 weeks' gestation in the 10th percentile graph tended to be similar (Fig. 3C). When graphs of singleton- and multiple-birth male and female infants overlapped by GA, more differences in BW were seen between multiple- and singleton-birth infants as

Table 5. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentile birth weight (g) for 22-42 weeks' gestation for singleton-birth male infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	27	356	378	411	462	516	566	610	635	652
23	82	417	443	483	547	616	684	743	777	800
24	162	478	508	555	634	720	806	882	928	958
25	205	541	577	633	726	830	935	1,030	1,087	1,124
26	278	609	652	718	828	951	1,074	1,186	1,252	1,296
27	375	683	734	812	942	1,084	1,225	1,351	1,426	1,475
28	538	766	827	920	1,070	1,232	1,390	1,529	1,611	1,664
29	604	865	936	1,043	1,213	1,394	1,568	1,719	1,808	1,865
30	793	985	1,065	1,184	1,372	1,571	1,760	1,924	2,020	2,081
31	1,003	1,128	1,215	1,342	1,546	1,761	1,966	2,143	2,247	2,313
32	1,338	1,295	1,384	1,518	1,733	1,963	2,184	2,377	2,491	2,563
33	1,974	1,482	1,571	1,708	1,931	2,174	2,412	2,623	2,748	2,828
34	3,830	1,681	1,770	1,907	2,136	2,389	2,642	2,869	3,005	3,093
35	7,105	1,888	1,976	2,112	2,342	2,602	2,865	3,106	3,251	3,345
36	17,178	2,093	2,179	2,313	2,543	2,805	3,074	3,321	3,472	3,571
37	60,877	2,287	2,371	2,503	2,730	2,990	3,259	3,509	3,662	3,762
38	186,011	2,464	2,546	2,675	2,897	3,153	3,419	3,667	3,820	3,920
39	210,574	2,619	2,698	2,824	3,040	3,291	3,553	3,797	3,948	4,048
40	174,769	2,753	2,830	2,952	3,163	3,408	3,664	3,905	4,053	4,152
41	40,813	2,873	2,948	3,066	3,271	3,510	3,761	3,997	4,144	4,241
42	1,674	2,987	3,060	3,174	3,373	3,606	3,851	4,084	4,228	4,324

GP, gestational period.

Table 6. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentile birth weight (g) for 22-42 weeks' gestation for singleton-birth female infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	28	354	366	387	426	477	540	609	658	694
23	69	412	428	455	506	572	652	738	798	841
24	139	467	488	522	586	669	766	869	938	987
25	230	520	546	590	670	771	886	1,003	1,080	1,133
26	270	575	609	664	762	883	1,015	1,145	1,228	1,284
27	329	636	679	747	866	1,007	1,156	1,297	1,385	1,443
28	505	710	763	846	987	1,147	1,311	1,461	1,553	1,612
29	496	802	865	962	1,124	1,303	1,481	1,641	1,736	1,798
30	661	916	988	1,098	1,278	1,474	1,666	1,837	1,938	2,003
31	743	1,056	1,135	1,254	1,449	1,661	1,869	2,052	2,161	2,231
32	1,069	1,220	1,302	1,427	1,634	1,861	2,085	2,286	2,405	2,482
33	1,466	1,401	1,485	1,614	1,830	2,071	2,313	2,531	2,662	2,748
34	2,888	1,595	1,680	1,810	2,033	2,285	2,542	2,777	2,920	3,013
35	5,316	1,797	1,881	2,013	2,238	2,497	2,764	3,012	3,163	3,262
36	13,186	1,999	2,082	2,212	2,437	2,698	2,969	3,223	3,379	3,481
37	49,484	2,191	2,272	2,401	2,623	2,881	3,151	3,405	3,561	3,664
38	161,640	2,365	2,444	2,570	2,788	3,041	3,306	3,555	3,709	3,811
39	196,832	2,516	2,594	2,717	2,930	3,177	3,436	3,678	3,828	3,927
40	184,778	2,646	2,723	2,843	3,051	3,292	3,544	3,779	3,924	4,020
41	47,525	2,762	2,837	2,955	3,159	3,394	3,639	3,868	4,009	4,102
42	1,882	2,871	2,945	3,061	3,260	3,490	3,729	3,951	4,088	4,178

GP, gestational period.

GA increased (Fig. 4).

When BW of singleton-birth male and female infants were compared with other data in South Korea from 2000-2004 for the 10th, 50th, and 90th percentile graphs (6), the patterns were similar for 30-32 weeks, whereas the 10th percentile graph of the present study showed a lower mean BW before 30 weeks' gestation (Fig. 5A). In contrast, when twin male and female infants were compared in the 10th, 50th, and 90th percentiles, BW increased after 37 weeks' gestation compared to the data of 2000-2004 (Fig. 5B).

Graphs of data from 7,993,166 singleton-birth infants born in Brazil between 2003 and 2005 were compared with the 10th,

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Table 7. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentile birth weight (g) for 22-40 weeks' gestation for multiple-birth male infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	19	368	386	413	457	506	554	597	622	638
23	41	426	449	485	544	608	670	725	758	779
24	76	478	509	556	632	713	791	859	899	925
25	77	531	570	629	723	822	916	998	1,045	1,076
26	111	588	637	708	821	938	1,049	1,144	1,199	1,234
27	147	657	714	797	928	1,063	1,190	1,299	1,362	1,402
28	185	742	806	900	1,047	1,198	1,340	1,462	1,533	1,578
29	173	848	918	1,020	1,180	1,345	1,500	1,634	1,711	1,760
30	228	973	1,046	1,155	1,325	1,501	1,667	1,809	1,892	1,944
31	316	1,114	1,190	1,303	1,480	1,665	1,840	1,991	2,078	2,134
32	545	1,264	1,341	1,456	1,640	1,833	2,017	2,176	2,269	2,328
33	743	1,415	1,493	1,611	1,801	2,003	2,197	2,366	2,465	2,529
34	1,396	1,564	1,643	1,764	1,960	2,171	2,376	2,555	2,661	2,729
35	2,401	1,705	1,786	1,910	2,112	2,332	2,547	2,737	2,850	2,922
36	5,206	1,828	1,912	2,039	2,249	2,479	2,706	2,908	3,028	3,106
37	7,081	1,925	2,012	2,145	2,367	2,612	2,855	3,073	3,203	3,287
38	2,197	1,989	2,082	2,226	2,465	2,731	2,997	3,236	3,379	3,472
39	301	2,026	2,127	2,284	2,547	2,841	3,136	3,402	3,562	3,666
40	120	2,048	2,159	2,331	2,620	2,946	3,275	3,573	3,753	3,870

GP, gestational period.

Table 8. Smoothed 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, and 97th percentile birth weight (g) for 22-40 weeks' gestation for multiple-birth female infants

GP	No.	3rd Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile	97th Percentile
22	15	350	365	389	429	472	515	554	577	591
23	34	410	430	461	512	567	621	670	698	717
24	65	467	493	532	595	664	732	792	827	850
25	80	525	556	603	681	766	850	924	968	996
26	79	587	623	680	773	875	977	1,068	1,122	1,157
27	144	657	700	765	874	994	1,113	1,221	1,285	1,326
28	149	737	787	862	987	1,124	1,259	1,380	1,451	1,498
29	135	830	887	973	1,113	1,265	1,413	1,544	1,622	1,672
30	216	938	1,001	1,097	1,251	1,416	1,576	1,716	1,799	1,851
31	260	1,063	1,131	1,233	1,399	1,575	1,745	1,894	1,982	2,038
32	479	1,201	1,272	1,379	1,552	1,739	1,920	2,079	2,172	2,232
33	725	1,343	1,416	1,527	1,709	1,905	2,097	2,266	2,366	2,430
34	1,317	1,489	1,564	1,678	1,866	2,071	2,273	2,451	2,557	2,626
35	2,332	1,630	1,707	1,824	2,018	2,231	2,441	2,629	2,740	2,812
36	5,028	1,760	1,839	1,960	2,161	2,382	2,601	2,798	2,914	2,990
37	7,217	1,869	1,951	2,077	2,287	2,519	2,750	2,957	3,080	3,160
38	2,213	1,955	2,042	2,176	2,399	2,646	2,893	3,115	3,248	3,334
39	287	2,021	2,114	2,258	2,498	2,765	3,032	3,273	3,418	3,511
40	100	2,076	2,176	2,331	2,590	2,880	3,171	3,433	3,591	3,694

GP, gestational period.

50th, and 90th percentile graphs; both boys and girls were heavier than singleton-birth infants in Brazil in the 10th percentile but lighter in the 90th percentile (Fig. 6) (15). Compared with data of 676,605 singleton births in Canada between 1994 and 1996 (16), Canadian infants were lighter or similar in BW until 36 weeks' gestation, but BW of Korean infants were much lower than those of Canadian infants after 36 weeks' gestation (Fig. 7). While BW of twins were higher than those of American and Taiwanese boys and girls, the gap decreased after 38 weeks' gestation (Fig. 8) (17,18). In the American study, the fetal growth of each twin was estimated from regression curves fit to ultrasonographic fetal weight measurements, and the estimated data could have a bias.

DISCUSSION

The most basic characteristic of babyhood is growth, and since abnormal growth may be a critical signal of disease, its evalua-

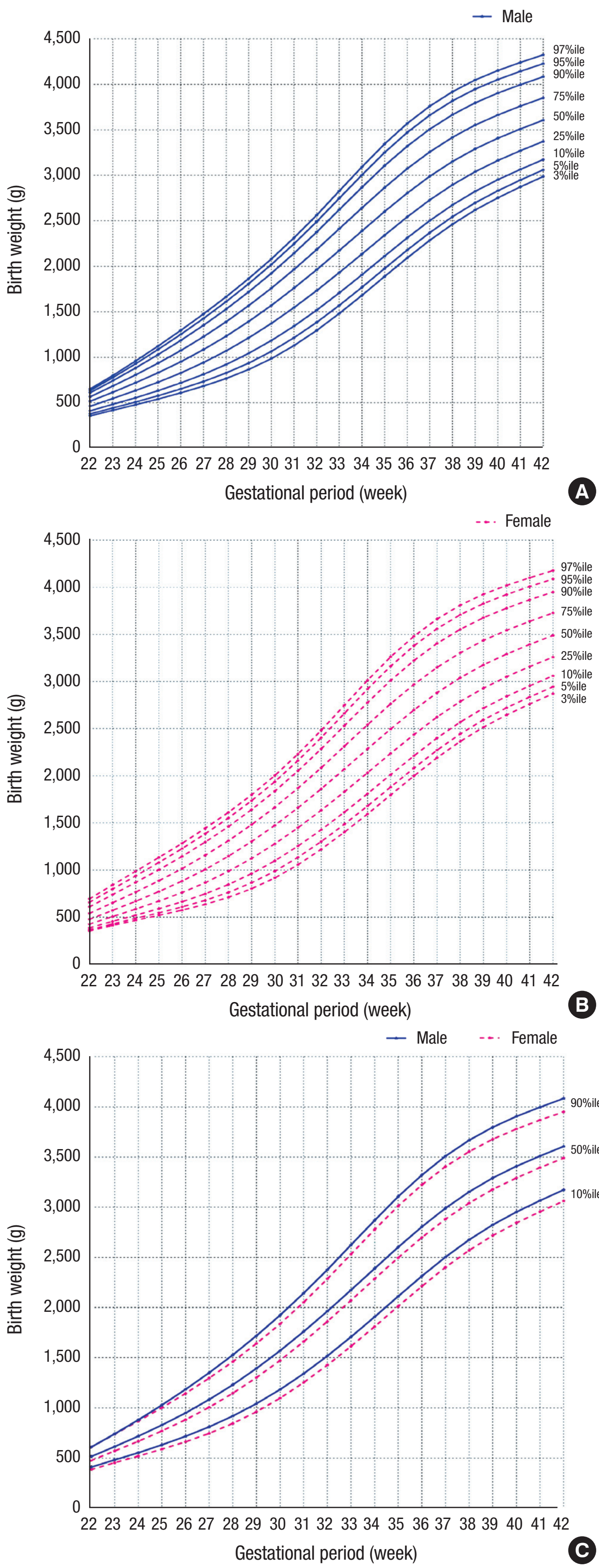

Fig. 2. Smoothed percentile curves of birth weight distribution by gestational age for singlet (A) male, (B) female, and (C) male + female populations. %ile, percentile.

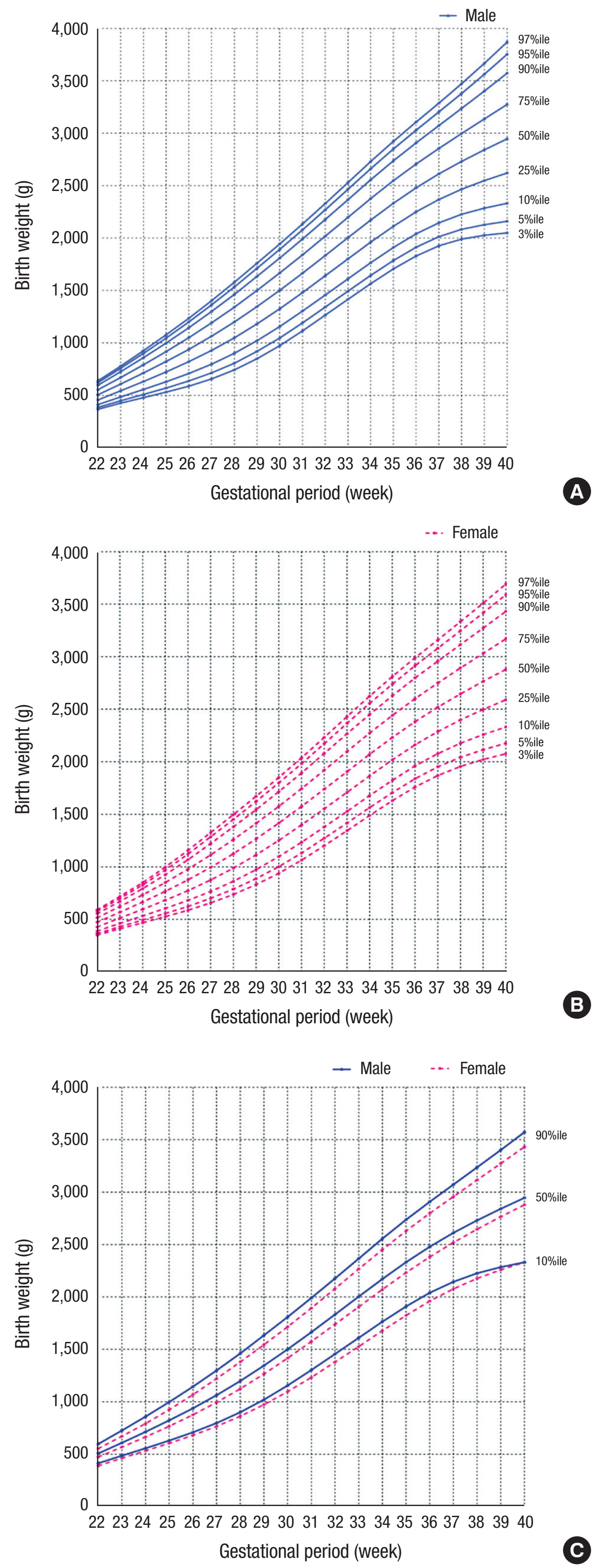

Fig. 3. Smoothed percentile curves of birth weight distribution by gestational age for twin (A) male, (B) female, and (C) male + female populations. %ile, percentile.

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tion is essential (19). Growth begins in the uterus, and BW, the starting point after birth, is an important index for quantifying uterine and later growth and related to complications including perinatal mortality and perinatal distress (20). BW is also related to the development of cardiovascular disease, diabetes, and hypertension in adulthood (21). However, since infant BW is affected by both environmental and genetic factors, it is important to identify the percentile distribution of BW during pregnancy using recent data to evaluate infants (22). In fact, the reference BW of the 90th percentile, which was the reference for 30 weeks' gestation singleton births in the present study, was 1,924 g for boys and 1,837 g for girls. These weights were higher than those reported in Korea approximately 10 years previously (boys, 1,855 g; girls, 1,758 g). In addition, the reference BW were higher than those reported in the United States for 257,855 singleton births between 1998 and 2006 (boys, 1,761 g; girls, 1,693 g), and in Canada for 676,605 singleton births between 1994 and 1996 (boys, 1,837 g; girls 1,783 g). The reference BW for the 10th percentile at 40 weeks' gestation were 3,000 g for boys and 2,890 g for girls. These weights were higher than those in Korea 10 years previously (boys, 2,898 g; girls, 2,790 g) and those reported in the US (boys, 2,950 g; girls, 2,855 g) but were lower than those in a Canadian report (boys, 3,079 g; girls, 2,955 g) (6,16,23).

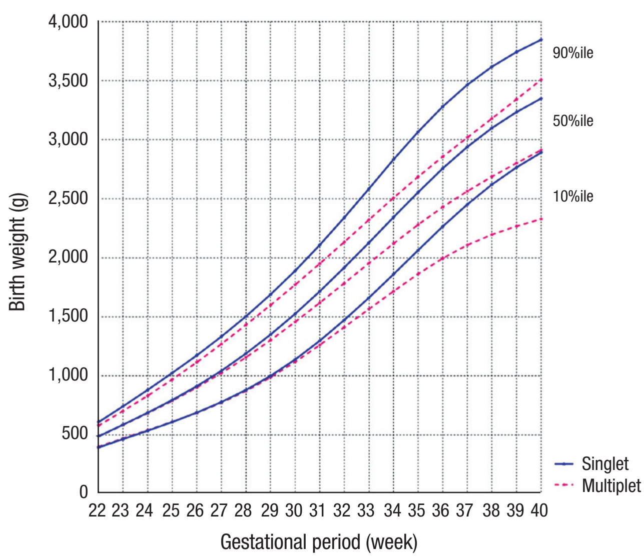

Fig. 4. Comparison of singleton and multiple percentile curves of birth weight by gestational age for male and female infants. %ile, percentile.

In this study, male singleton and multiple infants had higher BW than female infants at each GA. These findings are consistent with those of other studies. According to the report by Kramer et al. (16), the mean BW of male singletons is approximately 50 g heavier than that of female singletons at the 90th percentile at 30 weeks' gestation, increasing to 120 g heavier at the 10th percentile at 42 weeks' gestation. Roberts et al reported that the mean BW of male twins is approximately 100 g heavier than that of female twins at 27-29 weeks' gestation, increasing to 150 g heavier at 40 weeks' GA (24). Fetal growth is generally influenced by placental properties and the fetus's inherent growth potential. This observed gender-specific difference may be caused by gender-dependent differences in "sensitivity" to the placental and fetal tissue to fasting plasma glucose or weight gain-associated factors (25). The differences in BW between males and females reportedly differed less in multiples than in singletons (26). However, our study showed that this gender difference was almost the same within singleton and multiple births.

Compared to singleton-birth infants, multiple-birth infants have limited growth within the uterus; therefore, the evaluation

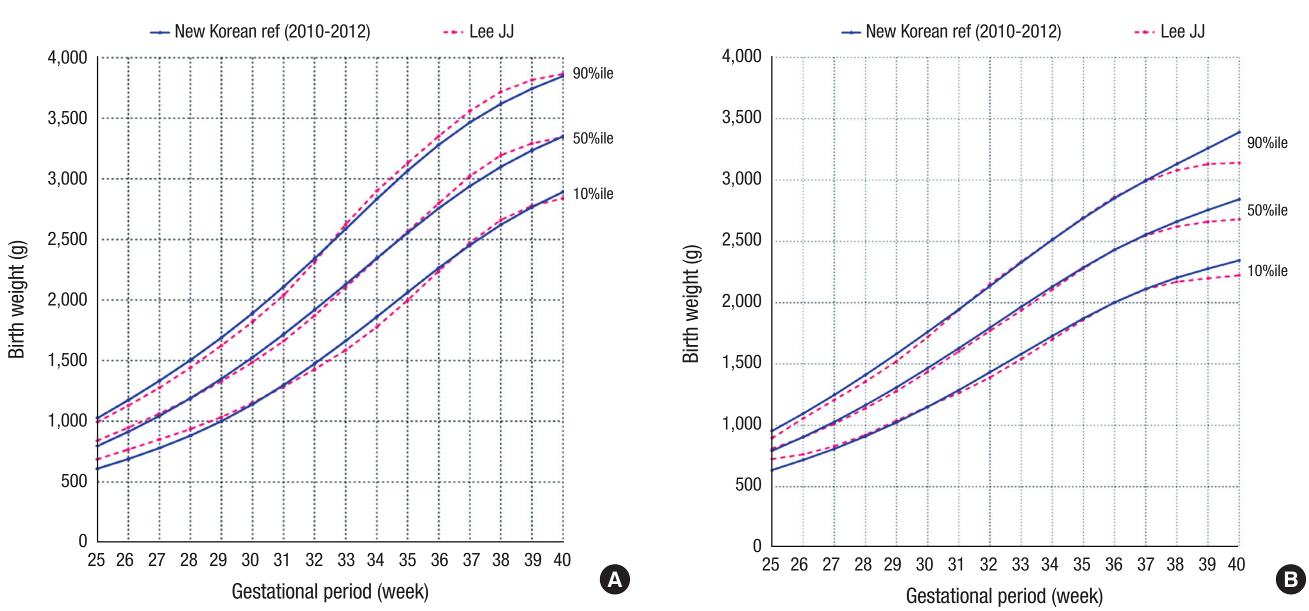

Fig. 5. Comparison of (**A**) singleton, (**B**) twin birth weight percentile curves for male and female infants among different study of Korean populations. %ile, percentile.

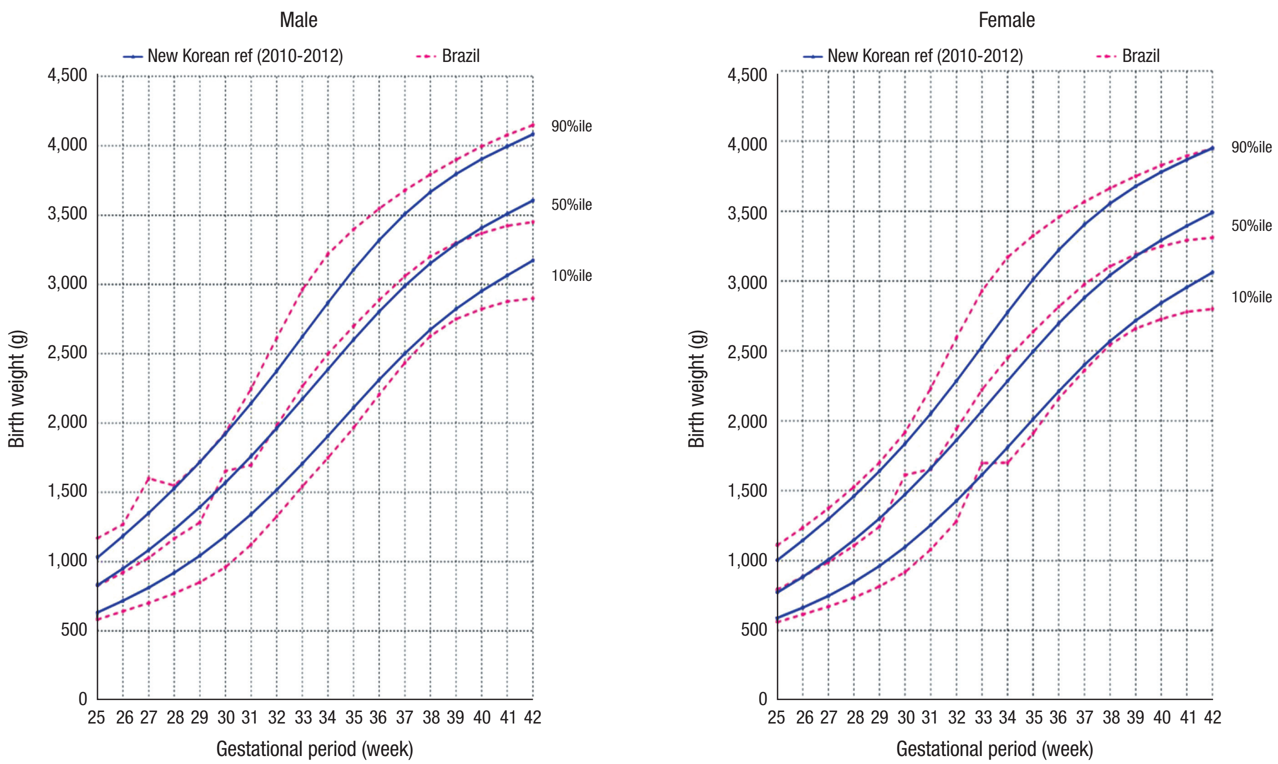

Fig. 6. Comparison of singleton birth weight percentile curves of Brazil. %ile, percentile.

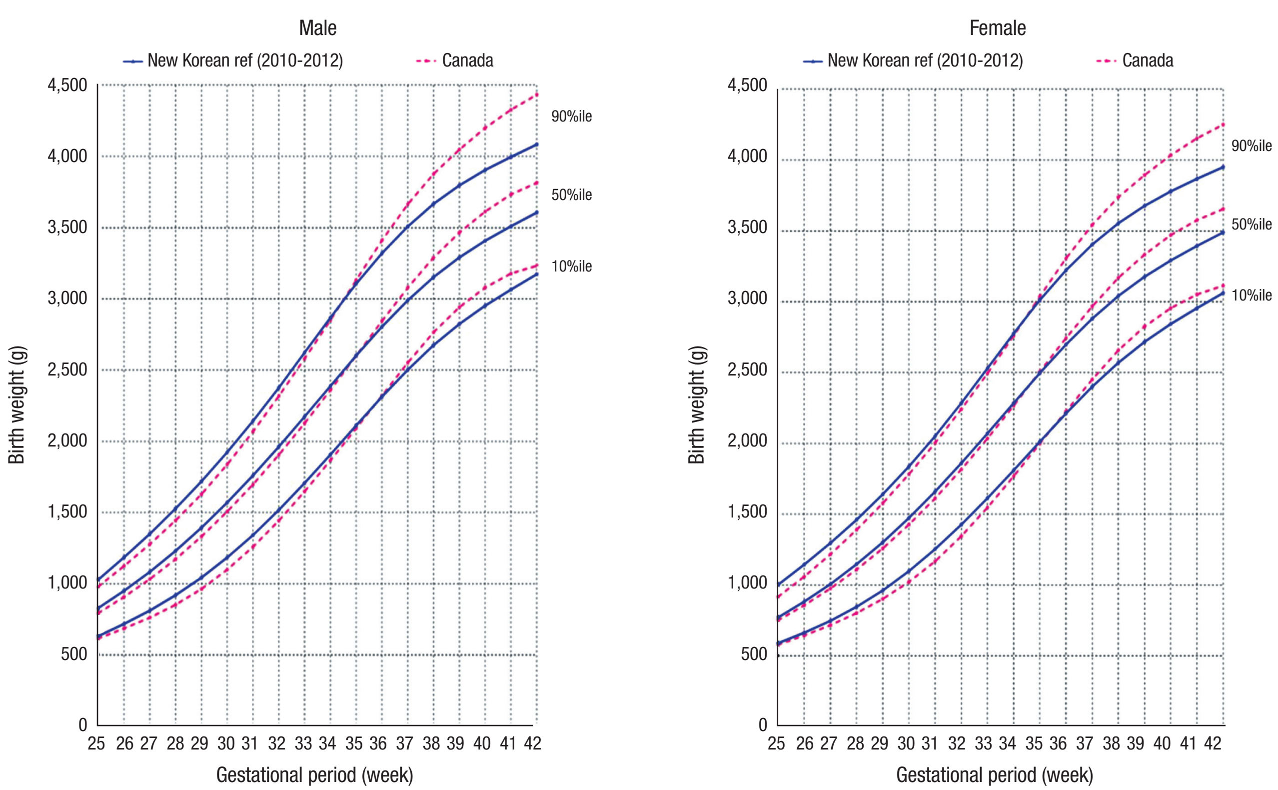

Fig. 7. Comparison of singleton birth weight percentile curves of Canada. %ile, percentile.

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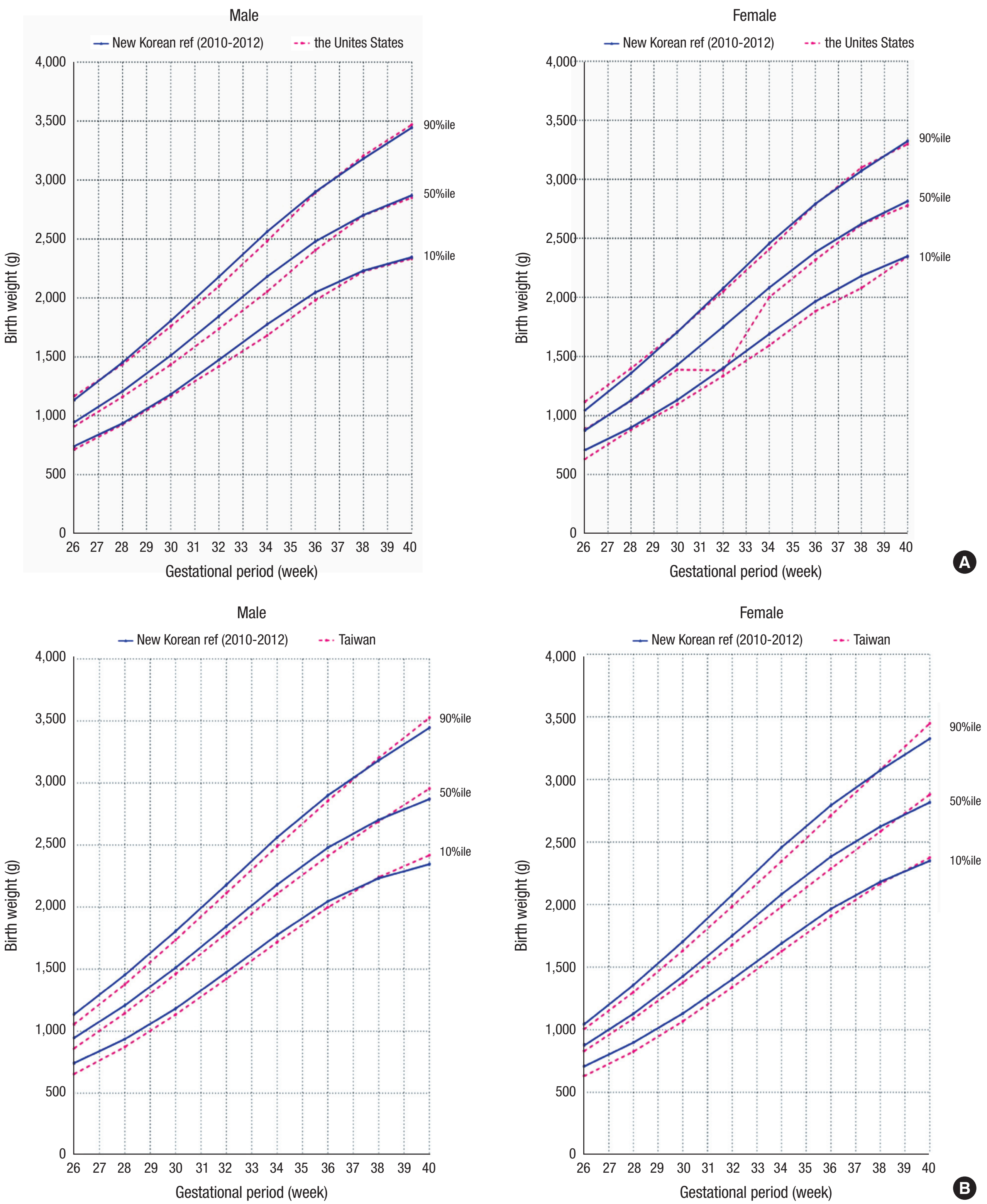

Fig. 8. Comparison of twin birth weight percentile curves of the United States (**A**) and Taiwan (**B**). %ile, percentile.

criteria for infant BW need to be changed depending on singleton or multiple births (17). The growth of twins and triplets is reportedly similar to that of singleton-birth infants until 32 and 29 weeks' gestation, respectively, after which point it differs from that of singleton-birth infants. In contrast, it has been reported that a difference in growth between singleton- and multiple-birth infants began to appear after 28 weeks since multiple-birth infants showed growth limitations after 28 weeks' gestation (23,27). According to the report by Bleker et al. (26), the difference in BW between singletons twins at 39-40 weeks' gestation was 600 g. Our study showed a similar difference in BW between singletons and multiples until about 30 weeks' gestation, but as GA increased after 30 weeks, the difference was greater. As such, the mean BW of male singletons is approximately 460 g heavier than that of female singletons, while that of male multiples is 410 g heavier than that of female multiples at the 50th percentile at 40 weeks' gestation.

We compared our new curve with previously published data on singleton (both sexes) and twin BW percentiles by GA in 2000-2004 in Korea. When the validation samples were categorized as small for GA (SGA; < 10th percentile of a standard BW curve for GA)/appropriate for GA (10th percentile ≤ appropriate for GA ≤ 90th percentile of a standard BW curve for GA)/large for GA (> 90th percentile of a standard BW curve for GA), the new curves had lower average weights at younger GA until 30-31 weeks and higher or similar average weights after 31 weeks on the SGA curve. The differences found between our new curves and previous curves may be explained in part by differences in the infants who were born in 2010-2012 versus those born in 2000-2004. These differences in BW distribution may be explained by multiple factors that influence BW in developed countries, such as smoking, low weight gain during pregnancy, low pre-pregnancy body mass index or demographic changes by increasing numbers of multicultural families in Korea (28,29). On the contrary, the new curves had higher average weights at younger GA until 32-33 weeks and lower average weights after 33 weeks on the large for GA curve. Data from Statistics Korea reported that the percentages of HBW infants among total live births decreased over the years as follows: 6.7% (1993), 6.3% (1995), 5.1% (1997), 4.5% (2000), and 3.5% (2010). Between 1993 and 2010, the average BW of Korea was reduced from 3.31 kg in 1993 to 3.22 kg in 2010 by approximately 0.1 kg (30). Recent changes in percentages of HBW infants and average BW could help to explain why the new curves are shifted down in the older GA on the appropriate GA and large for GA curves. Compared with twin curves, our twin curve had similar average weights at < 37 weeks but higher weights at > 37 weeks. The reason for these differences is currently unknown and should be confirmed in further studies that include fetal outcome.

Despite the fact that the total number of newborns in 2010 was lower than that in 2000, the number of multiple gestations increased from 10,723 in 2000 to 12,841 in 2010, while the multiple birth rate increased 1.6 times from 16.9 in 2000 to 27.3 in 2010 as results of the ovulation inducing agent related to artificial insemination and the increased use of in vitro fertilization (31-33). Although multiples compared with singletons have higher mortality and morbidity rates, few studies have examined the BW of multiples in Korea (34,35). In this study, we tried to establish the distribution of BW percentiles considering newborn plurality. However, the overall data of newborns by the Korean Statistical Information (2010-2012) have estimated errors at 28-32 weeks' gestation. The distribution curves represent the double humped curve. The estimated error data were located on the right, which means heavier newborns for GA. This is the limitation of the large data analysis, but this report removed errors using the Finite Gaussian mixture model.

In this study, we established the new reference range of the neonatal BW percentiles considering GA, sex, and plurality of newborns in Korea. We expect the updated data to be utilized as a new Korean reference to improve clinical growth assessments in newborns.

DISCLOSURE

The authors have no potential conflicts of interest to disclose.

AUTHOR CONTRIBUTION

Study conception and design: Lee JK, Jang HL, Kang BH, Shim KS, Choi YS, Bae CW, Chung SH. Data acquisition: Lee KS. Statistical analysis: Lim JW. First draft of the manuscript: Lee JK, Chung SH. Manuscript approval: all authors.

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