Original Article

Normalized Weight of Iranian Newborns According to Gestational Age: A Nationwide Study

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Abstract

Background: By organizing birth weights according to gestational age at birth, reference weight values for different sex-gestational ages are provided.

Methods: Data of 1,090,779 mothers and their neonates were gathered from 30 provinces of Iran. Pregnancy complications, maternal risk factors, type of delivery, maternal outcome, neonatal sex and APGAR score were determined. Birth weights were quantified into 3rd, 50th and 97th centile. Regression analysis was used to estimate birth weight of neonates.

Results: Birth weight showed an enhancing trend with age; boys weighed more, multiparous women had higher neonatal birth weight, mothers with cardiovascular disease and diabetes mellitus had heavier infants, and mothers aged below 20 years had lower estimated infant birth weight. Gestational age (beta = 147.3) and male sex (beta = 114.9) were the most important independent variables, respectively for predicting birth weight (R-square = 0.512 and $P < 0.001$). In other words, with each unit increase in gestational age, birth weight would increase by 147.3 grams. Male fetuses were also 114.9 grams heavier than females of the same gestational age. Value of R-square shows relatively acceptable goodness of this statistical model.

Conclusion: A national reference for fetal growth patterns and related factors was determined in this study.

Keywords: Birth weight, delivery, fetal development, obstetric

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Introduction

Neonatal health comprises a special complex set of criteria which are very essential in overall health of the individual and may even influence the health condition of later childhood and adulthood.[1]

Among these criteria, weight has always been the most accessible and easy to determine, which is also very sensitive and influenced by various variables including maternal risk factors, pregnancy complications, and neonatal malformations in the pregnancy process. These characteristics highlight birth weight as a determiner to inform about the infant development quality during pregnancy. On the other hand, birth weight is considered a strong indicator of future quality of the infant's life regarding its association with later development of diseases, morbidity and mortality.[2,3]

Although higher birth weight is generally informative of a healthier infant and better pregnancy care, it is not always interpreted this way as it leads to other kinds of complications such as caesarean section (CerS).[4] There are some other labor interventions which harm mother and child or may restrict the child's development period by antedating the time of labor leading to more preterm neonates as the mothers of these fetuses have higher gestational weigh and higher preterm labor risk.[5]

The WHO has established some goals to achieve at least one third reduction in low birth weight infants between 2000 and 2010,[6] as well as 30% reduction from 2012 to 2025.[7] Low birth weight index was 7% in Iran in 1995 which is very promising amount compared to the world.[6] Unfortunately, later on, this rate proceeded to increase rather than decrease, which warrants further researches for evaluation of its causes and consequences.[7]

Ethnical and regional conditions affect the fetal growth pattern during pregnancy. The differences are significant and may cause misdiagnosis if applied to other populations. So, availability of a documented population-based weight reference of fetuses and neonates during pregnancy is fundamentally important to take care of the growth, screen the diseases, and reduce the adverse maternal and neonatal outcomes.[8,9]

To our best knowledge, our study is the first survey conducted in a national population establishing these birth weight references for Iranians.

In the current paper, we evaluated the birth weight of Iranian children matched with their gestational age at birth, and tracked their relationship while taking into account the different aspects of pregnancy affecting mother and child. Moreover, by selecting a subgroup of healthy neonates and deliveries, we obtained a reference weight value for different sex-gestational age groups of neonates. We also discussed the intrauterine and labor-related aspects of this subject which could provide a better picture about neonatal healthcare condition during pregnancy and illuminate the way for future interventions to improve it. This could be of

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significant importance as by tighter and more practical monitoring of fetal growth during pregnancy, many of the causes of ongoing high frequency of low birth weight deliveries can be prevented.[6,7]

Patients and Methods

In this national birth cohort study, we investigated data from 30 (out of a total 31) provinces (except Kermanshah province). In-hospital data of all deliveries between March 2013 and March 2014 were gathered and cleaned for further analysis. Data related to mother and infant, including demographics (city or province of birth, type of hospital (educational, non-educational, and private), season of the birth (spring, summer, autumn, and winter) and mother nationality), mothers' related data (gravid, para, abortion number, presence of any delivery complication, third or fourth degree tearing of perineum, administration of blood or blood products, delivery without any intervention, episiotomy, labor induction, strengthening labor contractions, using forceps or vacuum, mother outcome (death, neonatal intensive care unit (NICU) admission, transfer to obstetric ward, and reoperation), maternal age, maternal risk factors (diabetes, hypertension, and cardiovascular diseases)), neonates related data [sex, birth weight, delivery type (normal vaginal delivery (NVD) or cesarean section (CerS))], gestational age (<37 weeks: preterm, 37–40 weeks: term, and >40 weeks: postdate), 1st and 5th minute APGAR (0–3, 4–6, ≥7), and presence of any malformation (hand or foot, cardiovascular, head and neck, neural tube defect, down syndrome, other chromosomal malformation, musculoskeletal, nervous system, gastrointestinal, genitourinary system, cleft lip or palate, ear or eye, and other) were collected.

Stillbirth or dead neonates, non-Iranian mothers, and neonates with any malformation were excluded from the final analysis. We only considered singleton births.

Some training was done for personnel involved in data collection for validity assurance. In addition, many clearances strategies were implemented on data. However, some data with lower reliability were removed from analysis like 1st minute APGAR.

In this study, nulliparous mothers are cases with their first pregnancy. Others have been considered as multiparous.

Ethics

The proposal of this project and its related ethics issues were approved by the World Health Organization office in Iran. Moreover, the Institutional Review Board in the Iranian Ministry of Health approved the study.

Statistic

We used frequency, median, ≤3 and ≥97 percentile (as normal lower limit: NLL and normal higher limit: NHL, respectively) for analysis of data using SPSS 20 (SPSS Inc. Chicago, Illinois, USA). Stepwise linear regression was used for estimating birth weight based on other predictors. All variables with P-value less than 0.2 entered the model. Considering significant R-square change and collinearity, the best model with lowest number of predictors was selected.

Results

Out of 1,207,304 deliveries, 1,090,779 neonates were eligible for inclusion in final analysis. Among them, 43.6% were NVDs and 56.4% C/Ss (18.0% emergent C/Ss, and 38.4% elective C/Ss). In most of the cases (99.3%), 5th minute APGAR was acceptable. Type of hospital was non-educational in 56.9%. Season of delivery was distributed relatively equally with a slight tendency (26.9%) for summer. Birth-weight of most cases (89.5%) was 2500–4000 grams. Gestational age was 37–40 weeks in 89.1% of cases. Child birth assistant was an obstetrician in 65.4% and a registered midwife in 33.3% of cases. Mean (SD) values of gravid, para and abortion were 2.01 ± 1.18, 0.81 ± 0.99, and 0.20 ± 0.52, respectively.

Mother outcome was transfer to obstetrics ward in 96.8% of the cases. Boys accounted for 51.6%. In 49.4% of the cases, there were delivery complications. Third or fourth degree tearing of vagina was observed in 0.4%, administration of blood products in 1.2%, delivery with intervention in 20.5%, episiotomy in 11.8%, labor induction in 9.8%, strengthen labor contractions in 5.2%, and forceps vacuum in 0.5% of cases.

Different cut-offs of weight according to neonates' sex, mothers' para, mothers' risk factor, maternal age, gestational age, neonates' outcome, 5th minute APGAR, type of delivery, and season are shown in Table 1. Both lower and higher limits of birth weight were higher in boys in comparison with girls. Multiparous mothers in comparison with nulliparous, postdates in comparison with term or preterm neonates, and neonates with higher 5th APGAR minute also had a similar pattern. Lower limit of birth weight in neonates with better outcome was higher (Table 1).

Except for some instances, both lower and higher limits of birth weight increased with increasing gestational age. Boys had higher limits than girls most of the time (Table 2).

The best model in view of higher R-square with lower number of predictor was a model with R-square = 0.512 and $P < 0.001$ showing that gestational age and male sex were the most important independent variables, respectively for predicting birth weight (Table 3). In other words, after adjusting for para, maternal risk factor, maternal diabetes mellitus, maternal hypertension, maternal cardiovascular disease, maternal other risk factors, maternal age, and season, with each unit increase in gestational age, birth weight would increase by 147.3 grams. Male fetuses were also 114.9 grams heavier than females with the same gestational age. Value of R-square shows relatively acceptable goodness of this statistical model (Table 3).

Trend of birth weight with gestational age between boys and girls (Figure 1A), mothers' para (Figure 1B), maternal age (Figure 1C), maternal risk factors (Figures 1D and 1H) and season (Figure 1I) shows that male neonates born in summer from multiparous diabetic mothers with higher maternal age had higher birth weight (Figures 1A to 1I). However, there are some changes in patterns of birth weight in different gestational ages. For example, mothers aged between 20 and 29 years had babies with higher birth weight if gestational age was lower than 32 weeks (Figure 1C). A similar pattern was observed about season. Babies born in spring at 32nd week of gestational age or sooner had higher, and those born in 37th week of gestational age or later had lower birth weight in comparison with other seasons (Figure 1I).

Discussion

As expected, gestational age had the most powerful relationship with birth weight among all covariates (Table 3). The median of birth weight generally followed an enhancing trend except in 22 to

Table 1. Birth weight of Iranian singleton births without congenital anomalies according to different parameters from 2013–2014.

Variables		*n*	Birth weight centile		
			≤3	50th	≥97
Neonates' sex					
	Boys	563210	2200	3240	4100
	Girls	527097	2150	3120	3950
Mothers' para					
	Nulliparous	503602	2100	3150	4000
	Multiparous	587177	2220	3200	4085
Mothers' risk factor					
	Diabetes mellitus	14958	2050	3250	4300
	Hypertension	397010	2200	3200	4000
	Cardiovascular diseases	12242	2020	3230	4300
	Without risk factor	595772	2100	3200	4000
Maternal age (years)					
	< 20	117405	2160	3150	3950
	20 – 29	577631	2200	3200	4000
	30 – 39	360667	2150	3200	4100
	40 – 50	26070	1960	3200	4100
Gestational age					
	Preterm	76055	980	2480	3510
	Term	971429	2450	3200	4000
	Postdate	43295	2600	3400	4220
Neonates' outcome					
	Transfer to mothers' room	1018276	2370	3200	4000
	Transfer to neonates' room	45298	1450	3000	4200
	Admission to NICU	27205	800	2330	3854.1
APGAR at 5th minute					
	0 – 3	1649	535	1710	3800
	4 – 6	5737	690	2050	3827.2
	≥ 7	1083393	2200	3200	4000
Type of delivery					
	Normal vaginal delivery	475156	2250	3200	4000
	Cesarean section	615623	2100	3200	4050
Season					
	Spring	253550	2150	3200	4000
	Summer	292954	2200	3200	4000
	Fall	268459	2170	3200	4000
	Winter	275816	2200	3200	4000

23 and 42 to > 43 weeks of gestational age. This may be because of selection bias due to lower number of involved infants in these two extremes of measured age and earlier entry of pregnancies with average infant weight of 3400 grams into labor phase. So, with median values of 3500 and 3400 grams of boys and girls, respectively in 42 weeks of age, one can propose that most of the pregnancies lasting more than 42 weeks, consists a lower weighted infant, otherwise they have been forced to start labor.

Overall, the median, the highest and lowest percentile of birth weight were higher in boys (Table 3, Figure 1A), as the male sex was the second most powerful covariate related with birth weight (Table 3), pointing to the effect of sexual related genes and hormones before birth, which has been previously reported by other studies.[10–12]

During pregnancy, sex differences in birth weight medians are not clear until 26 weeks of gestational age when male infants' weight begins to dominate. This is in accordance with a study by Parker *et al*. study which reported the beginning of intrauterine growth gap between genders at about 28 weeks of age.[11] Other studies have reported this age in the early[12] or late[10] second trimester. This variation may be explained by ethnical reasons or number of individuals included in these studies. Our results are

Table 2. Birth weight of Iranian singleton births without congenital anomalies according to different sex and gestational age from 2013–2014.

Gestational age (weeks)	Boys				Girls			
	n	Birth weight centile			*n*	Birth weight centile		
		3	50th	97		3	50th	97
22	43	406.4	800	1284	32	400	800	1150
23	63	496.8	680	1364	47	500	630	1370
24	127	200	700	1496	119	500	700	1580
25	216	500	800	1696	198	500	800	1700
26	428	600	900	2026.5	360	568.3	877.5	1950.2
27	414	633.5	1040	2777.5	393	600	1000	2909
28	842	720	1200	3071	707	692.4	1150	3157.6
29	645	800	1350	3270	625	700	1250	3000
30	1158	850	1515	3300	950	900	1500	3139.4
31	1232	1000	1700	3190.1	1069	971	1600	3147
32	2190	1130	1900	3222.7	1801	1050	1800	3200
33	2642	1322.9	2090	3127.8	2227	1210	2000	3000
34	4855	1500	2300	3353.2	4267	1430	2200	3289.6
35	8233	1750	2550	3500	6914	1660	2450	3400
36	17768	2000	2800	3700	15450	1900	2700	3600
37	48131	2250	3035	3900	42929	2140	2950	3800
38	180234	2500	3200	4000	166669	2400	3100	3900
39	158682	2590	3300	4100	150241	2500	3200	3950
40	113604	2600	3390	4200	110525	2500	3250	4000
41	19724	2680	3470	4300	19787	2600	3300	4100
42	1813	2624.2	3500	4450	1630	2509.3	3300	4200
≥ 43	166	2400.6	3450	4599.5	157	2450	3300	4300

Table 3. Linear regression analysis for estimating birth weight.

Independent variable	Unstandardized coefficients[#]		Standardized coefficients	Sig.
	Beta	Standard error		
Gestational age	147.3	0.243	0.500	<0.001
Male sex[*]	114.9	0.811	0.117	<0.001

[*] = in comparison with females. [#] = adjusted for para, maternal risk factor, maternal diabetes mellitus, maternal hypertension, maternal cardiovascular disease, maternal other risk factor, maternal age, and season.

also compatible with these findings as seen in Figure 1A, which shows that the gap of birth weight trends between two genders starts to progress at 25–32 weeks of gestational age.

The Iranians fetal weight exceeds the American counterparts of the same age in both boys and girls until 32nd weeks. However, the median of both countries are approximately the same at the 33rd week, and afterwards until 42nd week, the American fetuses weigh more.[13] Canadians follow the same pace except that their girls proceed earlier, and they weigh more than the Iranian counterparts at 29th week, 31st week and later.[14] In comparison with the Italian population as a representative of European countries, United States generally has higher birth weights, and the fetal weight of Iranian boys and girls remains higher until 39th week, and then falls behind up to 42nd week.[15]

In Brazil, as a representative of South America, the median fetal weigh is lower than Iran until 29th week of gestation, when it starts to dominate until 37th week, and the weights are seemingly equal with acceptable variations from 38th to 42nd.[16]

According to data from India, interestingly the pioneer prominence of Iranians is reversed and it is the average Indian fetus which weighs more, until 35th week and then Iranians proceed afterwards until 42nd week.[17]

Cameroon, as an African country, almost always has higher weighing male infants than Iran during pregnancy, whereas in female infants, it is obviously higher only at 31st to 37th weeks with nearly equal results with some variations outside this period.[18]

As we discussed above, Iranian infants weigh more than Americans and infants in India and Cameroon weigh even more than Iranians. This raises the suspicion that in developing countries, high risk pregnancies may happen outside of the health facilities. However, we believe that the percentage of these pregnancies (out of hospital facilities) is very low (about 5%) in 2013 in Iran.[19] So, selection bias, if any, has low probability in our study.

These disparities may be influenced by different measurement

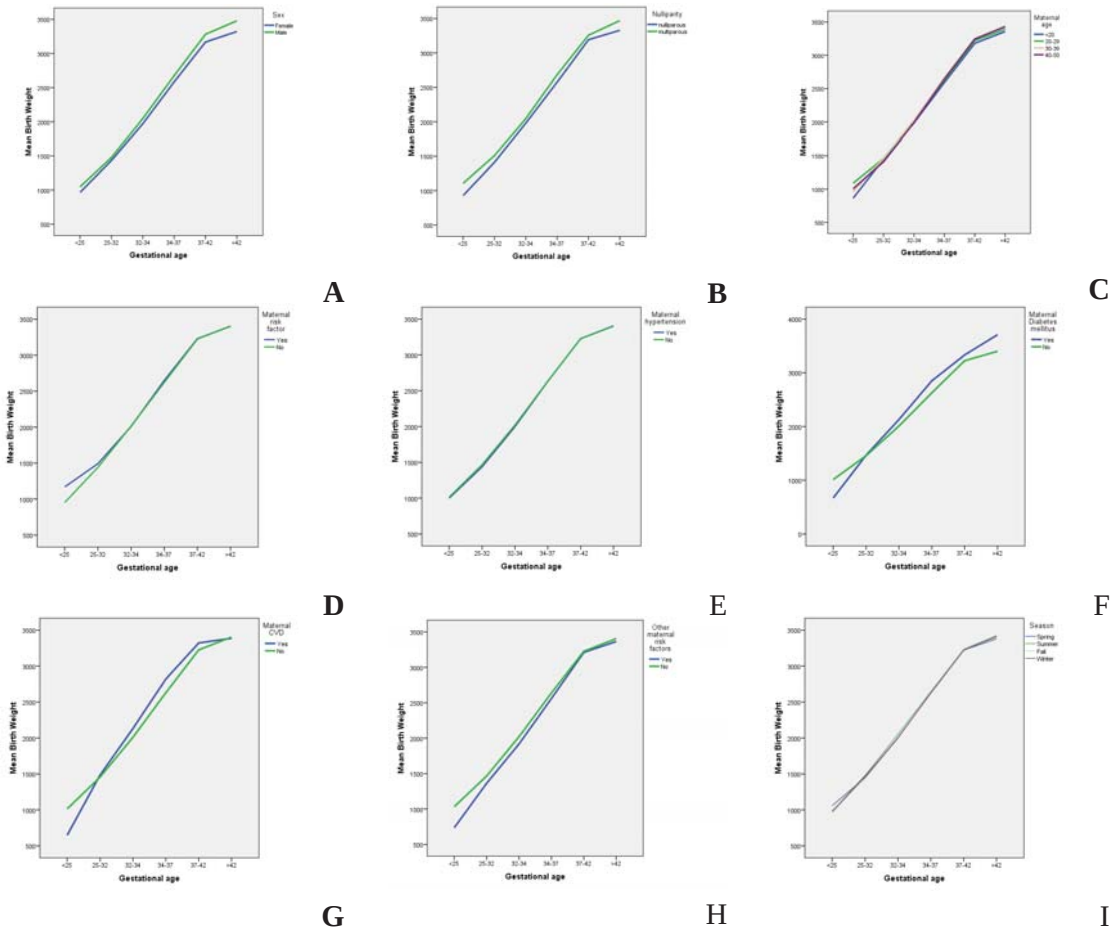

Figure 1. Correlation between birth weight and gestational age **A)** in each sex, **B)** in mothers with different para, **C)** in different maternal ages, **D)** in mothers with either cardiac, hypertension or diabetes, **E)** hypertensive mothers, **F)** in mothers with diabetes mellitus, **G)** in mothers with cardiovascular disease, **H)** in mothers with other maternal risk factors, **I)** in different seasons of birth.

methods between studies which reduce the validity of comparison of charts of different countries.[20,21]

Multiparous women had higher neonatal birth weight in all 3 centiles and overall (Figure 1B). This has been shown by other studies, as well. Shah *et al.* in a meta-analysis on 41 papers concluded similar concept that nulliparity is associated with higher risk of low birth weight (LBW) and small for gestational age (SGA) infants.[22]

Considering maternal age in our study (Figure 1C), mothers aged below 20 years had lower estimated infant birth weight. In addition to neonatal birth weight, it is well-known that pregnancy complications, congenital anomalies, fetal growth retardation, still births and infant mortality are also proved to be higher in these mothers.[23,24] These may be due to unprepared body physiology of mothers for pregnancy in this age period as part of human normal growth is about to complete before 20s. So, the substance and energy used for pregnancy is reduced after 20s. However, further research is needed to confirm this. Birth weight of infants with mothers aged 40–50 and after that 30–40 was considered highest when approximately the 34th week of gestational age is passed; this could be explained by the probable higher parity of these mothers and better intra-uterine growth opportunity after 34th week of gestational age.

By ignoring the lowest birth weight percentile, mothers with cardiovascular disease (CVD, Figure 1G) and diabetes mellitus (DM, Figure 1F) separately had heavier infants. Other studies significantly point to this effect of DM[25] highlighting the probable rule of hormones. However, our detected CVD relationship does not correspond with the available data which indicate that women with preterm or low birth-weighted infants will be at higher risk of CVD and related mortality.[26,27] This disparity may be due to positive effect of drugs used to treat CVD in the blood supplementation of the fetus, but when not on drugs, CVD occurs more prevalently in mothers of LBW infants.

Unlike other studies,[28,29] we did not find any differences in birth weight of infants of hyper and normotensive mothers (Figure 1E). This may originate from ethnical disparity, as it is reported that the population ethnical aspect can influence this relationship.[28]

When considering mothers with one of the risk factors of DM, CVD or hypertension (HTN), the results are mostly the same as healthy mothers (Figure 1D); this could be explained by the high frequency of HTN and its equalizing effect between these two groups in our study.

Regarding neonatal outcome, neonates transferred to NICU were obviously lighter. This is in correlation with gestational age and APGAR score as most of these neonates are preterm

with lower APGAR scores. Tamim *et al.* also showed that birth weight is a major indicator of NICU admission of newborns prior to Body Mass Index (BMI) or Ponderal index.[30] It is of note that neonatal death as an outcome is also proved to be higher in low birth weight neonates.[31]

Third percentile of neonatal birth weight was lower and 97th percentile was higher in CerS deliveries. This data corresponds with other studies results, as they mentioned higher rate of CerS at the two extremes of birth weight.[32,33]

Unlike studies conducted in other countries,[34,35] season turned out to be unlikely to have much effect on birth weight in our population (Figure 1I). A common reason proposed for seasonal variation of birth weight in these studies is sun exposure leading to vitamin D production.[34,35] Our result can be justified regarding to low basal sun exposure and vitamin D levels among Iranian people, especially women, because their exposed body surface to sun does not vary much seasonally regarding their stable kind of dressing due to social and religious rules.

The strength of our study is using a full national data from all over Iran (except one province) with a large study population. Moreover, we assessed the relationship of neonatal birth weight with various neonatal and maternal aspects of pregnancy and labor which was relatively a pioneer approach. Because of census method of sampling, we did not calculate p-values and numbers are real values of Iran at 2013–2014.

Our study has also some limitations. Most importantly, we did not prove any cause-effect issue and only detected the existence of relationships. Second, we did not measure neonatal mortality after discharge from hospital to be indexed in the neonatal outcome results. Third, comparing growth charts of different countries may not be sufficiently valid because in this way, we cannot distinguish between constitutional low growth of each ethnicity and existence growth retardation and also the measurement method is substantially variable between studies.[8,21] Fourth, our study does not cover pregnancies that happen outside of hospital facilities.

In conclusion, fetal and neonatal weight have to be considered as valuable variables even before birth because they help us to understand various conditional aspects of pregnancy and mother and child health status and prepare us to prevent and to solve many suspected complications and problems by helping to predict the approximate future of many obstetric health-care measures.

Conflict of interests

There is no conflict of interest.

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Author contribution

Participation in study design: SSG, FT, VE, AA, AK; execution: SSG, FT, AK; analysis: SSG, AK; manuscript drafting: SSG, FT, VE, AA, AK; critical discussion: SSG, FT, VE, AA, AK

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