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Investigating the accuracy of Johnson's rule in estimating fetal weight

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Abstract:

BACKGROUND: Birth weight has a significant impact on perinatal mortality. Therefore, the estimation of fetal weight greatly influences the policies necessary for care during and after delivery. We aimed to investigate Johnson's rule in estimating fetal weight.

MATERIALS AND METHOD: This study was a single-group longitudinal study that was conducted in 6 months from October 2021 to April 2022 on 150 pregnant women in Isfahan-Iran. The sampling method was accessible. Inclusion criteria include being term, singleton, without abnormality, intact membranes, cephalic presentation, and exclusion criteria include diagnosed polyhydramnios or oligohydramnios and mother's abdominal or pelvic known masses. After completing the informed consent, fetal weight was estimated by Johnson's rule and was compared with the birth weight. Descriptive and analytical statistics (mean-standard deviation (SD), number-percentage, t-paired, and Spearman's correlation coefficient) were used to achieve the objectives of the study. The receiver operating characteristic (ROC) curve was also used to determine the sensitivity, specificity, and positive and negative predictive value of Johnson's law.

RESULT: The mean (SD) birth weight was 3032.88 ± 481.11 g and the mean (SD) estimated fetal weight (EFW) by the clinical method was 3152.15 ± 391.95 g. There was a significant difference between the averages ($P < 0.001$). The percentage error of EFW showed a significant negative correlation (r = -0.286; $P < 0.05$) with gestational age (GA) and a significant positive correlation (r = 0.263; $P < 0.05$) with the fetal head station. The sensitivity and specificity of EFW with Johnson's rule, in normal fetal birth weight, were higher than in low birth weight fetal. The accuracy of EFW with ± 10% of the actual weight was higher in average for gestational age (AGA) (84.3%) and high-for-gestational-age (LGA) (70%) than in low-for-gestational-age (SGA) (4%). The EFW mean percentage error in SGA was higher than in the other two weight groups. This method, especially for AGA and LGA fetuses, can be a suitable alternative to other weight estimation methods.

CONCLUSION: Clinical estimation of weight via Johnson's rule due to availability and no cost can be a suitable method for managing childbirth based on fetal weight.

Keywords:

Accuracy, birth weight, fetal weight, perinatal mortality

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Introduction

The estimation of fetal weight significantly affects the necessary policies for care during delivery, and any deviation from the normal weight of the baby at the time of delivery increases maternal and newborn risks. The significant rate of infant mortality due to birth conditions (39–130 deaths per 1,000 live births) is still a major cause of concern in developing countries.[1] Birth weight has a significant effect on perinatal mortality.[2] Because the care of babies with abnormal weight requires special conditions and must be done in centers with suitable facilities, therefore, when the fetal weight is estimated with a deviation from the normal range, the need for preparation and

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detailed planning to increase the survival of the baby is increasing.[3,4] As a result, to prevent birth complications, especially in suspected cases of macrosomia or delayed fetal growth, as well as in premature births, determining the fetal weight as accurately as possible becomes important.[3] There are various scientific methods to estimate or measure fetal weight, including ultrasound and magnetic resonance imaging (MRI). None of the studies that have been done so far have definitely stated which method to estimate fetal weight is preferable over others.[5] One of the most well-known clinical methods in estimating fetal weight is the use of Johnson's rule[6]. Johnson and Toshach proposed a method of estimating fetal weight with quantitative extrauterine measurement[7] and 3 years later, Johnson modified this formula and used MacDonald's method to measure the height of the uterus and the position of the fetal head in the new formula.[8] Johnson's rule calculates the estimated fetal weight by measuring the height of the uterus and the position of the fetal head in the mother's pelvis.

Fetal weight estimation at the time of birth as well as the need to access an easy, cheap, and practical method for health service providers have always been important. Considering that no special skills are needed for clinical examination and calculation of fetal weight based on Johnson's formula, this will lead to timely dispatch of the puerperia to more equipped centers and reduce mortality and maternal and neonatal complications. In addition, according to conflicting reports regarding the effectiveness of clinical methods in estimating fetal weight, in some studies, clinical methods are considered the best methods for one or two categories of fetal weight groups (low weight, normal, or macrosomia). It has rarely been a successful method for estimating fetal weight in all three categories. The present study was designed to evaluate the accuracy of Johnson's rule in estimating the baby's weight compared to the actual birth weight.

Materials and Methods

Study design and setting

This research was a longitudinal and single-group-correlation research that was conducted during 6 months from September 2021 to April 2022 in Shahid Beheshti Educational Hospital.

Study participants and sampling

The sampling method was convenience-sampling method. The samples of this study included 150 full-term pregnancies (37–42 weeks), singletons, without abnormalities, intact membranes, and cephalic and fetal station of 0 to -3 and they terminated their pregnancy by cesarean or natural delivery method. Exclusion criteria included diagnosed polyhydramnios or oligohydramnios pregnancy, as well as abdominal or pelvic masses that were detected during pelvic examination by a gynecologist or included in the mother's medical record. The sample size is aimed to estimate the average weight of newborns of pregnant women referred to a selected hospital in Isfahan. The confidence level of 95%, with a standard deviation (SD) of 442 g, based on the results of a previous study,[6] was taken into account, and the accuracy of estimation of 70 g was also considered for a total of 150 pregnancies.

$$n = \frac{z^2 s^2}{d^2} = 150$$

Data collection tool and technique

Data collection tools included demographic information questionnaires, standard cloth meters, and standard weights of adults and babies. The cloth meter and scale used in this research were standard and similar for everyone, and each time before weighing, the scale was set to zero and once a week, the scale was tested for quality with a weight (1 kg). All the mothers who met the inclusion criteria completed the informed consent form and a questionnaire containing demographic information to measure the desired clinical information (height, weight, wrist circumference (cm) to determine the height of the mother (height (cm)/wrist circumference (cm))). After ensuring that the mother's bladder was empty to prevent errors in the measurement, the height of the mother's uterus was measured in the position of lying on her back using a cloth meter during uterine rest and the absence of uterine contractions. For this reason, after performing the Leopold maneuver by the researcher and identifying the apex of the uterus, the height of the uterus was measured in centimeters from the upper edge of the pubic symphysis (pubic hair growth line) tangent to the abdominal wall to the highest point of the uterine crest and recorded in the observation sheet. It should be noted that all the researcher's measurements have been carefully monitored under the supervision of the project supervisor until the same measurement is achieved.

After that, a vaginal examination was performed to detect the placental organ (head) and the position of the fetal head in relation to the ischial spines; moreover, the fetal weight was estimated using the clinical method (Johnson's rule). After delivery, the real weight of the baby after birth (at most 1 h after birth) was measured and recorded with a standard electronic scale for babies. The cloth meter and scale used in this research were standard and similar for everyone and each time before weighing, the scale was re-set to zero and once a week, the scale was tested for quality with a weight (1 kg).

Based on the following formula, the estimated weight was calculated by the clinical method (Johnson's rule):

Fetal weight (g) = (uterine height - N) ×155.

If the position of the fetal head is parallel to the ischial spines, n = 12, however, if the position of the fetal head is higher than the level of the ischial spines, n = 13. It is claimed that Johnson's rule can estimate the weight of the fetus within the range of ± 350 g.[3] After collecting the data, the birth weight of babies was classified into three groups: low birth weight (LBW, <2500 g), normal weight (2500-4000 g), and macrosomia (>4000 g). To calculate the percentage of estimation error, the following formula was used for weight:

Percentage of error (PE) = Actual weight/100*(Actual weight-estimated weight)

Data entry and information analysis were done using IBM SPSS 18 software (SPSS V.18 Inc., Chicago, IL, USA). Descriptive and analytical statistics (mean-SD, number-percentage, paired *t*-test, and Spearman's correlation coefficient) were used to achieve the objectives of the study. The receiver operating characteristic (ROC) curve was also used to determine the sensitivity, specificity, and positive and negative predictive value of Johnson's rule. *P* value >0.05 was considered significant.

Ethical consideration

This study was approved by the code of ethics IR.MUI.NUREMA.REC.1400.077 in Isfahan University of Medical Sciences. The researcher introduced herself to the research units. The research objectives and the work process were explained to the research units. All the information obtained from the research units remained confidential and their names were not mentioned in the questionnaire. It was explained to the research units that their participation in the research is not mandatory and they can withdraw from the research at any stage of the research. It was also explained to the participants that participation or non-participation in the research does not affect their care and treatment process. Moreover, informed consent was taken from them to participate in the study.

Result

The findings of the study showed that the average age of mothers was 29.9 ± 6.3 years and their average gestational age (GA) was 38.7 ± 1.4. The number of nulliparous mothers participating in the study was 67 (44.7%) and multiparous mothers were 83 (55.3%). In addition, the findings indicated that 56.66% of the mothers had big figures, 42% had normal figures, and the others had small figures. Table 1 demonstrates the individual information of the study subjects.

The average estimated fetal weight using Johnson's rule was 3152.15 ± 391.95 g with a minimum-maximum of 2092.00–4417.50 g and the average actual birth weight of the newborn was 3032.88 ± 481.11 g with a minimum-maximum of 4050–4050.00 g. The average difference between the estimated weight and the actual weight of the baby was 119.26 g. Statistical analysis with paired *t*-test showed that there was a statistically significant difference between the average weight estimated by the clinical method (Johnson's rule) and the actual weight (*P* value < 0.001).

Research data showed that there was a negative correlation ($P < 0.001$, r = -0.286) between GA and the mean percentage error of fetal weight. It was also found that there is a positive correlation between the position of the fetal head and the mean percentage error of estimated fetal weight ($P < 0.05$, r = 0.263), which indicates an increase in the error in fetal weight estimation as the fetal head station increases, but size, body mass index (BMI), parity, and the height of the mother's uterus did not have a significant relationship with the percentage error of fetal weight. More information can be found in Table 2.

The findings showed that considering the accuracy of ± 350 g for the clinical method, the overall sensitivity of Johnson's rule was 87.7% and its specificity was 80.6%, and for fetuses weighing less than 2500 g, the sensitivity was 50% and the specificity was 90.5%. The sensitivity of the clinical method for fetuses with normal weight was 92.6% and the specificity was 53.3%. The positive

Table 1: Frequency distribution of fertility characteristics

Fertility Characteristics	Number	Percent
Gestational Age (weeks)		
37–38.9	82	54.7
39–40.9	50	33.3
41–42	18	12
BMI		
<25	20	13.3
25–29.9	55	36.7
30–34.9	49	32.7
35≤	26	17.3
Station		
0	9	6
-1	30	20
-2	33	22
-3	78	52
Height of the uterus		
<30	29	19.3
30–35	106	70.7
>35	15	10

predictive value of the clinical method was reported to be 93.4%.

Moreover, taking into account the accuracy of ± 500 g, the overall sensitivity of Johnson's rule was 78.7% and its specificity was 100%, and for fetuses weighing less than 2500 g, the sensitivity was 58.8% and the specificity was 70%. The sensitivity of the clinical method for fetuses with normal weight was 90% and the specificity was 100%. In this case, the positive predictive value of the clinical method was reported as 100%.

Diagram 1 shows the ROC curve for the accuracy of Johnson's rule with ± 350 g of actual weight.

After dividing the weight based on the GA, we concluded that the accuracy of weight estimation based on ± 10% of the actual weight was much higher in average for gestational age (AGA) and high-for-gestational-age (LGA) babies than in low-for-gestational-age (SGA) babies. Moreover, the weight estimation error in SGA babies was more than in the other two groups [Table 3].

Discussion

Estimating the fetal weight can be considered one of the important factors in the management of maternity care, especially in women who have SGA and LGA fetuses.[7] The fetal weight cannot be measured directly, so the anatomical characteristics of the mother and fetus are used to estimate the weight. Using Johnson's rule is one of the common methods of weight estimation.

The results showed that there was a significant difference between the actual weight and the estimated fetal weight ($P < 0.001$). That is, Johnson's rule estimated the fetal weight more than the actual weight. The results of the study by Joshi *et al*.[8] in 2017 have shown that there was a significant difference between the actual weight and the estimated fetal weight using the clinical method. In their research, the clinical method estimated the fetal weight more than the birth weight. In a study conducted by El-Sayed *et al*.[9] in 2019 on 84 pregnant women, they reached the same conclusion. A study conducted by Njoku *et al*.[10] in 2013 on 200 term pregnant

Table 2: Comparison of mean and checking the correlation with the average error percentage in individual variables

Individual variables	Average actual weight	Estimated average weight	*P*	Average error percentage	*R*	*P*
Gestational age (week)						
37–38.9	2839.93±505.40	3017.73±402.68	0.000	7.67±12.33	-0.286	0.000
39–40.9	3231.20±328.42	3281.33±318.78	0.044	1.76±5.52		
41–42	3361.00±302.58	3405.69±276.85	0.414	1.71±8.00		
Number of pregnancies						
Nulliparous	2948.25±519.71	3088.41±420.88	0.000	0.865	0.014	0.865
Multiparous	3103.20±438.88	3203.60±361.34	0.000	4.13±9.77		
Height of the uterus						
<30	2449.13±327.08	2605.56±230.13	0.007	7.63±12.60	-0.092	0.265
30–35	3099.43±367.24	3203.07±208.17	0.000	4.35±10.33		
>35	3691.20±185.06	3849.06±212.60	0.003	4.35±4.62		
BMI						
<25	2847.25±379.37	2960.45±306.52	0.064	4.83±10.86	0.129	0.116
25.1–30	3036.09±446.50	3133.77±387.73	0.001	3.88±8.32		
30.1–35	3163.12±467.74	3209.11±372.29	0.228	2.36±9.72		
35<	2923.46±588.36	3231.15±458.63	0.000	12.38±12.41		
Station						
0	3397.00±353.67	3461.66±369.65	0.423	2.06±6.78	0.263	0.001
-1	3201.33±366.26	3193.00±378.79	0.760	-0.20±4.84		
-2	3040.30±395.07	3144.59±301.40	0.024	4.33±10.36		
-3	2922.98±529.80	3103.92±420.78	0.000	7.60±11.55		
The figure of mothers						
Small	2825.00±459.61	3061.00±55.15	0.561	9.64±15.88	0.039	0.633
Medium	3025.07±431.14	3112.27±349.44	0.003	3.66±8.55		
Big	3043.56±519.29	3183.85±424.17	0.000	5.85±11.54		

Table 3: Comparison of accuracy and error of estimated weight in three weight groups (SGA-AGA-LGA)

	SGA (*n*=25)	AGA (*n*=115)	LGA (*n*=10)	*P*
EFW accuracy with ±10%	1 (4%)	97 (84.3%)	7 (70%)	0.001
EFW average percentage error	19.26±11.14	2.53±7.42	-2.4±78.13	0.001
Average EFW	2718.66±305.90	3192.30±309.30	3774.200±330.89	0.001

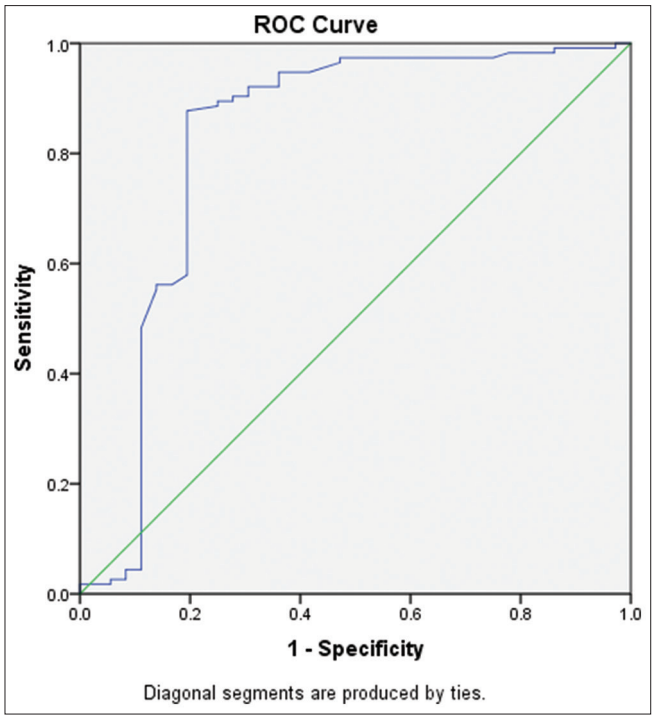

Diagram 1: ROC curve for the accuracy of Johnson's rule

mothers showed that there was a significant difference between the actual weight and the estimated weight by the clinical method, and the clinical method estimated the fetal weight more than the birth weight. The results of Poonam *et al*.'s study[11] in 2021 were also in line with our results. The results of the study by Yadav *et al*.[12] in 2016 showed that the average weight estimated by the clinical method was lower than the birth weight, which was contrary to the result of our study. This difference can be due to the choice of different exclusion criteria of that study (not exclusion of oligohydramnios samples). In a study conducted by Khani *et al*.[13] on 174 pregnant women of 29–41 weeks, the results showed that there is no significant difference between the estimation of fetal weight by the clinical method and the birth weight, which is not in line with the result of this study. This may be due to different inclusion criteria (GA of 29–41 weeks).

The obtained results indicate that the descent of the fetal head and the increase in GA can reduce the percentage error of estimated fetal weight. However, there was no correlation between the mother's height, parity, BMI, and uterine height with the percentage error of estimated fetal weight using the clinical method.

In the retrospective cohort study conducted by Goetzinger *et al*.[14] in 2013 with 3797 study subjects, no correlation between station and weight estimation error was seen. This may be due to the difference in the number of samples or the difference in the investigated stations. In the current study, we examined stations from -3 to zero. However, in the study of Goetzinger *et al*., stations from -3 to +3 were investigated.

Noumi *et al*.[15] conducted a study on 192 mothers, and they did not find any correlation between maternal variables such as GA, parity, Bishop's score, and maternal age with a weight estimated by the clinical method.

Goetzinger *et al*.[14] concluded that as GA increases, the estimation error of fetal weight decreases. This result is consistent with the result of our study. The results of Field *et al*.'s study[16] in 1993 on mothers with a GA of 25–43 weeks showed that there is no correlation between BMI and estimation error. In this study, the samples included full-term and preterm pregnant mothers, and BMI greater than 29 was considered in this study. In the study of Farrell *et al*.[17] in 2002, no correlation was found between the weight estimated by the clinical method and the mother's BMI. In this study, BMI was divided into less than 32 and more than 32. The results of these studies are in line with the present study.

However, Fox *et al*.[18] conducted a retrospective cohort study in 2008 aiming to investigate the effect of body mass index on the accuracy of fetal weight estimation on 400 term pregnant mothers. They found a positive correlation between BMI and estimation error of fetal weight. They concluded that the weight estimation error increases as the mother's BMI increases. The reason for the difference in the results can be due to the difference in the number of study subjects and the different range of mothers' weight.

In our study, considering the accuracy of ± 350 g, the overall sensitivity of Johnson's rule was higher than the accuracy of ± 500 g. For fetuses weighing less than 2500 g, with both accuracy values (350 and 500 g), sensitivity and specificity were lower than normal birth weight fetuses. This means that the sensitivity of Johnson's weight estimation in weights less than 2500 g is lower than in weights between 2500 and 4000 g. In addition, the division of weight based on GA showed that the accuracy of weight estimation based on ± 10% of the actual weight was much higher in AGA and LGA babies than in SGA babies, and the weight estimation error in SGA babies was more than the other two groups.

The results of Khani *et al*.'s study[13] indicate that the sensitivity of Johnson's method was lower in infants weighing less than 2500 g than in infants weighing 2500–4000 g. Moreover, in AGA and LGA babies, they did not report a difference between the estimated weight and the actual weight, but in SGA babies, a significant difference has been observed between the estimated weight and the actual weight. In addition,

in a study conducted by Numprasert *et al*.[19] in 2003 on 400 pregnant women, they concluded that the accuracy of weight estimation by the Johnson method in weights under 2500 g is lower than its accuracy in weights of 2500 to 4000 g. Poonam *et al*.[11] reported the general sensitivity and specificity of Johnson's rule (76.06% and 79.31%), respectively.

The results of these studies were consistent with the results of our study. The results of the present study and related research indicate that clinical methods are important in estimating fetal weight and can be highly recommended as a method for estimating fetal weight. Although ultrasound is the most common method of estimating the fetal weight, so far no gold standard has been reported other than the actual birth weight, i.e. there is no method that can estimate the fetal weight 100% correctly and only the actual birth weight with a scale represents the standard method. This study shows that with Johnson's method for weighting, babies with a weight of 2500–4000 g are more accurately estimated than babies with a weight of less than 2500.

Limitations and recommendation

The small number of samples was one of the main limitations of this research due to the researcher's limited time. In addition, since the number of fetuses in the range of abnormal growth in the research was small, it is suggested that further studies be conducted using more samples with these characteristics. Another limitation of this research was that present of caput succedaneum on the fetal head, can lead to error in the exact evaluation of the fetal head position.

Conclusion

Compared to other weight groups, fetal weight estimation with Johnson's rule due to the low weight estimation error in LGA and AGA fetuses and high sensitivity in estimating the weight of fetuses with a normal weight range (4000–2500) can be taught by trained people in the hospital. Some factors may increase the accuracy of weight estimation by clinical methods. Among these cases, we can mention the descent of the fetal head and, as a result, the decrease in the station and the increase in GA.

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Conflicts of interest

There are no conflicts of interest.

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