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Evaluation of Head Circumference Index in Children under 18 Months and its Associated Factors in Zanjan City: A Retrospective Cohort

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Abstract

Background

The growth and development of infancy are vital to health and the quality of life throughout a person's life. We aimed to investigate the factors affecting the growth of head circumference in a sample of Iranian children under 18 months.

Materials and Methods: This is a retrospective cohort study conducted among 274 children aged under 18 months in Zanjan, Iran. Multi-stage cluster sampling was applied to obtain a representative sample of residents. About eight representative healthcare centers, including four urban health centers and four rural health centers, as clusters, were randomly selected. We used multiple linear regression and marginal models of Generalized Equation Estimators to examine the predictors of head circumference cross-sectionally and longitudinaly, respectively.

Results: Of the subjects, 49.5% (n=136) were females. The mean head circumference of newborns was 34.5±1.57. The marginal model showed that there is a significant association between sex of newborns, gestational age, high risk pregnancy, height and weight of newborns with head circumference over time (p<0.005). In multiple regression models, mothers' job and educational level also showed a significant association with head circumference in addition to sex of newborns (B=0.33, 95% CI:[0.31, 0.53]), gestational age (B=1.47, 95% CI:[0.99, 1.94]), high risk pregnancy (B=0.37; 95% CI:[0.15, 0.57]), height and weight of newborns (p<0.005).

Conclusion

In our study the mean of head circumference was similar to standard value of 34.9 cm. The sex, gestational age, high risk pregnancy, height and weight of newborns showed a significant association with head circumference, both in cross-sectional (at birth), and longitudinal models (at birth to 18 months); mothers job and educational level showed a significant association with head circumference only at birth.

Key Words: Head Circumference, Longitudinal, Risk Factors, Birth Outcome.

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1- INTRODUCTION

The growth and development of infancy is vital to health and the quality of life throughout a person's life. On the other hand, motor and cognitive development during infancy will have a great impact on the performance of individuals during their school years and also on their success rate in their future career (1–4); while repeated measurements of infants' weight and height are a key tool for assessing growth status, periodic and repeated measurements of head circumference are important in assessing infants' developmental status. Head circumference can be associated with the brain volume, where world health organization (WHO) suggests Intergrowth-21st criteria to classify head circumference (HC) based on gestational age (5). The issue of ethnicity and race can be very important in head circumference measurements and clinical decisions based on it. As a result, a national or local estimate of this index can be very helpful (6–10). Head circumference is one of the cheap, simple, safe, economical and reliable indicators for assessing infants' brain development and developmental status. The accuracy of the measurement of this index can be greatly affected by the expertise of the raters, that the staff in the primary health care departments have acquired the necessary expertise in this regard (11). Interestingly, three very important abnormalities, microcephaly and macrocephaly and hydrocephaly can be easily screened by assessing head circumference (12). Early detection of hydrocephalus and prompt surgical procedures can play a decisive role in the current and future health status of the infant (13,14). Genetics, and biological mechanisms are associated with brain growth, so determining the HC growth in early childhood could have an important role for prediction abnormalities (15). Given the importance of head circumference in assessing the developmental status of the child, determining modifiable factors on this indicator can be very important. As a result of this study, in order to evaluate the head circumference status in infants in Zanjan province and the factors affecting it. The objective of this study was to determine the predictors of HC index in the early childhood as well as longitudinally in healthy population in Zanjan city, Iran.

2- MATERIALS AND METHODS

This retrospective cohort study, considering the recommended ratio of sample to the number of variables at least 10:1 for panel data (16), was conducted on 274 infants from the records of 18-month-old children referred to primary health care centers in Zanjan, Iran. About eight representative healthcare centers, including four urban health centers and four rural health centers as a cluster, were selected randomly, then 35 samples were selected randomly from each center (cluster). Infant’s health care experts provided the measurements with high accuracy from April 2017 to April 2019.

2-1. Inclusion and Exclusion criteria

The Iranian infants younger than 18 months at the time of data collection were considered as inclusion criteria. Infants with a history of genetic or congenital disorders, chronic infection disease, disability, growth disorder, and incomplete information were excluded from the study.

2-2. Measurements

We used a self-administered questionnaire for data drawn from health registration system. Data were extracted through a health registration system that contains maternal demographic information including mother’s height, mother’s weight, mother’s education, maternal residence, mother’s age, maternal weight gain, high risk pregnancy status, height of newborn, weight of newborn, and job, sex of infant, duration of breastfeeding, duration of exclusive breastfeeding upto 6 months, gestational age, birth weight, and child head circumference at first, second, fourth, sixth, ninth, twelfth and eighteenth months. In current study, HC was used as the response variable. The HC measurements were performed at birth, 1-2, 2-4, 4-6, 6-9, 9-12, and 12-18 months of age. Head circumference was measured by trained staff according to the World Health Organization guideline.

2-3. Data Analyses

These analyses were performed in SPSS software version 24.0, with 95% Confidence Interval (95% CI). In this study, since the head circumference should be repeatedly evaluated, the observations of a single participant will be correlated. As a result, we utilized the marginal model using the Generalized Equation Estimate (GEE) in which considering the correlations between observations in a longitudinal data a more exact estimation of head circumference can be obtained. Overall, the (GEE) marginal models of longitudinal and repeated data can be summarized by the following equation:

$$g(\mu_{ij}) = X'_{ij}\beta, i = 1,2,..n, j = 1,2,\ldots,n_i$$

Where, β denotes regression coefficient vector, X_{ij} and μ_{ij} are the vector of independent variables and expected value for the ith individual in th jth time, respectively, and g(.) is a link function. To estimate the parameters related to regression model, we applied maximal likelihood model using GEE (17).

3- RESULTS

This retrospective cohort study was conducted on 274 infants less than eighteen months in Zanjan city, Iran. The baseline characteristics of participants are shown in **Table.1**. As a result, about 136 (49.5%) of the samples were females. 160 (58.3%) of the mothers had an educational level under diploma, 59 (21.4%) had diploma and 55 (20.2%) had higher education level of education.

Table-1: Baseline characteristics of mothers and children under 18 months.

Characteristics	Category	Frequency	Present (%)
Child's gender	Boy	138	50.5
	Girl	136	49.5
Maternal residence	Urban	152	55.6
	Rural	122	44.4
Mother's education	High-school	160	58.3
	Diploma	59	21.4
	Higher education	55	20.2
High risk pregnancy	Yes	144	52.6
	No	130	47.4
Mother's job	Homemaker	238	86.8
	Employee	36	13.2
Mother's age	Under18(year)	32	3.3
	18-35	242	88.3
	35and more	48	8.4
BMI (Body mass index)	Under weight	10	3.8
	Normal weight	167	61
	Over weight	77	28
	Obese	20	7.2
Gestational age	Under 37(weeks)	15	5.6
	37 and more(weeks)	259	94.4
Exclusive Brest feeding	6 months	60	22
	No	29	10.4

The employment rate was 13.2% among mothers. About 122(44.4) percent of mothers were resident in rural area. The mean± standard deviation (SD) of head circumference of newborn, maternal age, mother's BMI, height of newborn, weight of newborn and gestational age, were 34.5 (1.57) [cm], 25.9(5.4) [years], 24.3 (3.7) [kg/m^2], 48.8(2.7) [cm], 3242 (513) [gr], and 38.7 (1.7) [weeks], respectively. Also, 60 (22%) of the children had exclusive breastfeeding for 6 months. The mean head circumference and related standard deviation were displayed in **Table.2** and **Figure.1**. According to our data, the highest percentage was stunted growth related to age of 12-18 months (4.7%).

Table-2: Frequency distribution of Head circumference measurements of children, n=274.

Variables	Head circumference status				Head circumference measurements				-
	Stunted growth		Normal growth		Girl		Boy		P-value
	Number	%	Number	%	Mean	SD	Mean	SD	
Age (month)	-	-	-	-	34.4	1.56	34.7	1.59	0.013
0-1 month	4	1.4	270	98.6	36.6	1.44	36.9	1.40	0.002
1-2 months	3	1.2	271	98.8	38.5	1.42	38.8	1.51	0.016
2-4	6	2.3	268	97.7	40.7	1.57	41.1	1.58	0.002
4-6	4	1.4	270	98.6	42.7	1.68	43.2	1.54	0.005
6-9	4	1.4	270	98.6	44.6	1.70	45.0	1.60	0.001
9-12	6	2.3	268	97.7	46.1	1.71	43.4	1.48	0.046
12-18	3	4.7	261	95.3	47.7	1.69	48.0	1.49	0.027

SD: Standard deviation.

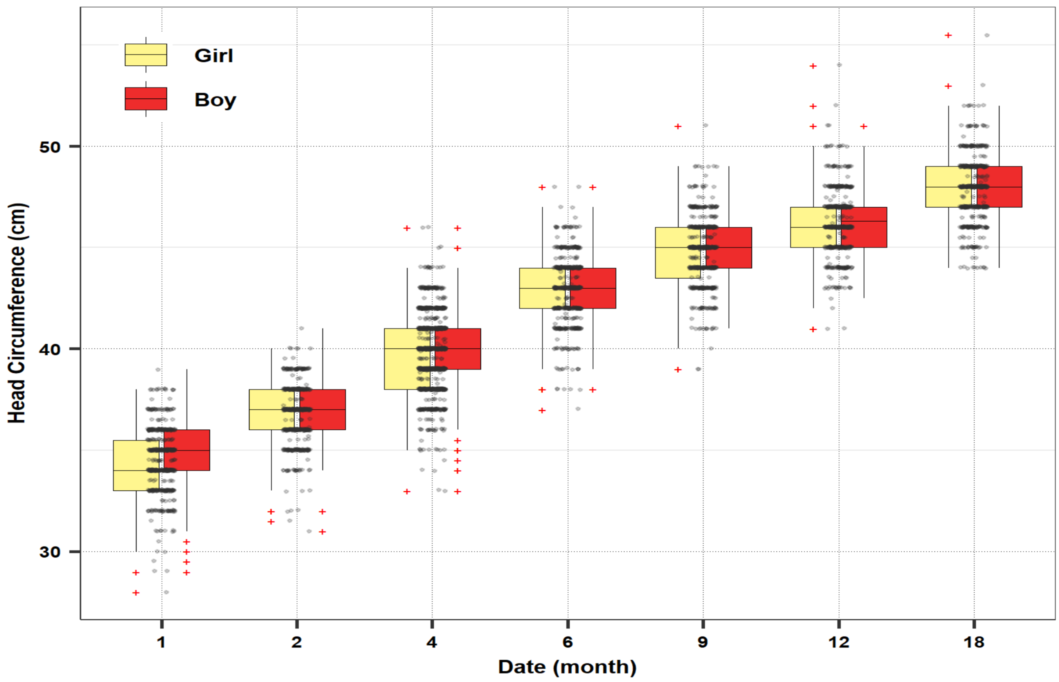

Fig.1: Comparison of the head circumference between girls and boys across time period.

Multiple linear regression results showed that there is a significant association between sex and head circumference (p=0.001), so that removing the effect of other variables, the head circumference in male children was 0.33 cm more than that in female. Our results also showed the head circumference of children whose mothers were employed was higher (0.31cm) than those of unemployed women. We also obtained a significant association between the newborn weight, newborn height and head circumference (p<0.001). More details are reported in **Table. 3**.

Table-3: Multiple linear regression results for assessing the relationship between different indicators and Head circumference.

Characteristics	Category	B	SE	95% CI		P-value
				Lower	Upper	
Child's gender	Girl	Reference	-	-		-
	Boy	0.33	0.10	0.13	0.53	0.001
Mother's education	High School	Reference	-	-		-
	Diploma	0.03	0.13	0.09	0.73	0.012
	Higher education	0.41	0.16	-0.23	0.13	0.288
High risk pregnancy	No	Reference	-	-		-
	Yes	0.37	0.10	0.16	0.57	0.005
Mother's job	Homemaker	Reference	-	-		-
	Employee	0.47	0.18	0.10	0.83	0.012
Gestational age (week)	< 37	Reference	-	-		-
	≥37	1.47	0.24	0.99	1.94	0.005
Mother's age (year)	--	-0.04	0.01	-0.03	0.04	0.128
Height of newborn (cm)	--	0.07	0.02	0.03	0.11	0.002
Weight of newborn (gr)	--	0.01	0.002	0.01	0.02	0.005
Body mass index	--	0.02	0.01	-0.09	0.05	0.171

B: Estimate of the model parameter
SE: Standard error of the estimate
CI=Confidence Interval; LL=lower limit, UL=upper limit.

The results of marginal model showed that there is a significant association between sex and head circumference over time (p<0.005), so that removing the effect of other variables, the head circumference in male children was 0.37cm more than that in females. We also obtained a significant association between the newborn weight and newborn height with head circumference over time (p<0.001). More details are reported in **Table.4**.

Table 4: Marginal model (GEE)* results for assessing the relationship between different indicators and Head circumference.

Characteristics	Category	B	SE	95% CI		P-value
				LL	UL	
Child's gender	Girl	reference				
	Boy	0.37	0.09	0.19	0.55	0.005
Mother's education	High-school	reference				
	Diploma	0.20	0.17	0.13	0.54	0.238
	Higher education	0.168	0.16	0.14	0.48	0.290
Admission to critical	No	reference				

care unit	Yes	0.32	0.09	0.131 0.51	0.001
Mother's job	Homemaker	reference			
	Employee	-.07	0.18	-0.43 0.28	0.687
Gestational age (weeks)	less than 37	reference			
	37 and more	0.96	0.24	0.49 1.42	0.005
Exclusive breast feeding	6 months	reference			
	Under 6 month	-0.02	0.10	-0.23 0.19	0.854
Height of newborn	--	0.07	0.02	.03 0.11	0.001
Weight of newborn	--	0.01	0.001	0.008 0.05	0.005
Body mass index	--	0.01	0.01	-.02 0.03	0.597

GEE: Generalized Estimating Equation
B: Estimate of the model parameter
SE: Standard error of the estimate
CI: Confidence Interval; LL=lower limit, UL=upper limit.

4- DISCUSSION

In this study, we evaluated the head circumference at birth and in the first trimester, second trimester, third and fourth trimesters and the factors affecting it. Based on the results of our study, the average head circumference of male and female newborns was 34.4± 1.56 and 34.7± 1.59 cm, respectively. In similar findings reported in Iran (18–21), the mean of HC was estimated from 34.2 to 35.13. A study in Nigeria estimated the average head circumference of girls and boys to be 34.6±2.16 cm and 34.1±2.02cm, respectively (22). Another study in the United States reported that the average head circumference in male and female infants at 39 weeks of gestation was 34.6±1.6 cm and 34.0±1.5 cm, respectively. However the mean gestational age in our study was 38.7± 1.7 weeks (23). The differences observed between different studies may largely depend on racial and ethnic factors. This emphasizes the importance of providing local and regional charts for the head (6, 8). In longitudinal models, gestational age, high risk pregnancy, sex, height and weight of infants showed a significant relationship with head circumference. The relationship between head circumference at birth and gestational age is so obvious that in the the Newborn Cross-Sectional Study of the INTERGROWTH-21st Project of head circumference curves by birth, this issue is clearly shown (24). The present study also showed an association between head circumference and gender, with male infants having significantly higher head circumference than female infants. Previous studies in the United States and Nigeria have shown similar results to ours. Based on the similar previous findings, WHO and other related organizations developed the head circumference charts in girls and boys, separately (20, 21). The association between head circumference and height, even at a young age, has been confirmed by previous studies (22 ,23). Where Mansour et al. reported a significant association between head circumference and height in a young population of 17 to 25 year olds (27). Krishan et al. also showed a significant association between head circumference and stature in an adolescent population in North India (28). Geraedts et al. found a strong relationship between height and weight with HC, where they suggest charts of HC based on height as a useful instrument to interprete the HC (29). It is worth noting that Astrid Lunde genetic factors explain 27% of the variation in head circumference and 31% of the normal variation in birth weight and birth length, while maternal genetics explain 19% of the variation in head circumference and length of neonates and 22% of the variation in birth weight (30). As a result, the genetic factors can be considered the main mediators of association between height and weight of neonates with head ciecumference. In addition to genetic factors that can jointly play a decisive role in the weight, head circumference and height of infants, some environmental factors can also affect these three indicators simultaneously (26, 27). Our study showed a significant relationship between head circumference and education level of newborns at birth, where mothers with a higher education level had the newborns with a higher head circumference. Bouthoorn et al. showed an association between education level of mothers and head circumference in neonates. However they emphasazied that pregnancy-related factors, such as birth weight and gestational age can play a role as cofounders in this relationship (33).

According to the results of our study, high-risk pregnancies showed a significant relationship with lower head circumference in infants, both at birth and during the first year after birth. Previous studies have also reported some environmental exposures during pregnancy and maternal conditions associated with high-risk pregnancies affecting microcephaly. For example, Liu et al. assessed preeclampsia, TORCH (i.e., T. gondii, rubella virus, cytomegalovirus, HSV) infection, and exposure to certain peripheral teratogens to be associated with a higher prevalence of microcephaly (16). Another study by Auger et al. reported Torch syndrome and exposure to secondhand smoke and alcohol consumption during pregnancy were associated with microcephaly in infants. These are some of the criteria for high-risk pregnancies (9). On the other hand, malnutrition in mothers, which can show itself with shorter height, lower weight and lower body mass index, is associated with lower head circumference in newborns. However, in the present study, no correlation was found between body mass index and head circumference in neonates (34).

4-1. Study Limitations

Our study had a large sample size that was conducted in healthly infants, which might limit the generalizability the results to population with abnormality. In addition, the number of infants with stunted HC was low, that limits the subgroup comparation.

5- CONCLUSION

Our study had a large sample size that was conducted in healthly infants, which might limit the generalizability the results to population with abnormality. In addition, the number of infants with stunted HC was low, that limits the subgroup comparation.

6- CONFLICT OF INTEREST: None.

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