Evaluation of Impact of Residence at High Altitude on the Anthropometric Measurements of Newborn Babies in Saudi Arabia

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ABSTRACT

Anthropometric parameters at birth, particularly, the birth weight are widely used indicators of newborn health and neonatal mortality. This study aims to evaluate the effect of residence at high lands on the anthropometric measurements of newborns in Taif province, Saudi Arabia (high altitude area) to provide guidelines for neonatal assessment in high lands. A cross-sectional study included 1534 newborns in Taif city (2000 to 2400 meters above sea level), Western Province of Saudi Arabia, collected during a period of 6 months (from November 2014 through April 2015). The newborns and their mothers were subjected to various measurements of body dimensions and body weight. The data were developed in comparison with the international growth references and national populations residing at sea level. We found that the birth weight and birth length of Taif newborns are significantly lower than those of international standards and those of newborns residing at sea level, in Saudi Arabia. Also, there was a high incidence of low birth weight (15.6%) and preterm babies (10.9%) in Taif newborns. In this study, we concluded that high altitude reduces, significantly, the birth weight and birth length independent of other affecting factors. Other risk factors appear to influence newborn measures at high altitude in much the same way as at other altitudes. The effect of residence at high altitude on the prematurity rate needs further investigations.

ITRODUCTION

High altitude areas exhibit decrease in barometric pressure and subsequently the partial pressure of inspired oxygen decreases leading to hypobaric hypoxia. Long-term exposure to hypoxia has many adverse effects on the human body including respiratory disorders, muscle fatigue, changes in mental performance and sleep quality (West, 2004). The human body, usually, compensate this hypoxia through several physiological modulations, termed as acclimatization, including increase in ventilation, metabolic changes, hemodynamic and hematologic changes

(West, 2004). Several studies have confirmed that the residence at high altitude areas acts, independently from other factors, to induce neonatal growth retarding effects (West, 2004; Khalid *et al.*, 2016). Birth weight declines, progressively, with increasing altitude, so that, infants born to women residing permanently at high altitudes are at a greater risk of low birth weight than those born at sea level (Khalid *et al.*, 2016). In addition, residence at high altitude is associated with other neonatal complications including pulmonary hypertension, respiratory distress syndrome, and developmental defects leading to congenital anomalies (West, 2004). This is generally attributed to the reduction of oxygen delivery to the uteroplacental circulation in pregnant women residing at high altitude (Julian *et al.*, 2008). Available evidence indicates that it is likely chronic hypoxia per se that is leading to a decrease in fetal growth

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(Julian *et al*., 2007).

Anthropometry of the human body means study of the body composition in terms of the body weight and body dimensions. Anthropometric measurements are sensitive indicators of the health and well-being of the entire population (Patton and McPherson, 2013). Anthropometric parameters at birth, particularly, the birth weight are widely used indicators of newborn health and neonatal mortality (Lin *et al*., 2007). Across the world, neonatal mortality is 20 times more likely for low birth weight full-term babies (≤ 2.5 kg) compared to normal babies (WHO, 2004). Moreover, low birth weight is considered as a risk factor for type 2 diabetes (Frayl and Hattersley, 2001), cardiovascular diseases (Rich-Edwards et al., 1997), liver diseases, and metabolic syndrome (Donma and Donma, 2003). Subsequently, the impact of birth weight on the offspring health has significant public health implications and imposes an actual economic load due to the costs of immediate care and long-term disability (Meis *et al*., 1998).

According to the international published data of higher prevalence of low birth weight in high altitude (López Camelo *et al*., 2006), more cases of growth retardation and subsequent increase of neonatal mortality are expected to be reported in Taif Province, Saudi Arabia (2000 to 2400 meter above sea level). This study was designed to evaluate the possible effects of altitude on the anthropometric measurements of newborns in Taif city to provide guidelines for neonatal assessment in such areas.

MATERIALS AND METHODS

Study setting and design

A cross-sectional study was conducted on consecutive singleton newborns admitted to public hospitals in Taif city, Western Province of Saudi Arabia, representing a high altitude area (2000 to 2400 meter above sea level). Data were collected during a period of 6 months (from November 2014 through April 2015). A total of 1534 newborns were included after the exclusion of stillbirths, twins and those with major congenital anomalies. Only women who had been residents of Taif area for a minimum of one year were involved in this study. The majority of participants (90%) were of Arab ethnicity and the minority were of miscellaneous Asian and African races. We excluded women who suffered from chronic hypertension, diabetes or chronic renal or cardiac disease during pregnancy. Data were collected daily by nurses and research assistants using standardized measurements under the supervision of the authors. Gestational age was calculated from the first day of the last menstrual period to the termination of pregnancy. Anthropometric measurements were taken within 24 h of birth, and all required details were entered into a unified reporting checklist. The data collected for Taif newborns was developed in comparison with the corresponding data collected for a total of 1578 newborn babies born to mothers residing in Al-Kharj area, Rhiyadh province, Saudi Arabia, representing a sea-level area and having the same ethnic diversity that exists in Taif sample. This data was collected by Al-Saleh *et al*. (2014a), following the same procedures, conditions, and standards. Comparison with the United States growth charts was made using data from the United States Centers for Disease Control and Prevention (CDC)/National Center for Health Statistics (NCHS) (Ogden *et al*., 2002), for birth weight, birth length, and head circumference. Each mother was asked to join the study and informed consent was obtained. The study protocol was approved by the Research Ethics Committee, College of Medicine, Taif University and by the ethics committee of King Abdul-Aziz Hospital in Taif.

Anthropometric measurements

The methodology for taking the anthropometric measurements was adopted as described by Cogill (2003). All measurements were taken using standardized instruments.

The newborn anthropometry included birth weight, length (crown-heal), and head circumference. Weight was taken on an electronic digital scale to the nearest ±10g. The length was measured by a standardized neonatometer to the nearest±0.5 cm. Occipito-frontal head circumference is measured by a paper tape measure to the nearest±0.5 cm.

The ponderal index (PI) was calculated as follows:

$$PI = 100 \times BW/L^3$$

where BW is the birth weight in Kilograms and *L* is the crown-heal length in m.

The maternal measurements included the mother's weight and height and were obtained after hospitalization for delivery. The mother's weight was determined on a scale to the nearest 100 g. The mother's height was determined on a scale of height to the nearest ± 1.00 cm. The body mass index (BMI) for mothers was calculated as follows:

$$BMI = MW/MH^2$$

where MW is the maternal weight in kg and MH is the maternal height in m.

The lean body mass (LBM) was calculated as follows:

$$LBM = 1.07 \times MW - 148 \times MW^2/MH^2$$

Where MW is the maternal weight in kg and MH is the maternal height in cm (James Formula) (Absalom *et al*., 2009).

Statistical analysis

The collected data were organized, tabulated and

statistically analyzed, using Statistical Package for Social Science (SPSS) version 19 (SPSS Inc, Chicago, USA), running on IBM compatible computer. Mean, standard deviation, range, frequency and percentage were used as descriptive statistics. Student's t-test and Pearson correlation tests were used for testing the significance of observed differences between studied groups for quantitative data and the Chi-Square test for qualitative data. Percentiles of measures of the studied newborns were determined as; 10th, 25th, 50th, 75th, and 90th percentiles were calculated exactly using the frequencies procedure. Comparison of the newborns' values with CDC 2000 standards was made through 4 percentile bands: ≤10th, 11-50th, 51-90th and >90th using the Chi-square test. The level of significance was set at p< 0.05%.

RESULTS

General characteristics of the studied mothers and newborns

Different selected measurements of the studied mothers and their newborns are presented in (Table I). The mean age of the participating mothers was 28.73±5.94 year; mean mothers' weight was 72.34±14.58 kg and mothers' height was 155.77±6.37cm. The mean body mass index (BMI) of mothers was 29.86±5.99 kg/m² and mean lean body mass (LBM) was 44.28±4.54. The main parity rate of the participants was 3.57±2.43. The mean birth weight was 2.94±0.50 kg; the mean birth length was 46.81±6.19 cm and the mean head circumference was 36.59±6.08cm.

Table I. General characteristics of the studied mothers and newborns.

Measures	Mean ± SD (Range)
N= 1534	
Mothers	
Age (years)	28.73 ± 5.94(16-48)
Weight (Kg)	72.34 ± 14.58 (41-115)
Height (cm)	155.77 ±6.37 (125-173)
Body mass index (kg/m²)	29.86 ± 5.99(18-39)
Lean body mass	44.28 ± 4.54 (11-65)
Parity	3.57 ± 2.43(1-12)
Newborns	
Gestational age (weeks)	38.63±2.13 (24-43)
Birth weight (kg)	2.94±0.50 (2.08-4.71)
Birth length (cm)	46.81±6.19 (23-58)
Head circumference (cm)	36.59±6.08 (23-50)
Ponderal index (Kg/m³)	32.69±19.95 (6.99-55.20)

Table II shows the distribution of newborns regarding the mode of delivery, gestational age, and birth weight. The percentage of cesarean sections was 12.3% and the induced labor represents only 4.7%. The mean gestational age (as shown in Table I) was 38.6 weeks and the preterm birth (<37 weeks) consists of 10.9% of all cases (167/ total of 1534). The percentage of newborns with low birth weight (<2.500 kg.) or with small for gestational age (≤10th percentile) was 15.6 % and 10.0 %, respectively.

Table II. Distribution of newborns regarding the mode of delivery, birth weight, and gestational age.

Variables	Category	Number N=1534	Percent-age %
Mode of delivery	Normal/ C- sections	1345 / 189	87.7/ 12.3
Induced labor	Yes / No	72 / 1462	4.7/ 95.3
Low birth weight	<2.500 kg/>2.500 kg	240 / 1294	15.6/ 84.4
Preterm birth	<37 week/ >37 week	167 / 1367	10.9/ 89.1
Small for gestational age (SGA)	≤10th percentile/ >10th percentile	152 / 1382	10.0/ 90.0

Table III shows percentiles of birth weight, birth length and head circumference for the studied male and female newborns. The distribution showed that 10% of male and female babies had birth weight ≤ 2.38 kg and ≤ 2.35 kg, respectively. 50% of newborns had birth weight below 3.00 kg for males and 2.91 kg for females. Also, 10% of newborns had birth length ≤34 cm and head circumference ≤33 cm for both male and female babies.

Table III. Local percentiles of newborn measurements of the studied sample.

Parameter	Gender	Percentile 10th	25th	50th	75th	90th
Birth weight (kg)	Male	2.38	2.69	3.00	3.27	3.55
	Female	2.35	2.65	2.92	3.18	3.51
Birth length (cm)	Male	34	47	49	50	52
	Female	34	47	49	50	51
Head circumference (cm)	Male	33	34	34	36	49
	Female	33	34	34	35	49

Among 1534 examined newborns there were 766 male (49.93%) and 768 female (50.07%). The male newborns were significantly heavier than the females (p<0.007), but no significant difference between male and female newborns regarding the birth length or head circumference as shown in (Table IV).

Table IV. Comparison between male and female newborns regarding body measurements (Mean±SD).

Measurements	Male (N=766)	Female (N= 768)	T*	P
Birth weight (kg)	2.96 ±.0.51	2.90 ± 0.05	2.695	0.007*
Body Length (cm)	47.05±6.10	46.56±6.28	1.563	0.118
Head circumference (cm)	36.56±5.95	36.67±6.21	0.491	0.624

T, student test; *, significant at *P*< 0.05.

Correlation of mothers and newborns anthropometric measurements

Correlation coefficients between maternal and newborn measurements are presented in (Table V). The strongest associations were seen for birth weight with all maternal measurements. Maternal age has a significant association only with the birth weight. Also, maternal height and lean body mass were significantly associated with birth weight, head circumference and ponderal index of the newborn.

Percentile band distribution of newborn measurements compared with CDC standards

Comparison with the United States (CDC) / (NCHS) 2000, growth charts are demonstrated in (Table VI). The comparison shows that the Taif newborns are significantly lighter than those of international standards (p<0.001), where 31.1% of males and 33.3% of females were below the 10th percentile. Also, a total of 88.0% of boys and 84.1% of girls were below the 50th percentile. Moreover, Taif newborns were shorter (p<0.001), where 20.9% males and 21.2% females were below the 10th and 76.4% males and 55.1% females were below the 50th international percentile. For the head circumference, the same finding was obvious.

Comparison between Taif and Al-kharj data regarding the newborn measurements

A comparison between the anthropometric measurements of Taif newborns and those of Al-Kharj sample are presented in (Table VII). The sample size in the two cities was approximate. Taif sample was 1534 live newborns. Al-Kharj sample ranged from 1570 to 1578 according to the participation of subjects in different measurements.

Table V. Correlation matrix (correlation coefficient (r)) of mothers and newborns parameters.

Newborn	Mother				
	Age (years)	Height (cm)	Weight (Kg)	Body mass index	Lean body mass
Gestational age (weeks)	- 0.028	- 0.014	0.036	0.037	0.018
Birth weight (grams)	0.094**	0.076 **	0.204**	0.179 **	0.137 **
Head circumference (cm)	0.016	0.070 **	0.030	0.007	0.073 **
Birth length (cm)	0.019	- 0.049	0.039	0.057	- 0.033
Ponderal index	0.010	0.066 **	0.031	0.009	0.077 **

** Pearson correlation coefficient (r): is significant at the 0.01 level (** *P* < 0.01).

Table VI. Percentile band distribution of newborn measurements compared with CDC standards.

CDC percentile band	Gender	Birth weight		Length		Head circumference		Expected percentage
		Number	%	Number	%	Number	%	
≤ 10th	Male	238	31.1	160	20.9	149	19.5	10
	Female	256	33.3	163	21.2	168	21.9	10
11th -50th	Male	436	56.9	425	55.5	405	52.9	40
	Female	390	50.8	260	33.9	353	46	40
50th -90th	Male	70	9.1	134	17.5	172	22.5	40
	Female	87	11.3	289	37.6	177	23	40
>90th	Male	22	2.9	47	6.1	40	5.1	10
	Female	35	4.6	56	7.3	70	9.1	10
P value		<0.001*		<0.001*		<0.001*		

The percentage of newborns of our sample for each CDC percentile band was developed in comparison with the expected percentage of CDC growth charts 20 using Chi-square analysis. *, significant at *P* < 0.05.

Table VII. Comparison between Taif and Al-kharj values regarding the newborn measurements.

Measurements	Taif values		Al-Kharj values		t	P
	Number	Mean±SD (Range)	Number	Mean±SD (Range)		
Gestational age (weeks)	1534	38.63± 2.1 (24-43)	1578	37.96±1.77 (22-43)	9.549	0.001*
Preterm birth %	10.9 %		6.9 %			
Birth weight (kg)	1534	2.94±0.50 (0.58-4.71)	1572	3.14±0.5 (0.43-5.07)	10.976	0.001*
Low birth weight %	15.6 %		10 %			
Birth length (cm)	1534	46.81±6.1 (23-58)	1576	50.15±2.97 (24-59)	19.235	0.000*
Head circumference (cm)	1534	36.59±6.0 (23-57.0)	1576	34.11±2.05 (18-55)	15.338	0.000*
Ponderal index (kg/m3)	1534	32.7±20.0 (7.0-55.2)	1570	24.80±3.91(6.7-82.1)	15.405	0.000*

Preterm birth= < 37-week gestational age. Low birth weight = <2.500 kg. *, highly significant ($P < 0.01$).

The mean gestational age in Taif sample was 38.63±2.13 weeks and ranged from 24 to 43 weeks. In Al-Kharj sample the mean gestational age was 37.96±1.77 weeks and ranged from 22 to 43 weeks. Taif sample showed a high incidence of preterm babies (<37 weeks of gestational age); a total number of 167 newborns were preterm birth (10.9%). While only 109 babies (6.9%) in Al-Kharj sample were preterm.

The most prominent findings in this study are the significant differences between the anthropometric measurements of Taif babies and those of Al-Kharj sample. The mean birth weight of Taif sample was 2.94±0.50 kg while that of Al-Kharj sample was 3.14±0.54 with a highly significant difference (p<0.001). The low birth weight babies (<2.500 kg) of Taif sample consist (15.6%) while they consist only (10%) of Al-Kharj sample. Moreover, the mean birth length in Taif and Al-Kharj is 46.81±6.19 and 50.15±2.97, respectively, showing a highly significant difference (p<0.000). Contrariwise, the mean values of head circumference and ponderal index (PI) increased, significantly, in Taif sample (p<0.000), where they were 36.59± 6.08 cm and 34.11± 2.05 cm for head circumference and 32.69±19.95 and 24.80± 3.91 for the ponderal index in Taif and Al-Kharj, respectively.

DISCUSSION

The present study, obviously, demonstrates that the Taif newborns are lighter and shorter than those of the reference CDC population. Anthropometric measures of Taif newborns were significantly less than that of the United States CDC standards. 88.0% of boys and 84.1% of girls had birth weight below the 50th CDC percentile. The same differences were evident for birth length and head circumference. These findings, fundamentally, reflect the ethnic, nutritional and environmental variations.

The most prominent findings in this study were the

significant differences between the measurements of Taif (high altitude) newborns compared to those of Al-Kharj area (sea level). The birth weight and birth length of Taif sample are significantly lower than that of Al-Kharj sample (p<0.001). Furthermore, the Taif sample shows an incidence of (15.6%) of low birth weight babies (≤ 2.5 kg). Although this incidence is convergent with the mean global ratio (15.5%) (WHO, 2004), it is still higher than that of Al-Kharj sample (6.9%) and higher than the estimated general ratio in Saudi Arabia (11%) (WHO, 2004). There are many known risk factors leading to low birth weight, the most significant of which are socio-economic (De Bernabé *et al*., 2004), genetic (Lunde *et al*., 2007) and environmental factors as well as maternal health and lifestyles (Al-Saleh *et al*., 2014b). Considerable studies have confirmed that the high altitude acts, independently from other factors, to induce growth retarding effects (West, 2004). The negative impact of socioeconomic, genetic and maternal factors on the newborn measures is more expected in Al-Kharj, as a small semi-rural town, than in Taif. The decline in newborn anthropometry in Taif seems to be attributable not to an increase in known affecting factors but rather to the effects of altitude acting additively and independently with other risk factors. Other risk factors appear to influence newborn measures at high altitude in much the same way as at other altitudes. The effect of high altitude is generally attributed to the reduction of oxygen delivery to the uteroplacental circulation (Zhang, 2005). Furthermore, chronic hypoxia reduces the pregnancy-associated dilatation of the uterine artery; this will slow down the fetal growth and subsequently induces growth retarding effects (Julian *et al*., 2008).

The mean value of head circumference showed a relative increase in Taif sample than in Al-Kharj sample. This is, probably, attributed to the higher socioeconomic status in Taif. In addition to ethnic variations, the socioeconomic positions may affect the growth of head

circumference (Bouthoorn *et al.*, 2012). Residence at high altitude per se does not affect the fetal head circumference (Bouthoorn *et al.*, 2012). Fetal hypoxia or malnutrition has no significant effect on head circumference because there is classically relative preservation of the fetal brain (fetal head sparing theory) (Keith and Oleszczuk, 2000). This phenomenon is associated with asymmetrical intra-uterine growth restriction (IUGR) and characterized, pathologically, by an increased brain to liver ratio (BLR) (Keith and Oleszczuk, 2000).

Ponderal index (PI) indicates the proportionality of body growth and allows evaluation of wasting and overgrowth either prenatally or postnatal (Haggarty *et al.*, 2004). PI is useful for differentiation between the growth-retarded infants and the small but normally grown neonates. Based on our data, the mean value of PI showed a significant increase in Taif sample (p<0.000) compared to Al-Kaharj sample. This increase is due to a relative decrease of the birth length compared with the birth weight in Taif babies. This is, mainly, associated with the high incidence of preterm babies in Taif sample than in Al-Kharj sample. It has been reported that the proportion between the birth weight and birth length (PI) varies with the gestational age of the infant (Landmann *et al.*, 2006).

Moreover, the present study showed a high incidence of preterm babies (10.9%) in Taif compared with (6.9%) for Al-Kharj sample. The maternal BMI was nearly equal in the two cities, subsequently; maternal obesity is excluded as the reason for the high prevalence of prematurity in Taif sample. Other risk factors related to maternal health, lifestyle and mode of delivery have no considerable differences between the two samples. However, Steer (2005) and Lackman *et al.* (2001), reported that poor fetal growth at a high altitude is an evident cause of preterm birth, both spontaneous and iatrogenic. Furthermore, fetal hypoxia resulting from living at high altitude or maternal smoking is strongly associated with preterm delivery with a dose-response effect (Fantuzzi *et al.*, 2007).

The male neonates, in the studied sample, were significantly heavier than females (p<0.007), but there is no significant difference between male and female babies in the other measures. Sex differences in birth measurements were recorded by many studies (Lampl *et al.*, 2010). It is, clearly, established that birth weight is significantly larger in male than in female babies born both at full term and prematurely (Kirchengast and Hartmann, 2003). In explanation, fetal sex might regulate various genetic and environmental determinants of fetal growth (Lampl *et al.*, 2010). So, there is a sex-specific growth pattern for each of the individual fetal parameters.

On the other hand, the present study revealed strong associations for birth weight with all maternal measurements. Head circumference is significantly associated with maternal height and lean body mass. These findings coincide with previous studies in Austria (Kirchengast and Hartmann, 2003) and Sudan (Elshibly and Schmalisch, 2009). Maternal age in this study seems to be associated mainly with the birth weight.

CONCLUSION

The major implication of our findings is that high altitude reduces, significantly, the birth weight and birth length independent of other affecting factors. Other risk factors appear to influence newborn measures at high altitude in much the same way as at other altitudes. The effect of residence at high altitude on the prematurity rate needs further investigations. Therefore, for comparison and assessment of newborn status, the effect of altitude on growth should be taken into account. Also, high altitude areas should be considered a priority in providing maternal and neonatal care services.

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The authors have declared no conflict of interest.

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