ORIGINAL ARTICLE

Maternal predictors of neonatal anthropometric measurements in the Sultanate of Oman

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ABSTRACT

This study aims to detect an association between potential maternal predictors and neonatal anthropometry in Oman. A retrospective cross-sectional study was conducted in Sultan Qaboos University Hospital, Oman, between November 2014 and November 2015. The study included all term healthy Omani neonate-mother pairs. Summary descriptive statistics of neonatal (N) weight (Wt), length (L), head circumference (HC), and potential maternal (M) characteristics were collected. Multiple linear regression analysis was used to assess associations between maternal predictors and neonatal anthropometry. The study cohort identified 2,783 eligible pairs. The data showed that parity, maternal weight (MWt), and height (MHt) explained a significant amount of the variance in birth weight ($F$-ratio = 115.4, $p$-value < 0.001, and $R^2$ adjusted = 0.12). MWt and MHt were significant predictors of length ($F$-ratio = 65.3, $p$-value < 0.001, and $R^2$ adjusted = 0.048). The predictors of HC were MWt, MHt, and parity ($F$-ratio = 53.1, $p$-value < 0.001, and $R^2$ adjusted = 0.57). Primiparous mothers were 2.2 times at greater risk of delivering low birth weight (LBW) newborns. There were no significant differences in anthropometric outcomes between consanguineous and nonconsanguineous groups. Maternal weight and height had significant positive associations with the three newborn anthropometric outcomes. Additionally, primiparity was associated with the increased risk of LBW. Consanguinity was not associated with LBW in term Omani neonates.

KEYWORDS
Maternal predictors; Anthropometric measurements; Neonates; Oman.

INTRODUCTION

Anthropometry is the quantitative measurement of the body’s physical dimensions and combination of biological measurements.
of those with age and gender to assess growth status, which encompasses a number of neonatal (N) measurements, including weight (Wt), height/length (L), and head circumference (HC) [1]. Anthropometry is considered an easy, convenient, quick, reliable, and feasible procedure to assess fetal intrauterine and postnatal growth and can also predict potential short- and long-term health complications [2]. Neonate anthropometric measurements that deviate from the normal may be associated with increased perinatal morbidity and mortality [3]. Maternal (M) factors, such as MWt and height (MHt) and the derived body mass index (MWt/MHt^2), have been found to directly influence neonatal parameters [4]. Omani females are lighter and shorter than their North American counterparts and some of their Arabian Gulf peers [5]. Additionally, sociodemographic and obstetric characteristics like maternal age, education, and parity contribute to neonatal anthropometric outcomes [4]. Moreover, some authors have reported that consanguinity may lead to a reduction in overall intrauterine growth [6]. This assertion is particularly important in Oman as the consanguinity rate reaches up to 50% among the population [7]. There is a dearth of epidemiological evidence regarding child and maternal health in the Gulf area in general and the Sultanate of Oman in particular [26]. Hence, this study was devised to detect any associations between potential maternal predictors and neonatal growth in the Omani population. The aim is to identify patterns of correlation, if any, between those predictors and neonatal anthropometric outcomes. The results are anticipated to contribute to the knowledge gap and help improve maternal and child health in Oman.

**MATERIALS AND METHODS**

This cross-sectional study was based on secondary data collected at Sultan Qaboos University Hospital (SQUH), Muscat, Sultanate of Oman, from November 2014 to November 2015. The study included all term Omani neonates who were products of singleton pregnancies with an absence of maternal and child health constraints. The study excluded expatriates, preterm neonates (less than 37 weeks gestation), postterm neonates (more than 41 weeks), products of multiple pregnancies, and any case with established maternal or neonatal health complications. Maternal health problems included hypertension, diabetes, chronic kidney disease, cardiovascular and respiratory illnesses, bleeding disorders, neurologic and psychiatric diseases, infectious diseases, autoimmune diseases, and anemia, while neonatal problems included birth defects and chromosomal abnormalities. Secondary data were routinely obtained by nursing midwives who completed personal information and then measured and recorded the maternal anthropometric data. Maternal weight was measured at the time of delivery using electronic digital weighing scales with 0.1 kg precision. Maternal height was measured with a reference stadiometer with 0.1 cm precision. The mothers usually carried an antenatal care (ANC) card that contained basic demographic and follow-up information; the card is consistently used across the Sultanate. For neonates, NWt was measured using digital weighing scales with a 0.001 kg precision level. Length was measured using a standard measuring tape with 0.1 cm precision. HC was measured using flexible nonstretchable tape to the nearest 0.1 cm. Data were abstracted from electronic files in coordination with the Department of Health’s information system.

Variables obtained included demographic data, region of origin, presence or absence of consanguinity, maternal age, and newborn gender. The data also included MHt (cm), MWt (kg), parity, NWt (kg), NL (cm), and HC (cm). Potential maternal predictors were assessed using the multiple linear regression model; parity, maternal age, MWt, MHt, consanguinity, and region of origin were the potential predictor variables to the individual outcome variables of the newborn anthropometric measurements. Furthermore, Student’s t-test was used to detect the level of significance of any difference in the mean values between neonates of consanguineous and nonconsanguineous marriages. Analysis of variances (ANOVA) was used to compare mean values across various geographical regions. In addition, the Games-Howell post-hoc test was used to confirm the difference between geographical regions because the assumption of homogeneity of variances was violated for the independent
variables under scrutiny [8]. Significance was set at \( p < 0.05 \). The analysis was carried out using IBM’s SPSS software version 21.

**RESULTS**

**Data overview**

A total of 4,867 neonates were born in SQUH between November 2014 and November 2015 according to the postnatal ward registers. The eligible mother-neonate pairs were \( n = 2,783 \) apparently healthy term Omani neonates born to healthy mothers according to the retrieved data. Figure 1 shows the details of the data cleansing process.

**Characteristics of the data**

Missing data did not exceed 5% for all variables except for geographical region in which 28.8% were missing. The data were reviewed for any implausible values; none were found. The Kolmogorov-Smirnov test indicated that data might not be from a normal distribution [9], which can possibly be explained by the tests’ oversensitivity to the relatively larger sample sizes and, therefore, biasing results [10].

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**Figure 1.** The data cleansing process.

<table>
<thead>
<tr>
<th>n = 4867</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded ( n = 228 )</td>
</tr>
<tr>
<td>- Non-Omani ( n = 93 )</td>
</tr>
<tr>
<td>- Nationality missing ( n = 135 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>n = 4639</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded ( n = 618 )</td>
</tr>
<tr>
<td>- Gestational age missing ( n = 64 )</td>
</tr>
<tr>
<td>- Preterm ( n = 284 )</td>
</tr>
<tr>
<td>- Postdate ( n = 238 )</td>
</tr>
<tr>
<td>- Twin twins ( n = 32 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>n = 4021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded ( n = 1238 )</td>
</tr>
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</table>

Including a variety of maternal illnesses: diabetes, hypertension, anemia, thyroid problems, renal problems, asthma, bleeding disorders, autoimmune problems, neurological problems, psychiatric problems, infectious diseases e.g. hepatitis.
it is appropriate to examine histograms, compare mean and median values, and explore Q-Q plots [10]. The histograms indicated that the data approximated normal distributions; the mean and median values were very approximate; and the Q-Q plots were exactly linear except for a few values in the extremities, indicating that the data sufficiently approximated normal distribution and were appropriate to conduct the proposed parametric tests.

**Neonatal characteristics**

Of the eligible 2,783 neonates, 1,401 (50.7%) were male and 1,365 (49.3%) were female. The mean and SD values for birth weight, length, and HC for males were 3.16 (SD = 0.39) kg, 52.0 (SD = 2.6) cm, and 33.8 (SD = 1.3) cm, respectively, while for females the equivalent values were 3.06 (SD = 0.38) kg, 51.4 (SD = 2.6) cm, and 33.3 (SD = 1.3) cm, respectively.

**Maternal characteristics**

The maternal characteristics are summarized in Table 1.

**Multiple linear regression**

After testing the normality and linearity assumptions, stepwise multiple linear regression was used in order to obtain a model that included maternal predictors associated with neonatal anthropometry. Potential predictors included maternal age, MHt, MWt, and parity in relation to the three neonatal anthropometric outcomes. Maternal age had no significant association with neonatal anthropometry and was eliminated from all multiple regression models.

Parity, MWt, and MHt explained a significant amount of the variance in birth weight \[F\text{-ratio} = 115.4, p\text{-value} < 0.001, R^2 = 0.118, \text{ and } R^2 \text{ adjusted} = 0.117\]. The regression equation to predict weight can be expressed as follows:

\[
\text{Birth weight} = 1.6 + 0.028 \text{ Parity} + 0.008 \text{ MWt} + 0.006 \text{ MHt}.
\]

As illustrated in Table 2, primiparous mothers were found to be at 2.2 times greater risk of developing low birth weight (LBW) newborns compared to multiparous mothers.

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**Table 1. Maternal characteristics.**

<table>
<thead>
<tr>
<th>Maternal characteristics</th>
<th>Mean (SD)</th>
<th>Number (%)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>28.33 (5.01) years</td>
<td>15 to 49 years</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>72.2 (13.7) kg</td>
<td>41.6 to 156.0 kg</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>156.7 (5.5) cm</td>
<td>134.5 to 177.0 cm</td>
<td></td>
</tr>
<tr>
<td>Parity</td>
<td>1 (median)</td>
<td>0 to 10 deliveries</td>
<td></td>
</tr>
<tr>
<td>Consanguinity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consanguineous</td>
<td>945 (35.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonconsanguineous</td>
<td>1,742 (62.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geographical region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Batinah</td>
<td>868 (43.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscat</td>
<td>855 (43.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>169 (8.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Sharqiya</td>
<td>69 (3.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Dhahira</td>
<td>17 (0.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dhofar</td>
<td>2 (0.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Wosta</td>
<td>1 (0.1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Furthermore, only MWt and MHt were significant predictors of length \(F\)-ratio (df regression = 2, df residual = 2,578) = 65.3, \(p\)-value < 0.001, \(R^2\) and \(R^2\) adjusted were both = 0.048. The regression equation to predict neonatal length can be expressed as follows:

\[
\text{Length} = 49.03 + 0.031 \text{MWt} + 0.051 \text{MHt}
\]

Finally, the predictors of HC were MWt, MHt, and parity \(F\)-ratio (df regression = 3, df residual = 2,577) = 53.14, \(p\)-value < 0.001, \(R^2\) = 0.58, and \(R^2\) adjusted = 0.57. The regression equation for predicting HC at birth can be expressed as follows:

\[
\text{HC} = 29.7 + 0.086 \text{Parity} + 0.016 \text{MHt} + 0.017 \text{MWt}
\]

For consanguinity, an independent sample \(t\)-test was conducted and revealed that there was no significant difference in the mean values for weight, length, or HC between consanguineous and nonconsanguineous groups. For weight, \(t\)-statistic = 0.073, df = 2,670, and \(p\) = 0.942. For length, \(t\)-statistic = -1.536, df = 2,667, and \(p\) = 0.125. For HC, \(t\)-statistic = -0.959, df = 2,668, and \(p\) = 0.338.

Two geographical regions (Al Wosta and Dhofar) with very few observations were marked as missing. Using ANOVA, statistically significant differences were found between the geographical regions with means for weight, length, but not for HC. \(F\)-statistic was 3.63, df between groups = 4, df within groups =1,958, and \(p\) = 0.006 for weight and \(F\)-ratio = 4.14, df between groups = 4, df within groups = 1,956, and \(p\) = 0.002 for length. According to Levene’s test, both weight and length violated the assumption of homogeneity of variances. Thus, the \textit{post-hoc} test of choice was Games-Howell [8]. For weight, the Interior geographical region was significantly lower than both Muscat and Al Batinah, with a mean difference of 0.103 and 0.106 kg and \(t\)-values of 0.013 and 0.015, respectively. For length, no significant difference was identified using the \textit{post-hoc} test, which may be explained by variation in the sample size in each group [11].

\textbf{DISCUSSION}

Although this was a single-center study, it was strengthened by the fact that 70% of the Omani population reside in urban areas, with 50% residing in the two regions of Muscat and Al Batinah, both of which are served by SQUH. Moreover, due to the unique geographical location of SQUH, interposed between the two most highly populated areas in Oman, the study included around 7% of live births in the country [12]. A significant positive association was found between MWt and MHt and the three newborn anthropometric outcomes, while parity had a significant positive association with neonatal weight and HC. In this cohort, the relative odds of LBW in primiparous mothers was 2.2 times greater than in multiparous mothers. These findings are consistent with multiple studies, some of which reported first babies to have a 2.1 times higher risk of LBW compared to babies of multiparous women [13-15]. Elshibly and Schmalisch [15] studied 1,000 African mothers and suggested a cut-off point of 156 cm to define short mothers in a regression model with good sensitivity and specificity to predict LBW neonates. They found that short mothers had a 1.5 times higher risk of having a LBW neonate compared to those of greater height [15]. The present study showed no significant differences in the relative risk of

\begin{table}[h]
\centering
\caption{Impact of selected maternal predictors on the risk of developing LBW.}
\begin{tabular}{lccc}
\hline
 & \textbf{Odds ratio of LBW} & \textbf{p-value} & \textbf{95\% CI} \\
\hline
Primiparous & 2.21 & < 0.0001 & (1.60, 2.10) \\
Consanguineous marriage & 1.08 & 0.680 & (0.75, 1.56) \\
Short maternal height\(^a\) & 1.27 & 0.340 & (0.92, 1.75) \\
\hline
\end{tabular}
\textbf{CI, Confidence interval; LBW, low birth weight.} \\
\(^a\)Height less than 156 cm was considered short as per previous effective predictive classification model.
\end{table}
LBW babies between mothers of less than 156 cm height and those above 156 cm. This finding may be attributable to the significant difference ($p < 0.001$) in the mean maternal height between African (mean = 159.6 cm, SD = 6.2) and Omani mothers (mean = 156.7 cm, SD = 5.5); $t = 13.82$; $df = 3,781$; 95% CI = 2.49, 3.31 [15]. Although the effect of maternal age on predicting LBW neonates was found to be an insignificant factor in this Omani cohort, uncertainty remains as different authors have reported different findings [14,16].

Consanguinity did not influence neonatal anthropometric outcomes, which was in accordance with results from Saudi Arabia and Turkey [17,18]. This outcome was not the case in similar studies carried out in Lebanon, Israel, and India [19-21]. In Lebanon, a negative association was reported between birth weight and consanguinity, stating that consanguinity contributed to a 1.8% reduction in birth weight. However, those authors reported a substantial amount of missing data on consanguinity (around 22%) [19]. The Lebanese study also highlighted that the negative association between birth weight and consanguinity was confounded by low parity and maternal smoking status; most of the negative impact was reported in mothers who smoked and had low parity. Also of note, the sample sizes for the Israeli (610) and Indian (322) studies were relatively small [20,21]. The Indian study showed a dose-response relationship between the degree of consanguinity and LBW; uncle-niece marriages produced neonates of significantly lower birth weight than first-degree cousins. First-degree cousins, in turn, had significantly smaller newborns than the nonconsanguineous group. However, the only potential confounder the study adjusted for was the social class of the father, which did not differ significantly between consanguineous and nonconsanguineous groups. This finding may weaken the generalizability of the results due to the high homogeneity of the study’s sample background. In addition, the Israeli study was conducted in an isolated Arab community in a village populated by people who were the descendants of around 20 founding families in which the prevalence of congenital birth defects was as high as 15.8%, which renders any inference about the exact cause of LBW a difficult task. In fact, a meta-analysis that included 24 case-control and cohort studies concluded that consanguinity may increase the risk of LBW [6]. However, recent evidence from Saudi Arabia, a country with similar demographic and social characteristics to Oman [22], concluded that consanguinity was neither associated with LBW nor with preterm outcome [23].

Being a single-center study led to over representation of the closest two areas, Muscat and Al Batinah, with a percentage approaching 80%. However, other underrepresented regions constitute a relatively small fraction of the total live births in Oman in a way that is relatively reflective to the 2015 national data; Al Wosta (1%), Dhofar (7%), Al Dhahira (6%), Al Saharqiyah (15%), Interior (15%), Musandam (1%), Al Burami (3%) (both from which data were not obtained) compared to Al Batinah (34%) and Muscat (18%) [24]. Indeed, this can be better addressed in future studies. Despite the advantages of large sample size and extensive data cleansing process, the limitations of using a secondary dataset must be acknowledged. For instance, it is difficult to ascertain from secondary dataset that MWt was always measured at the exact time of delivery as it was sometimes obtained from the last ANC visit. The authors opted to include the last record before delivery in maternal electronic records which represents MWt at the time of delivery for the vast majority of cases or the last recorded weight in ANC for the minority of mothers who presented late in second stage of labor. The adequacy of the ANC and delivery services in Oman reaches up to 99.1% [25], which is considered to be the case in our cohort. One of the major issues of the study’s data was the inconsistency in gestational age calculation, as some of the mothers reported their last menstrual period to calculate the date, while others had their gestational age calculated through an ultrasonographic scan. In addition, although the measuring instruments were calibrated regularly and the measurements were carried out according to the WHO guidelines (except for neonatal length), there were no available data about whether staff members were provided with regular sessions for updates and consolidation beyond initial training; ideally, that would have
been addressed in a context of a study design based on primary data collection. Furthermore, some important potential predictor variables (for example, socioeconomic status and maternal education) were not available from the secondary dataset. Due to the lack of specific information regarding the degree of consanguinity in the records, as well as the large amount of missing data regarding geographical region of origin, it was valuable to separate the two from the regression model to avoid erroneous conclusions.

**CONCLUSION**

This study of healthy Omani mother-neonate pairs found a significant positive association between MWt and MHt and the three newborn anthropometric outcomes. Furthermore, the study identified a significant positive correlation between parity and birth weight; primiparous mothers are at 2.2 times greater risk of delivering LBW newborns. Consanguinity was not associated with LBW of term Omani neonates.

**FUNDING**

This study was not funded and had no financial support from any source.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest in this study.

**ETHICAL APPROVAL**

Ethical approval was granted by Ethics Committee, College of Medicine and Health Science, Sultan Qaboos University, Muscat, Sultanate of Oman via reference number MREC # 1163 dated 5th October 2015. Participants’ guardian consent is not required for this retrospective (record-based) study, and confidentiality was ensured at all levels.

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