Interpreting Neonatal Growth Parameters in Oman
Are we doing it right?

Reem M. Abdulrahim,1 *Ahmed B. Idris,2 Asad Ur-Rahman,2 Mohamed Abdellatif,2 Nigel Fuller1

ABSTRACT: Objectives: This study aimed to compare reference anthropometric measures of Omani neonates with the international standard growth charts of the World Health Organization (WHO) in order to determine the appropriateness of these growth charts to assess the growth of Omani neonates. Methods: This cross-sectional study included all healthy full-term Omani neonates born between November 2014 and November 2015 at the Sultan Qaboos University Hospital, Muscat, Oman. Birth weight, length and head circumference measurements were identified and compared to those of the 2006 WHO growth charts. Results: A total of 2,766 full-term neonates were included in the study, of which 1,401 (50.7%) were male and 1,365 (49.3%) were female. Mean birth weights for Omani males and females were 3.16 ± 0.39 kg and 3.06 ± 0.38 kg, respectively; these were significantly lower than the WHO standard measurements (P <0.001). Similarly, the mean head circumferences of Omani males and females (33.8 ± 1.27 cm and 33.3 ± 1.26 cm, respectively) were significantly lower than those reported in the WHO growth charts (P <0.001). In contrast, mean lengths for Omani males and females (52.0 ± 2.62 cm and 51.4 ± 2.64 cm, respectively) were significantly higher than the WHO standard measurements (P <0.001). Conclusion: The WHO growth charts might not be appropriate for use with Omani neonates; possible alternatives should therefore be considered, such as national growth charts based on local data.

Keywords: Anthropometry; Growth Charts; Neonates; World Health Organization; Oman.

Advances in Knowledge
- The results of this study revealed that full-term Omani neonates have significantly lower birth weights and head circumferences and greater lengths than the international standards reported in the World Health Organization (WHO) 2006 growth charts.

Application to Patient Care
- This study provides preliminary evidence that the WHO standard growth charts might not be the best tool to assess the growth of full-term Omani neonates, indicating potential gaps in the interpretation of anthropometric measurements.
- Based on these findings, clinicians are advised to balance the use of international growth charts with a degree of well-informed clinical judgement in order to help reduce unnecessary clinic visits, investigations, costs and parental anxiety.

ANTHROPOMETRY IS THE QUANTITATIVE ASSESSMENT of an individual’s physical dimensions which, in combination with age and gender, can subsequently be used to assess growth status.1 Neonatal anthropometric measurements—such as birth weight, height and head circumference—are considered rapid, reliable and feasible indicators of fetal intrauterine and postnatal growth, as well as

1Department of Public Health & Policy, University of Liverpool, Liverpool, UK; 2Department of Child Health, Sultan Qaboos University Hospital, Muscat, Oman
*Corresponding Author’s e-mail: ahmed30411@gmail.com
Interpreting Neonatal Growth Parameters in Oman
Are we doing it right?

10th and 90th percentiles mark infants as either SGA or a normal distribution curve for weight in which the for gestational age (LGA) categories, according to age (SGA), appropriate for gestational age and large for gestational age (LGA), respectively. Neonates who are SGA are subject to extensive clinical interventions and investigations and are likely to have congenital abnormalities, while LGA newborns are prone to a wide range of neonatal complications such as respiratory distress, hypoglycaemia and polycythaemia. Additionally, head circumference values below the third percentile (i.e. microcephaly) might indicate serious genetic or acquired health problems.

Two types of growth charts are regularly used to assess neonatal anthropometric measurements. While reference charts merely describe the growth patterns of a certain population, standard charts apply strict inclusion and exclusion criteria to determine the optimal growth of children in favourable socioeconomic and health conditions. Internationally, the most widely used growth charts are the standard charts developed by the World Health Organization (WHO) which describe growth in optimal conditions. These charts were developed as a result of the Multicentre Growth Reference Study (MGRS) in which six countries participated, including Oman.

Currently, Oman has no specific national growth charts and the 2006 WHO standard charts have been adopted to assess the growth of Omani neonates. However, marked variation in the interpretation of child growth measurements can occur depending on the growth chart used. The potential misclassification of healthy children as having growth abnormalities has critical public health implications, particularly in terms of the burden on future healthcare management. Therefore, this study aimed to identify reference anthropometric measurements among Omani neonates and compare these to the WHO international standards in order to determine the appropriateness of the WHO growth charts within the Omani population.

**Methods**

This retrospective cross-sectional study included all healthy full-term Omani neonates born at the Sultan Qaboos University Hospital (SQUH) in Muscat, Oman, between November 2014 and November 2015. Only those neonates of Omani nationality between 37–42 gestational weeks and born from singleton pregnancies were included. Cases with significant maternal or neonatal illness were excluded. Neonatal characteristics and anthropometric measurements, including gender, birth weight, length and head circumference, were obtained from the electronic hospital information system. Gestational age was calculated according to dates of the mother’s last menstrual period and delivery. Birth weight was measured using digital scales to a precision level of 0.001 kg. A regular measuring tape was used to measure length to a 0.1 cm precision level. Head circumference to the nearest 0.1 cm was calculated using flexible non-stretchable tape.

In terms of sample size, the WHO Expert Committee recommends including at least 200 individuals in each age and gender group in order to construct reference growth curves with sufficiently precise estimates. However, no standard approach exists to establish precision for each percentile. Therefore, the Omani reference data were taken from a single time point with precise estimates of weight, length and head circumference. A minimum of 200 male and 200 female neonates were considered sufficient to establish precision at the 10th and 90th percentiles within 0.1 of a standard deviation (SD), with the range between the 3rd and 97th percentiles considered to be four SDs. The mean values and SDs for birth weight, length and head circumference measurements were calculated for males and females separately. Moreover, anthropometric measurements for the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentiles were also calculated. Subsequently, the mean values and percentiles of the Omani sample were compared to the standard measurements and percentiles reported in the 2006 WHO standard growth charts.

Data were analysed using the Statistical Package for the Social Sciences (SPSS) software, Version 21.0 (IBM Corp., Armonk, New York, USA). Mean values were compared using a Student’s t-test calculator (GraphPad Software Inc., La Jolla, California, USA). Percentiles were compared graphically by plotting the data points in a Word document, Version 2016 (Microsoft Inc., Redmond, Washington, USA). A $p$ value of $<0.050$ was considered statistically significant.

Ethical approval for this study was obtained from the Medical Ethics Committee of the College of Medicine & Health Sciences, Sultan Qaboos University (MREC #1163).
Results

A total of 4,867 neonates were born at SQUH during the study period. Following application of the inclusion/exclusion criteria, there were 2,766 eligible mother-neonate pairs [Figure 1]. While missing values were reported in the birth weight (0.4%), length (0.5%) and head circumference (0.5%) categories, the total percentage of missing data was considered acceptable at <5%.15 Of the 2,766 neonates, 1,401 (50.7%) were male and 1,365 (49.3%) were female. Table 1 shows the percentile values for birth weight, length and head circumference according to gender.

For the male neonates, mean birth weight, length and head circumference values were 3.16 ± 0.39 kg, 52.0 ± 2.62 cm and 33.8 ± 1.27 cm, respectively. The same measurements for females were 3.06 ± 0.38 kg, 51.4 ± 2.64 cm and 33.3 ± 1.26 cm, respectively. Both Omani male and female neonates had significantly lower mean birth weights and head circumferences when compared to data from the standard WHO charts (3.30 ± 0.40 kg and 3.20 ± 0.40 kg, respectively, and 34.5 ± 1.20 cm and 33.9 ± 1.10 cm, respectively; P <0.001 each). In contrast, the mean length of Omani male and female neonates was significantly higher than that indicated in the WHO charts (49.9 ± 1.89 cm and 51.4 ± 2.64 cm, respectively; P <0.001 each).

Table 1: Percentile values for birth weight, length and head circumference measurements among Omani neonates born at the Sultan Qaboos University Hospital, Muscat, Oman (N = 2,766)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Percentile</th>
<th>3rd</th>
<th>10th</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
<th>90th</th>
<th>97th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight in kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1,401</td>
<td>3.16 ± 0.39</td>
<td>0.01</td>
<td>890</td>
<td>3.30 ± 0.40</td>
<td>0.01</td>
<td>0.107–0.173</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>3.06 ± 0.38</td>
<td>0.01</td>
<td>838</td>
<td>3.20 ± 0.40</td>
<td>0.01</td>
<td>0.107–0.173</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length in cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1,401</td>
<td>52.0 ± 2.62</td>
<td>0.07</td>
<td>893</td>
<td>49.9 ± 1.89</td>
<td>0.06</td>
<td>1.901–2.298</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>51.4 ± 2.64</td>
<td>0.07</td>
<td>842</td>
<td>49.1 ± 1.89</td>
<td>0.06</td>
<td>2.094–2.505</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Head circumference in cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>1,401</td>
<td>33.8 ± 1.27</td>
<td>0.03</td>
<td>890</td>
<td>34.5 ± 1.20</td>
<td>0.04</td>
<td>0.595–0.804</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>33.3 ± 1.26</td>
<td>0.03</td>
<td>838</td>
<td>33.9 ± 1.10</td>
<td>0.04</td>
<td>0.496–0.703</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SD = standard deviation; SE = standard error; WHO = World Health Organization; CI = confidence interval.

Table 2: Comparison of mean birth weight, length and head circumference measurements among Omani neonates born at the Sultan Qaboos University Hospital, Muscat, Oman (N = 2,766) with the 2006 World Health Organization standard growth charts14

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Omani sample</th>
<th>WHO standards</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight in kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>1,401</td>
<td>3.16 ± 0.39</td>
<td>0.01</td>
<td>890</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>3.06 ± 0.38</td>
<td>0.01</td>
<td>838</td>
</tr>
<tr>
<td>Length in cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>1,401</td>
<td>52.0 ± 2.62</td>
<td>0.07</td>
<td>893</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>51.4 ± 2.64</td>
<td>0.07</td>
<td>842</td>
</tr>
<tr>
<td>Head circumference in cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>1,401</td>
<td>33.8 ± 1.27</td>
<td>0.03</td>
<td>890</td>
</tr>
<tr>
<td>Females</td>
<td>1,365</td>
<td>33.3 ± 1.26</td>
<td>0.03</td>
<td>838</td>
</tr>
</tbody>
</table>
and 49.1 ± 1.89 cm; *P* < 0.001) [Table 2]. Graphic representations of observed differences between the mean values for birth weight, length and head circumference are shown in Figures 2–4.

**Discussion**

The results of the current study raise concerns regarding the appropriateness of the WHO growth charts to assess the growth of Omani neonates. According to the WHO, their charts are prescriptive, indicating that any difference between chart values and those observed in a given population is due to a deviation from normal growth within that population. The underlying theory behind this assumption is that 90% of genetic variations are attributable to differences between people from the same continent, while only 10% are attributable to differences across continents, thus justifying the international generalisability of results from studies such as the MGRS. Nevertheless, some researchers have warned of the dangers of misinterpretations resulting from the 90/10% genetic variation.
When babies are diagnosed as being SGA based on the WHO recommendations, the expenditure of health resources and undue parental anxiety.24 There is existing evidence that inhabitants of the Eastern Mediterranean region have lower anthropometric measurements compared to international growth charts, while European individuals tend to have similar or even greater anthropometric measurements.25–27 In fact, an analysis of the data from each of the six MGRS sites in isolation indicates that Oman and India had the lowest mean values for neonatal birth weight, length and head circumference in comparison to the other sites.9 As an example to showcase the variability of these measurements, mean values for birth weight, length and head circumference were 3.2 ± 0.4 kg, 49.2 ± 1.7 cm and 33.4 ± 1.0 cm, respectively, among Omani neonates compared to 3.6 ± 0.5 kg, 50.4 ± 1.9 cm and 34.9 ± 1.2 cm, respectively, among Norwegian neonates.9

According to the findings of the current study, differences in neonatal birth weight, length and head circumference were consistent across all percentile values, indicating an overestimation of growth insufficiency in the birth weight and head circumference categories and an underestimation of overgrowth in the length category. For example, 8.9% of the Omani sample in the current study would be deemed to be SGA using the WHO charts in comparison to only 3.3% when using a normal distribution curve. Furthermore, according to the WHO chart, 10.4% of the Omani sample had microcephaly compared to 2.5% when the sample’s normal distribution curve was applied. Hence, utilisation of the WHO growth charts would potentially result in 201 and 220 neonates being misclassified as SGA and microcephalic, respectively. Such discrepancies can lead to the unnecessary expenditure of health resources and undue parental anxiety.25 When babies are diagnosed as being SGA or having intrauterine growth restriction, a number of investigations are needed, including viral screening and serial ultrasound measurements.25 In addition, sophisticated investigations such as brain imaging and genetic testing are necessary for infants with microcephaly.4 According to internal financial sources at SQUH, the 421 aforementioned potential misdiagnoses would result in unnecessary interventions costing approximately USD $250,000–300,000. 

Inconsistencies were noted in the length results compared to birth weight and head circumference findings in the current study. This can perhaps be attributed to the inaccuracy of the measurement instrument, as a measuring tape was used instead of a proper length board or infantometer, as per
the application of WHO recommendations. To this end, onsite reminder materials, regular assessments of staff competency and regular assessments of instrument accuracy and measurement reliability are also needed.

Conclusion

From the findings of the current study, it appears that the standard 2006 WHO growth charts might not accurately reflect growth patterns among Omani neonates. It is possible that such growth differences may continue into childhood, which will require further assessment of the appropriateness of childhood growth assessment tools. Meanwhile, in the absence of an Oman-specific neonatal growth assessment tool, clinicians are advised to account for potential discrepancies when using international growth assessment standards and to combine chart usage with well-informed clinical judgment.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

FUNDING

No funding was received for this study.

References


