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Body mass index values for newborns according to gestational age

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Objective: The combination of two anthropometric parameters has been more appropriate to assess body composition and proportions in children, with special attention to the Body Mass Index (BMI), as it relates weight and length. However the BMI values for the neonatal period have not been determined yet. This study shows the BMI for newborns at different gestational ages represented in a normal smoothed percentile curve.

Methods: Retrospective study including 2,406 appropriate for gestational age newborns following the Alexander et al curve (1996) from 29 to 42 weeks of gestational age. Weight and length were measured following standard procedures. For the construction of a normal smoothed percentile curve, the 3rd, 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles were determined and a statistical procedure based on the mathematical model “sinosoidal fit” was applied to establish a curve that estimates biological growth parameters.

Results: The Body Mass Index values for gestational age in all percentiles shows a steady increase up to 38 weeks, levels off up to the 40th week, followed by a slight decrease to the 42nd week in both genders.

Conclusion: The results show a direct correlation between gestational age and Body Mass Index for both genders in the nine percentiles, and can provide a useful reference to assess intra-uterine proportional growth.


Resumen

Objetivo: La combinación de dos parámetros antropométricos ha sido descrita como una manera más apropiada para determinar la composición y proporciones del cuerpo en niños, con especial atención para el índice de masa corporal (IMC), pues relaciona el peso y la estatura. Sin embargo, los valores del IMC para el periodo neonatal no han sido determinados todavía. Este estudio muestra el IMC para recién nacidos de diversas edades gestacionales presentados en una curva de percentiles suavizados.

Métodos: En un estudio retrospectivo incluyendo 2,406 recién nacidos apropiados para la edad gestacional según la curva de Alexander y cols. (1996), entre 29 y 42 semanas de edad gestacional. El peso y la estatura fueron medidas según los procedimientos estándares. Para la construcción de la referida curva fueron determinados los siguientes percentiles: 3, 5, 10, 25, 50, 75, 90 y 95. El modelo matemático de ajuste sinusoidal fue aplicado para establecer una curva que estimase los parámetros biológicos del crecimiento.

Resultados: Los valores del IMC para las edades gestacionales en todos los percentiles demostraron aumento constante hasta 38 semanas, estabilización hasta 40 semanas, seguida por una leve disminución hasta 42 semanas en ambos los sexos.

Conclusión: Los resultados demuestran una correlación directa entre la edad gestacional y el IMC para ambos sexos en todos los percentiles estudiados, y pueden proporcionar una herramienta útil para determinar un crecimiento intrauterino proporcional.


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Introduction

The nutritional assessment of the newborn has been a challenging issue and any deviation from the normal is associated with an increased risk of morbidity and mortality.\textsuperscript{1,2,3} Anthropometric parameters have been the most useful methods to evaluate newborn nutrition.\textsuperscript{4} They are important for reflecting intrauterine growth and for defining a baseline for infants’ nutritional follow-up. A single standard anthropometric factor, as the measure of simple weight, cannot assess the nutritional status of the newborn properly.\textsuperscript{4} The use of a combination of two anthropometric factors has been more appropriate to assess body composition and proportions.\textsuperscript{4,5} The Body mass index (BMI) has become the measure of choice for the determination of body proportions and to estimate adiposity during pediatric years, as it assesses the relationship between weight and length;\textsuperscript{4,6} however there is a lack of reference values in the neonatal period.

This report aims to present references for the Body Mass Index of the newborn at different gestational ages in both sexes and to construct a normal smoothed percentile curve.

Material and methods

All the appropriate for gestational age live born infants admitted to the Newborn Nursery of Clinics Hospital, School of Medicine, University of São Paulo between the gestational ages of 29 to 42 weeks, born between January 1993 to December 2004 were included in the sample. Exclusion criteria were newborns with impaired fetal growth or abnormalities such as hydrops fetalis, congenital malformations, congenital infection or multiple births. To avoid the influence of unhealthy or growth restricted newborns due to unknown causes, the Alexander et al. curve\textsuperscript{6} was adopted as a pre-classification criteria and weight and length measurements below the 10\textsuperscript{th} percentile and above the 90\textsuperscript{th} percentile were also excluded.

The weight and length measurements were obtained using standard pediatric measurement procedures\textsuperscript{6}.

The weight was determined when the baby was born; using a digital scale with an accuracy of 0.1 gram at the obstetric room, and the length was obtained by two trained pediatricians in the first 24 hours after birth. The length assessment was performed using a wood length board with a fixed headpiece and a movable footpiece, perpendicular to the surface of the table. One of the pediatricians held the infant’s head and the other held the infant’s feet against the footboard, applying a gentle pressure to extend the infant’s legs so that the heels of the infant touched the footboard firmly.

To establish an accurate gestational age for each infant, the date of the last normal menstrual period was considered first, followed by the gestational age based on the first trimester ultrasonographic measurement and finally confirmed by the postnatal examination method (Capurro for term infants and New Ballard for the preterms).\textsuperscript{10,11} The last menstrual period was considered reliable when it agreed, within two weeks, with the gestational age obtained by the prenatal ultrasonography and the postnatal clinical methods. The infants were grouped according to their gestational age, which was conventionally expressed as completed weeks. (eg 34 week-group includes infants with gestational ages between 34-week and 34-week and 6 days).

The overall sample size was determined by the need to obtain sufficient data for valid calculation of percentile values from 29 to 42 weeks, totaling 2,406 infants. The BMI was calculated based on the formula: [weight (kg)/ length (m)]\textsuperscript{2}, and nine selected percentiles (3, 5, 10, 25, 50, 75, 90, 95, 97) were determined for all target gestational ages.

In the BMI-for-gestational-age curve the gestational ages in weeks were represented on the “x” axis and the BMI (kg/m\textsuperscript{2}) on the “y” axis.

For the construction of the normal smoothed percentile curve, first the real BMI values for each percentile were ordered and the graphic model was analyzed. The distribution obtained fitted the mathematical model “sinusoidal fit”, as this mathematical model corresponded to the equation that best represented a biological parameter of growth and at the same time had a higher determination coefficient (R\textsuperscript{2}) in all the calculated percentiles with lower residuals errors.

The equation for the “sinusoidal fit” method is:

\begin{equation}
\text{y} = \text{a} + \text{b} \cos(\text{cx} + \text{d})
\end{equation}

As \text{x} represents the gestational age in weeks, \text{y} represents the BMI in kg/m\textsuperscript{2} and \text{a}, \text{b}, \text{c} and \text{d} were formula coefficients.

Through this formula the corresponding prediction values were calculated, smoothing the possible skew of the distribution and determining the final curve.

The data for the statistical analysis was compiled using Excel 97\textsuperscript{TM} to obtain the mean (X), standard deviation (SD) and confidence interval (CI), and the percentiles were calculated by the SigmaStat\textsuperscript{®} software (SigmaStat Statistical Software\textsuperscript{TM}, 1997). The estimated equations for the smoothing procedure were determined by the Software Curve Expert 1.3\textsuperscript{®} and the graphics were constructed using the Software HG 3\textsuperscript{®}.

Sex differences for BMI in each gestational age were tested using the Students’ t-test.

Finally, the validity of BMI as a good index of overweight and underweight depends on its degree of independence from length. The association between BMI and length was determined by the calculation of the Pearson correlation coefficient at each gestational age using the software SPSS 12.0\textsuperscript{®}.  

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Results

The dataset included 2,406 infants, consisting of 1,195 boys and 1,211 girls, for gestational ages between 29 and 42 weeks.

Table I and II give the BMI references for each gestational age in the studied percentiles 3, 5, 10, 25, 50, 75, 90, 95 and 97.

The 50th percentile for BMI is 8.78 kg/m\(^2\) in the 29th week and 13.97 kg/m\(^2\) in the 42nd week of gestational age for male infants, respectively, and 8.43 kg/m\(^2\) and 13.92 kg/m\(^2\) in the 29th and 42nd week of gestational age for female infants.

There was no statistical difference between the BMI values for the sexes in the 9 percentiles evaluated, except in the 32 week gestational age, where a statistical difference was detected (p = 0.044).

The Pearson’s correlation coefficients of BMI with length were very low, ranging from -0.21 to 0.07 in male and from -0.22 to 0.07 in female infants (fig. 1).

The final Body Mass Index curves for each gestational age in all percentiles show a steady increase up to

### Table I

<table>
<thead>
<tr>
<th>GA weeks</th>
<th>n</th>
<th>P 3</th>
<th>P 5</th>
<th>P 10</th>
<th>P 25</th>
<th>P 50</th>
<th>P 75</th>
<th>P 90</th>
<th>P 95</th>
<th>P 97</th>
<th>X ± SD</th>
<th>CI</th>
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<tr>
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<td>9.12</td>
<td>9.73</td>
<td>10.59</td>
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<tr>
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<td>8.67</td>
<td>8.92</td>
<td>9.16</td>
<td>9.76</td>
<td>10.40</td>
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<td>13.31</td>
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<td>11.06 ± 1.12</td>
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<td>13.76 ± 1.00</td>
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<td>13.96</td>
<td>14.57</td>
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<td>15.68</td>
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<tr>
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<td>13.92</td>
<td>14.69</td>
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<td>15.62</td>
<td>15.93</td>
<td>13.98 ± 1.08</td>
<td>0.21</td>
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</table>

![Fig. 1.—Pearson’s correlation coefficient of BMI with length for boys and girls.](image-url)
38 weeks, then a leveling off up to the 40th week, followed by a slight decrease in the 42nd week (figs. 2, 3).

Discussion

Despite technological advances, anthropometric parameters continue to represent the most practical method of assessing nutritional status and growth in the pediatric years, particularly during the neonatal period.

In general, the classification of newborn infants, by plotting their anthropometric parameters as birth weight, length and head circumference on standard growth curves, has provided pediatricians with information regarding the risk of neonatal mortality and metabolic complications such as hypoglycemia and polycythemia.3,5,12

The anthropometric parameters are important in reflecting intrauterine growth and to define a baseline to follow-up the nutritional progress of the infant. Many
authors have proposed that the assessment of body proportions may be more useful than single measurements for age alone for assessing newborn nutrition.\textsuperscript{6,7,13,14,19}

Weight adjusted for height provides a measure of the percentage body fat for older ages and many weight-for-length indexes have been proposed for this purpose.

In children, considering the power function of the equation weight/length\textsuperscript{2}; n = 2 has been shown to be a good way to correlate weight and length, which leads to the Body Mass Index (BMI) or Quetelet index.\textsuperscript{15,16}

This index provides a high estimate of body fat mass as it has a positive correlation with skinfold thickness and other methods of estimating the percentage of body fat, for example the bioelectrical impedance and densitometry.\textsuperscript{17,18}

Furthermore, this index takes advantage of the physiologic principle regarding sparing length at the expense of weight during mild to moderate malnutrition.\textsuperscript{19}

The Body mass index has been intensely used for nutritional assessment in adolescents and adults, and has already been validated for children from 0 to 36 months as a good way to evaluate adiposity and body proportions.\textsuperscript{20} However there is a lack of reference values during the neonatal period.

The validity of body mass index as an index of overweight and underweight depends on its degree of independence from length,\textsuperscript{21} so at each gestational age group, the Pearson’s correlation coefficient of BMI with length was tested. The results obtained were very low, ranging from -0.21 to -0.11 for boys and from -0.22 to 0.07 for girls, which confirms that in the neonatal period, the BMI (weight/length\textsuperscript{2}) is independent of length, thus fulfilling the validity criterion (fig. 1).

Many previous studies have shown concern about the correlation between birth weight, and intrauterine growth restriction, with clinical risk factors for cardiovascular diseases, including hyperlipidemia, elevated insulin and high blood pressure.\textsuperscript{22} Despite the fact that BMI values at younger ages have a weak association with adolescent or adult obesity,\textsuperscript{23} the consideration of how valid the neonatal Body Mass Index is, as a predictor of risk, should be answered.

The construction of a BMI curve for newborns at different gestational ages can be used to track body proportions through life and may complement the nutritional assessment for this period.

The presented curves show a steady growth of the BMI values for both sexes up to 38 weeks, then level off up to 40 weeks and is followed by a slight decrease in the 42\textsuperscript{nd} gestational week.

This pattern can be explained considering that in late gestation the fetal growth is constrained by maternal and placental factors.\textsuperscript{15} Late in the third trimester, an insufficient supply is nearly a universal occurrence, and the ability of the utero-placental unit to provide oxygen and nutrients to the fetus can negatively affect the fetal growth rate.\textsuperscript{23}

The BMI presented no significant statistical difference between males and females in almost all the gestational ages studied, except in the 32\textsuperscript{nd} week (p < 0.05), which might be considered as a random result and suggests that an increase in the sample size in this gestational age is needed.

Previous studies of Guihard-Costa et al., have shown that male newborns have higher weights and lengths, and the females have higher subscapular and tricipital skinfold thickness.\textsuperscript{15} but when the comparison of some weight-for-length indexes was performed, the gender’s difference was small or even disappeared, especially in preterm newborns.\textsuperscript{22,24} In our study the difference in the BMI for males and females was not detected, however

\begin{table}
\centering
\caption{Body mass index (kg/m\textsuperscript{2}) percentiles for gestational age in males}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
\textbf{GA weeks} & \textbf{n} & \textbf{P 3} & \textbf{P 5} & \textbf{P 10} & \textbf{P 25} & \textbf{P 50} & \textbf{P 75} & \textbf{P 90} & \textbf{P 95} & \textbf{P 97} & \textbf{X ± SD} & \textbf{CI} \\
\hline
29 & 38 & 7.02 & 7.31 & 7.59 & 8.09 & 8.78 & 9.57 & 10.39 & 11.02 & 11.50 & 8.64 ± 0.90 & 0.29 \\
30 & 41 & 7.43 & 7.72 & 8.02 & 8.58 & 9.22 & 10.00 & 10.92 & 11.59 & 12.12 & 9.58 ± 1.41 & 0.43 \\
34 & 100 & 9.76 & 9.98 & 10.35 & 10.80 & 11.52 & 12.34 & 13.29 & 14.02 & 14.75 & 12.37 ± 1.16 & 0.23 \\
35 & 100 & 10.38 & 10.58 & 10.95 & 11.57 & 12.16 & 12.98 & 13.84 & 14.52 & 15.07 & 13.27 ± 1.16 & 0.23 \\
36 & 100 & 10.95 & 11.14 & 11.52 & 12.11 & 12.72 & 13.58 & 14.35 & 14.99 & 15.51 & 12.82 ± 1.02 & 0.20 \\
37 & 100 & 11.47 & 11.64 & 12.01 & 12.58 & 13.20 & 14.07 & 14.78 & 15.38 & 15.87 & 13.25 ± 1.11 & 0.22 \\
38 & 100 & 11.89 & 12.06 & 12.41 & 12.95 & 13.60 & 14.45 & 15.12 & 15.69 & 16.15 & 13.89 ± 1.17 & 0.23 \\
39 & 100 & 12.21 & 12.37 & 12.71 & 13.21 & 13.88 & 14.70 & 15.36 & 15.90 & 16.34 & 13.87 ± 0.99 & 0.19 \\
40 & 100 & 12.41 & 12.56 & 12.88 & 13.36 & 14.04 & 14.82 & 15.50 & 16.00 & 16.44 & 14.10 ± 1.01 & 0.20 \\
42 & 100 & 12.41 & 12.56 & 12.84 & 13.28 & 13.97 & 14.64 & 15.43 & 15.89 & 16.34 & 14.03 ± 0.94 & 0.18 \\
\hline
\end{tabular}
\label{table2}
\end{table}
the absolute number of the BMI values in both gender in all gestational ages are different, which suggests that a single curve may not be sufficient for properly classify the newborn of different gender in the correct percentile.

For the first time, the Body Mass Index for newborns in different gestational ages is available. It might be a useful parameter for newborn classification, helping in the detection of intra-uterine growth disturbances and also assisting to validate the nutritional therapy through the time.

References