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Anthropometric indicators of nutritional status and growth in very low birth-weight premature infants hospitalized in a neonatal intensive care unit

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Abstract

Background: **Anthropometric indicators are difficult to interpret in very low birth weight (VLBW) premature infants, including both appropriate for gestational age (AGA) and small for gestational age (SGA) infants. Therefore, the purpose was to describe the anthropometric indicators of growth and nutritional status in VLBW premature infants AGA and SGA, hospitalized in a neonatal intensive care unit (NICU).**

Study design: **The descriptive and prospective study design included 114 preterm infants, adequate for gestational age/small for gestational age hospitalized in the intensive care unit. Head, thigh, mid upper arm circumference, skin-fold measurements and weight/age, length/age, and weight/length indices were obtained. Correlations were made among the anthropometric indices, and a multivariate regression analysis with weight/age as dependent variable was performed.**

Results: **Weight/age in AGA premature infants had high number of significant anthropometric correlations. The SGA premature infants had few and weak correlations. The regression analysis showed that anthropometric indices better explain changes in the weight/age index in adequate for gestational age premature infants.**

Conclusion: **Weight/age in the VLBW/AGA premature infants could reflect growth, nutritional status and energy stored as fat, but in the VLBW/SGA premature infants, thigh circumference and mid arm circumference would be better indicators just of nutritional status.**

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Key words: *Premature infants. Anthropometric indices. Intensive care.*

INDICADORES ANTROPOMÉTRICOS DEL ESTADO NUTRICIO Y CRECIMIENTO EN PREMATURO DE MUY BAJO PESO AL NACER HOSPITALIZADOS EN UNA UNIDAD DE CUIDADOS INTENSIVOS

Resumen

Introducción: **Los indicadores antropométricos son difíciles de interpretar en prematuros de muy bajo peso al nacer (MBPN), tanto con peso adecuado para la edad gestacional (PAEG) como peso bajo para la edad gestacional (PBEG). Por tanto, el propósito fue describir los indicadores antropométricos de crecimiento y estado nutricio en prematuros con MBPN con PAEG y PBEG hospitalizados en una unidad de cuidados intensivos neonatales (UCIN).**

Métodos: **En un estudio descriptivo y prospectivo se incluyeron 114 recién nacidos prematuros, con peso adecuado y bajo para la edad gestacional hospitalizados en la UCIN. Se obtuvieron las mediciones de circunferencia de cabeza, muslo, brazo, pliegues cutáneos y los índices peso/edad, longitud/edad y peso/longitud. Se realizaron correlaciones entre los diferentes indicadores antropométricos y se elaboraron modelos de regresión múltiple con el índice peso/edad como variable dependiente.**

Resultados: **El índice peso/edad en prematuros con PAEG tuvo el número más elevado de correlaciones significativas. Los prematuros con PBEG tuvieron pocas correlaciones y más débiles. El análisis de regresión múltiple mostró que los indicadores antropométricos explican mejor cambios en el índice peso/edad en prematuros con peso PAEG que en prematuros con PBEG.**

Conclusión: **El índice peso/edad en prematuros con muy bajo peso al nacer, adecuado para la edad gestacional podría reflejar el crecimiento, el estado nutricio y las reservas de energía. En prematuros con PBEG la circunferencia de muslo y de brazo serían mejores indicadores solo del estado nutricio.**

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Palabras clave: *Prematuros. Indicadores antropométricos. Cuidados intensivos.*

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Introduction

The interpretation of the anthropometric indices of growth and nutritional status differs according to different stages in the pediatric population.[1-3] During the first semester of postnatal life, the index weight/age (W/A) would be more useful than the indices length/age (L/A) or weight/length (W/L) for the diagnosis of malnutrition because during the early months of life, the W/A deficit is more pronounced.[4] Although head circumference (HC) is a natural indicator of brain growth (neurologic development), it is also a good indicator of growth and it is particularly useful during the first semester of postnatal life because it correlates well with L/A even in very low birth weight infants (VLBW).[1,5]

The mid upper arm circumference (MUAC) has been used for the assessment of nutritional status in children between 6 and 59 months of age.[6] The skinfold thickness has also demonstrated its reliability in estimating the percentage of subcutaneous body fat.[7] Some authors[8] have suggested that in newborn infants, the MUAC and tricipital skin fold (TSF) provide a simple measure of the body composition of neonates and are a useful tool for determining the degree of maturity of a newborn, independent of birth weight, even in premature infants small for gestational age (SGA).[9] Others (10) have stated that both measurements are inaccurate predictors of the regional body composition in preterm infants, appropriate-for-gestational-age (AGA).

In VLBW premature infants (≤ 1,500 g), the use of common anthropometric indices is difficult to interpret, especially in the comparison of premature infants that are AGA or SGA.[2,3] For these two conditions, the anthropometric diagnosis could have different interpretations because each anthropometric index would acquire a distinct dimension. This different interpretation is particularly true when VLBW premature infants are hospitalized in a neonatal intensive care unit (NICU) and require an integral evaluation of their nutritional status, growth and body composition.[2,10,11-14] Therefore, the purpose of this study was to describe the anthropometric indicators of nutritional status and growth in VLBW premature infants AGE and SGA that were hospitalized in a NICU.

Subjects and methods

A descriptive study design of two cohorts was used. This study was performed at a tertiary referral center on 114 VLBW preterm infants (≤ 1,500 g) of both sexes, with or without underlying pathology[15] who were appropriate or small for their gestational age according to the criteria by Battaglia and Lubchenco.[16] All subjects were hospitalized in the intermediate unit or the NICU at the Civil Hospital of Guadalajara Dr. Juan I. Menchaca from August 2008 to August 2009. The infants with major congenital malformations or those included in any other medical or nutritional protocols were not included into this study. The protocol of total parenteral nutrition starts on the 2nd day of life. When the patients were stable (no acidosis, normal arterial pressure, respiratory frequency less than 80 per min. and normal intestinal transit), the protocol of enteral feeding was initiated.

Malnutrition was defined as two standard deviations below the mean for one or more of the following indicators: weight for age or MUAC.[17] All subjects were born at the Civil Hospital of Guadalajara Dr. Juan I. Menchaca and were hospitalized in the intermediate and intensive care units. The infants who met the inclusion criteria were included in the study.

After inclusion, 13 cases were excluded because of death soon after the first measurements were made (up to a period of 7 days). From the remaining sample (n = 101), nine patients died during the study, twelve were discharged because their health improved and 80 completed the study.

The dependent variables were the following: weight, length, HC, MUAC, thigh circumference (TC), the sum of four skin folds (S 4SF) (tricipital, bicipital, sub scapular and suprailiac); and the W/A, L/A, and W/L indices assessed as the respective z-scores (z). The independent variables were: sex, birth weight, and gestational age; type of feeding and energy intake (kcal/kg/d). Before starting the study, two observers were trained in standardized anthropometric measurements following Habicht's method,[18] and they collected all the anthropometric measurements. The weight was measured with the infant not wearing clothes using a digital pediatric scale (SECA®, Model 364; Tokyo, Japan). The length was measured with an infant measuring board (SECA® Model 416, Tokyo, Japan). The HC, TC and MUAC measurements were taken with a 5 mm wide metallic metric tape (Rosscraft ANTTAPS Anthropometric Tape, USA). The tricipital (TSF), subscapular (SSF), bicipital (BSF) and supraliac (SISF) skin fold thicknesses were measured using a Lange skin fold caliper (Cambridge, Maryland, USA). All the measurements were obtained using standard procedures.[19,20] The anthropometric measurements and indices were taken 24 hours after admission and then 7, 15 and 30 days during hospitalization. The criteria for the evaluation of the anthropometric indices of growth were those recommended by the World Health Organization, including the normal limits of ± 2 z scores.[17] The reference standards for W/A, L/A, W/L, HC, and TC were those reported by Usher and McLean.[21] The reference standards for MUAC were those from Sasanow et al.,[22] and the references for the skin folds were those reported by Rodriguez et al.[23]

Statistical analysis

For description of the entire cohort, chi square tests were used to compare differences in proportions and for longitudinal analysis of growth outcomes over time; only the 80/101 infants who survived to discharge and remained in the NICU for the 30-day duration of the study were included. For these infants, differences in anthropometric measurements over time were assessed using repeated-measures analysis of variance for continuous variables and Friedman and Wilcoxon tests for qualitative variables. A matrix of multiple correlations (the Pearson test) among all the anthropometric measurements and indices was obtained at different stages of hospitalization for the adequate and low weight for gestational age of VLBW premature infants. A multivariate regression analysis was designed to determine the best anthropometric model for explaining the variation in the index weight/age. SPSS version 15 was used for all analyses.

Ethical considerations

The protocol was approved by the Bioethics Committee of Guadalajara's Civil Hospital and the University of Guadalajara. Adequate information was provided to parents about the importance of this non-interventional study, and authorization was given for the inclusion of each preterm infant in these cohorts.

Results

The mean gestational age was 30.1 ± 1.6 and 31.5 ± 2.0 weeks for VLBW/AGA (n = 57) and VLBW/SGA (n = 44) premature infants, respectively. The entire sample included 101 premature infants (43 males and 58 females). The frequency of SGA was higher in females (48.3%) than in males (37.2%), although the difference was not significant. The frequency of perinatal pathology was similar between SGA and AGA, with the exception of metabolic disturbances (hyperbilirubinemia, hyponatremia, hypoglycemia, hyperglycemia), which were higher in the SGA group (68.2%) than the AGA group (49.1%), (p = 0.056). In 96 cases (95% of the entire sample), feeding started between the second and third day of life. The anthropometric indicators of VLBW/AGA and VLBW/SGA premature infants during the hospitalization period at the NICU are presented in table I.

The L/A index decreased in both study groups during the first four weeks of extra-uterine life. The mean of z-scores of L/A in VLBW/AGA premature infants remained between the normality limits (-1 to -2 SD) during the first two weeks and dropped below -2SD at 30 days. The L/A in VLBW/SGA premature infants was below -2SD at all the measurements and dropped below -3SD after two weeks in the NICU. The HC in VLBW/AGA premature infants remained in between the limits < -1 to > -2 SD during the first four weeks of extra-uterine life. In VLBW/SGA infants, the HC remained below -2SD during the first four weeks of extra-uterine life (table II).

Table I
Anthropometric indicators of VLBW premature infants during the hospitalization period in the NICU

Indicators	*Appropriate for gestational age*[a]								*Small for gestational age*[b]							
	Admission		*Day 7*		*Day 14*		*Day 30*		*Admission*		*Day 7*		*Day 14*		*Day 30*	
	Mean	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*	*Mean*	*(SD)*
Weight (g)	1227	(170)	1171	(197)	1249	(228)	1486	(292)	1172	(217)	1211	(261)	1320	(284)	1549	(299)
Length (cm)	38.1	(1.7)	38.9	(1.8)	39.4	(1.9)	40.9	(1.9)	38.0	(2.4)	38.9	(2.5)	39.6	(2.5)	41.1	(2.4)
Head circumference (cm)	25.9	(1.6)	26.6	(1.6)	27.1	(1.9)	28.7	(1.9)	25.9	(1.9)	26.7	(2.0)	27.5	(2.3)	29.1	(2.5)
Mid arm circumference (cm)	5.6	(0.5)	5.4	(0.5)	5.5	(0.6)	6.0	(0,8)	5.4	(0.6)	5.8	(0.7)	5.8	(0.7)	6.2	(0.8)
Thigh circumference (cm)	8.3	(0.8)	7.6	(0.8)	7.7	(0.9)	8.7	(1.4)	8.1	(0.9)	7.8	(1.1)	8.2	(1.3)	9.0	(1.4)
Triceps skin fold (mm)	2.1	(0.4)	2.1	(0.4)	2.2	(0.4)	2.6	(0.7)	2.1	(0.4)	2.2	(0.4)	2.5	(0.5)	2.7	(0.5)
Biceps skin fold (mm)	1.9	(0.5)	2.0	(0.5)	2.2	(0.4)	2.5	(0.6)	1.9	(0.4)	2.1	(0.4)	2.4	(0.4)	2.6	(0.7)
Subscapular skin fold (mm)	2.1	(0.5)	2.0	(0.5)	2.3	(0.5)	2.6	(0.7)	1.9	(0.4)	2.1	(0.5)	2.4	(0.6)	2.8	(0.7)
Suprailiac skin fold (mm)	1.7	(0.5)	1.6	(0.6)	1.7	(0.5)	2.0	(0.6)	1.7	(0.5)	1.7	(0.6)	1.9	(0.7)	2.2	(0.7)

[a]Admission n = 57; Day 7: n = 53; Day 14: n = 52; Day 30: n = 49.
[b]Admission: n = 44; Day 7: n = 42; Day 14: n = 42; Day 30: n = 31.

Table II
Outcomes of length/age and head circumference for age in AGA and SGA VLBW premature infants during the hospitalization period

Time of measurement (days)	*AGA[a]*		*SGA[b]*		*p*
	Mean	*SD*	*Mean*	*SD*	
Length/age (z)					
Admission	-1.1	1.2	-2.7	0.7	< 0.001
7th	-1.8	1.1	-2.6	1.0	0.001
14th	-1.8	1.3	-3.2	0.7	< 0.001
30th	-2.3	1.3	-3.2	0.9	0.003
HC (z)					
Admission	-1.3	1.1	-2.7	1.0	< 0.001
7th	-1.8	1.0	-2.2	1.0	0.060
14th	-1.7	1.1	-2.5	1.1	0.001
30th	-1.9	1.3	-2.4	1.2	0.080

AGA: Appropriate for gestational age; SGA: Small for gestational age; VLBW: Very low birth weight; X: Mean. SD: Standard deviation; HC: Head circumference.
[a]Admission: n = 57; Day 7: n = 53; Day 14: n = 52; Day 30: n = 49.
[b]Admission: n = 44; Day 7: n = 42; Day 14: n = 42; Day 30: n = 31.

At admission and throughout the entire hospitalization period, the index W/A in the VLBW/AGA premature infants had high number of significant direct correlations, followed by the HC and MUAC. At admission, the VLBW/SGA premature infants had few and weak correlations, primarily with W/A index. At 14 and 30 days, the index W/A, and the indicator TC showed the majority of significant correlations. Tables III and IV

Table III
Correlation coefficients of anthropometric indicators in AGA/VLBW premature infants. The weight/age z-score was assigned as the dependent variable. All indicators were analyzed as z-scores

Day of measurement	*Anthropometrical indicators*					
	L/A	*W/L*	*HC*	*MAC*	*TC*	*Σ4SF*
Admission (n = 57)[a]	0.745†	0.455†	0.674†	0.540†	0.289*	–
7th (n = 53)[b]	0.798†	0.295*	0.786†	0.462†	0.649†	0.645*
14th (n = 52)	0.660†	0.382†	0.719†	0.569**	0.791†	0.388
30th (n = 49)	0.586†	0.502†	0.682†	0.709†	0.705†	0.641†

AGA: Appropriate for gestational age; VLBW: Very low birth weight; L/A: Length/age; W/L: Weight/length; HC: Cephalic circumference; MAC: Mid arm circumference; TC: Thigh circumference; SF: skin folds.
[a]Five premature infants died and three were discharged before the 30th day.
[b]Σ4SF n = 14.
*$p < 0.05$; **$p < 0.01$; †$p < 0.001$.

Table IV
Correlation coefficients of anthropometric indicators in SGA/VLBW premature infants. The weight/age z-score was assigned as the dependent variable. All indicators were analyzed as z-scores

Day of measurement	*Anthropometrical indicators*					
	L/A	*W/L*	*HC*	*MAC*	*TC*	*Σ4SF*
Admission (n = 44)	-0.064	0.472†	0.184	0.393**	0.341*	0.323
7th (n = 42)[a]	0.157	0.465**	0.251	0.223	0.616†	0.652†
14th (n = 42)	0.351*	0.367*	0.640†	0.145	0.692†	0.215
30th (n = 31)[b]	0.221	0.456*	0.704†	0.215	0.725†	0.343

SGA: Appropriate for gestational age; VLBW: Very low birth weight; L/A: Length/age; W/L: Weight/length; HC: Cephalic circumference; MAC: Mid arm circumference; TC: Thigh circumference; SF: skin folds.
[a]Σ4SF n = 14.
*$p < 0.05$; **$p < 0.01$; †$p < 0.001$.
[b]Two premature infants died and nine were discharged between the 14th and 30th day.

Table V
Multiple regression model[a] of the z-score of weight/age as the dependent variable and anthropometric indicators of growth and nutritional status as the independent variables in 57 VLBW AGA premature infants and in 44 VLBW SGA premature infants

Independent variables	*Regression coefficient (r)*	*Standardized coefficient (β)*	*p*
AGA premature infants			
Head circumference (z)	0.250	0.344	< 0.001
Thigh Circumference (z)	0.160	0.291	< 0.001
Weight/length (z)	0.248	0.233	< 0.001
Mid arm circumference (z)	0.103	0.206	0.005
Length/age (z)	0.158	0.187	0.015
Σ4 Skin folds	0.175	0.162	0.045
SGA premature infants			
Thigh circumference (z)	0.320	0.561	< 0.001
Head circumference (z)	0.272	0.415	< 0.001
Mid arm circumference (z)	0.123	0.247	< 0.001

VLBW: Very low birth weight (< 1,500 g); AGA: Adequate for gestational age; (z): z-score; [a]Adjusted R2 0.757; SGA: Small for gestational age; (z): z-score; [a]Adjusted R2 0.698.

show the correlation coefficients of the anthropometric indicators in the VLBW/AGA and VLBW/SGA premature infants. The W/A z-score was assigned as the dependent variable. All the indicators were also analyzed as z-scores.

Table V show the multiple regression models of the z-score of W/A as the dependent variable and the anthropometric indicators of growth and nutritional status as the independent variables in 57 VLBW/AGA and 44 VLBW/SGA premature infants. In the VLBW/AGA premature infants, HC was the major independent variable explaining the variability of the W/A index. In the VLBW/AGA premature infants, all the anthropometric indicators explained the variability on W/A (76%). In the VLBW/SGA premature infants, only three anthropometric indicators, TC, HC and MUAC, explained the variability of the W/A index (70%).

Discussion

This study showed that the probability of having a major number of significant correlations ($r > 0.5$) among anthropometric indicators was higher in the AGA premature infants than in the SGA premature infants. This outcome was particularly true at the initial and final stages of hospitalization. These results for the different weights for gestational age of VLBW premature infants can show two different situations. 1) The differences found in the growth and nutritional status on admission to the NICU continued until the end of four weeks of hospitalization. 2) The majority of the anthropometric indices of these VLBW premature infants (≤ 1,500 g) would be better markers of growth than of the nutritional status. However, the deceleration of growth in the early stage of life according to the anthropometric indices could reflect inadequate nutritional conditions. This deceleration could be explained by other fetal or maternal factors (including oxygen restriction; maternal infection; drug addiction; and congenital and/or genetic diseases) not strictly related to insufficient and/or inadequate prenatal and postnatal nutrient intake.[24] This interpretation is reinforced by combining all the significant correlations ($r > 0.5$) among the anthropometric indices in the first 30 postnatal days. The probability of having a major number of significant correlations was higher in the AGA premature infants than in the SGA premature infants [OR = 2.7 (1.3, 5.6), p = 0.006].

These findings could indicate that there is a major congruence among the anthropometric indices when the VLBW premature infants grow normally compared with the premature infants who potentially suffered intrauterine growth restriction of intrinsic or extrinsic mono- or multi-factorial causes.[25-27] This anthropometric profile tends to remain the same during hospitalization in the NICU because of mono- or multi-factorial causes.[13,14]

It was evident that at admission and after seven days of hospitalization in the NICU, the observed significant correlations among the anthropometric indicators would explain the nutritional status and growth in the VLBW AGA premature infants. In these early stages of life and hospitalization, the less useful indicators would be those reflecting the incorporation of fat (weight/length and S4SF). Although, limitations of using these anthropometric measures as predictors of body fat should be recognized,[28,29] and also, that skinfold thickness only estimates subcutaneous fat.[30] The VLBW SGA premature infants could show different anthropometric characteristics, especially at the initial and first week of postnatal life. In this group, the W/A index is an indicator of growth and nutritional status.

Ehrenkranz et al.[14] demonstrated significant positive correlations between the velocities of weight, length, HC, and MUAC gains, indicating that infants who tended to grow rapidly in one measure tended to grow rapidly in other measures. In this group of SGA premature infants, the inverse relationship observed between L/A and W/A indices at admission and at seven days appeared to reflect a non-harmonic growth with a more acute intrauterine restriction in the weeks close to delivery. These outcomes would coincide with a subjacent fetal and/or maternal pathology or might reflect those causes that triggered early delivery.[24] It was evident that at 14 and 30 days of hospitalization in the NICU, the VLBW SGA premature infants with probable intrauterine restriction would be affected by clinical conditions and/or insufficient nutrient and energy intake. This result causes significant correlations among the indicators of nutritional status and growth, including the W/A index, TC and HC.[13]

In the VLBW SGA premature infants and postnatal malnourished infants, MUAC was the only indicator that significantly correlated with S4SF, implying that MUAC would be a better indicator for evaluating nutritional recovery by the incorporation of subcutaneous fat. In those VLBW/AGA premature infants, HC was an important indicator that not only reflects the cerebral growth but also physical growth because it significantly correlated, during the hospitalization period, with the anthropometric indicators that better expressed growth (W/A, and L/A). At the time of hospitalization and after seven days of hospitalization in the NICU, the indicator HC of the VLBW/SGA premature infants showed non-significant correlations with the other anthropometric indicators. At 14 and 30 days, the correlations of HC with the other indicators of growth such as W/A, L/A, and TC were more significant. It is probable that clinical stabilization, especially in the later stages of hospitalization, with more stable nutrient and energy intake could have a favorable influence for showing more congruence among the different indicators of growth.

This outcome is significant because of the importance of weight gain and HC growth during the early neonatal period (during hospitalization in the NICU) for long-term neurodevelopment. Poor early neonatal HC growth has been associated with abnormal neurological examinations and abnormal mobility at the age of 5.4 years, and poor early neonatal weight gain has been associated with abnormal neurological examinations and lower mental processing composite scores in multiple regression models. These results could account for the relationship between perinatal risk factors and socioeconomic status.[13,31]

The main limitation of the study would be related to the progressive decrease in the number of premature infants during the 30 days of the hospitalization period. However, the final sample (n = 80) that completed the period of study and statistical analysis was apparently sufficient.

In conclusion the results obtained in the final multiple regression analysis would indicate that the index of W/A (z) in the VLBW/AGA premature infants could reflect growth, nutritional status and energy stored as fat. In the VLBW/SGA premature infants, the TC and MUAC could be indicators of nutritional status, and the HC, besides its importance as an indicator for long-term neurodevelopment, could be an indicator of growth. The SF thickness and W/L anthropometric indicators would be less useful for the evaluation of nutritional status in the VLWB/SGA premature infants hospitalized in the NICU during the early days of life.

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