Clinical Nutrition 30 (2011) 634–639

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Body mass index and weight-for-length ratio references for infants born at 33–42 weeks gestation: A new tool for anthropometric assessment

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ARTICLE INFO

Article history:
Received 8 October 2010
Accepted 24 March 2011

Keywords:
BMI percentile
Wt/L percentile
Neonates

SUMMARY

Background & aims: The risk of childhood obesity, an increasingly prevalent problem worldwide, might be predictable by early body mass index measurements. This study sought to develop body mass index and weight-for-length ratio references for infants born at 33–42 weeks gestation and to validate these data against the growth curves of the World Health Organization Multicenter Growth Reference Study.
Methods: Data were collected from the Neonatal Registry of Rabin Medical Center for all healthy singleton babies born live at 33–42 weeks gestation. Crude and smoothed reference tables and graphs for body mass index and weight-for-length ratio by gestational age were created for males and females, separately.
Results: Birth weight, length, and body mass index percentiles for full-term neonates were similar to the World Health Organization study, reinforcing the generalizability of our reference charts for infants born at 33–42 weeks. Cutoff values for small for date (<5th, <10th percentile) and large for date (>85th, >95th percentile) infants differed across gestational ages in both pre-term and full-term infants.
Conclusions: As body proportionality indexes provide an assessment of body mass and fatness relative to length, we suggest that BMI and Wt/L ratio percentiles be added to weight and length growth curves as a routine intrauterine growth assessment at birth.

1. Introduction

Overweight and obesity are recognized as major links in the development of type 2 diabetes mellitus and metabolic syndrome, including an increased risk of cardiovascular disease. In recent years, the prevalence of childhood obesity and obesity-related complications has increased to near-epidemic proportions.[1–4] Observational evidence in human studies suggests that increased maternal weight gain during pregnancy as well as higher birth weight and faster growth in the first months and years of life are associated with overweight in childhood and adulthood.[5–11]

Body mass index (BMI), defined as weight in kilograms divided by height in meters squared, is highly correlated with subcutaneous and total body fat.[10,12] BMI is currently the measure used most often to screen for obesity. As suggested by Must et al.[13] in 1991 and consensually validated by many authors and organizations, including the US Centers for Disease Control And Prevention, and the European Childhood Obesity Group,[12,14,15] the 85th and 95th BMI percentiles serve as the cut-offs for defining overweight and obesity in children. Several screening standards have been proposed for the younger pediatric population.[16–20] The American Academy of Pediatrics currently recommends screening for weight-for-length (Wt/L) in all infants from birth to age 2 years, and for BMI in all children starting from age 2 years.[21] However, recent studies noted that BMI at birth and weight and BMI gain at age 0–3 and 3–12 months are the best predictors of overweight at age 5–7 years and early adulthood,[5–11] suggesting that BMI screening should start even earlier.

At the other end of the spectrum, malnutrition, defined as a BMI below the 5th percentile, is associated with poor neuro-developmental outcome. Although relating outcome to BMI or Wt/L

Abbreviations: CDC, Centers for Disease Control and Prevention; WHO, World Health Organization; BMI, body mass index; Wt/L, weight-for-length; LMP, last menstrual period.

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0261-5614/$ – see front matter
doi:10.1016/j.clnu.2011.03.010

Table 1
Birth weight, birth length, and BMI for girls born at 37–42 weeks gestation: comparison of Rabin Medical Center (RMC) with WHO data.

	N	L	M	S	Percentile									
					1st	3rd	5th	25th	50th	75th	85th	95th	97th	99th
Birth weight														
RMC (kg)	37916	0.714	3.219	0.132	2.3	2.5	2.6	2.9	3.2	3.5	3.7	3.9	4.0	4.3
WHO (kg)	838	0.381	3.232	0.142	2.3	2.4	2.5	2.9	3.2	3.6	3.7	4.0	4.2	4.4
Birth length (cm)														
RMC	30754	2.133	49.585	0.037	45.0	46.0	46.5	48.0	49.5	51.0	51.0	52.0	53.0	54.0
WHO	842	1	49.148	0.038	44.8	45.6	46.1	47.9	49.1	50.4	51.1	52.2	52.7	53.5
BMI (kg/m^2)														
RMC	30748	0.400	13.096	0.093	10.4	10.9	11.2	12.3	13.1	13.9	14.4	15.2	15.5	16.2
WHO	838	−0.063	13.336	0.093	10.8	11.2	11.5	12.5	13.3	14.2	14.7	15.5	15.9	16.6

Table 2
Birth weight, birth length, and BMI for boys born at 37–42 weeks' gestation: comparison of Rabin Medical Center (RMC) and WHO data.

	N	L	M	S	Percentile									
					1st	3rd	5th	25th	50th	75th	85th	95th	97th	99th
Birth weight														
RMC (kg)	39683	0.737	3.347	0.132	2.3	2.5	2.7	3.1	3.3	3.6	3.8	4.1	4.2	4.4
WHO (kg)	890	0.349	3.346	0.146	2.3	2.5	2.6	3.0	3.3	3.7	3.9	4.2	4.3	4.6
Birth length (cm)														
RMC	32040	2.255	50.327	0.038	46.0	46.5	47.0	49.0	50.0	51.5	52.0	53.0	54.0	54.5
WHO	893	1	49.884	0.038	45.5	46.3	46.8	48.6	49.9	51.2	51.8	53.0	53.4	54.3
BMI (kg/m^2)														
RMC	32034	0.351	13.228	0.092	10.5	11.0	11.3	12.4	13.2	14.0	14.5	15.3	15.6	16.4
WHO	890	−0.305	13.407	0.096	10.8	11.3	11.5	12.6	13.4	14.3	14.8	15.8	16.1	16.9

ratio percentiles seems appropriate, data in preterm infants are lacking, and most reports focused only on low birth weight. The inclusion of measures of body proportionality, such as BMI or Wt/L, as a routine complementary means to monitor growth in premature infants[22] can best be accomplished in areas where gestational-age-specific percentile curves are available. The community-based World Health Organization (WHO) Multicenter Growth Reference Study (MGRS), performed between 1997 and 2003, sought to develop new international growth references for infants and young children,[20] but their data did not include premature infants. The design of this project combined a longitudinal study from birth to 24 months of single term birth infants with a cross-sectional study of children aged 18–71 months. A total of 1743 infants from 6 participating countries were enrolled in the longitudinal cohort, 6 of whom were excluded for morbidities affecting growth, leaving a sample of 1737 infants (894 boys, 843 girls). Eligibility criteria for inclusion were: gestational age between 37–42 completed weeks, single birth, absence of significant morbidity. Full-term low birth weight infants (<2500 g, 2.1%) were not excluded.

In 2008, our group published growth charts based on the birth weight, birth length, and head circumference of infants born at 24–42 weeks gestation at a major tertiary medical center in Israel.[23] The overall objective of the present study was to use these data to compute, for the first time, BMI and Wt/L growth references for the Israeli population of infants born at 33–42 weeks gestation. The specific objective was to determine the external validity (generalizability) of our charts by comparing our data for full-term infants (37–42 weeks gestation) with the WHO growth-curve data.

2. Methods

The Beilinson Computerized Medical Birth Registry was searched for all live-born singleton neonates delivered at 24–43 weeks gestation from 1991 through 2005. Data on birth weight and birth crown-heel length were collected. At our center, birth weight is routinely measured in the naked infant within 1 h of delivery by highly trained nurses using electronic scales that are accurate to 5 g and are calibrated before each measurement. Crown-heel length is measured at the same time to the nearest millimeter with an infantometer, with the head placed against the head plate and the knees extended to the maximum. From 1991 to 1997, the determination of gestational age in our department was based mainly on the last menstrual period (LMP) and recorded in complete weeks. Thereafter, early fetal ultrasound (crown-rump length measurement) was used

Table 3
Reference data for BMI for female infants at 33–42 weeks' gestation.

Gestation	N	L	M	S	SD	Percentile											
						1st	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th	99th
33	39	2.121	10.591	.119	1.237	7.8	7.8	7.9	8.2	9.6	10.5	11.3	11.4	11.5	12.3	12.8	12.9
34	167	1.222	10.812	.114	1.223	8.2	8.4	8.6	9.2	9.9	10.8	11.6	11.9	12.2	12.7	13.0	13.8
35	301	.770	11.373	.106	1.196	8.5	9.0	9.3	10.0	10.6	11.4	12.1	12.6	12.9	13.5	13.8	14.6
36	741	−.475	11.732	.109	1.349	9.3	9.6	9.8	10.2	11.0	11.8	12.5	13.0	13.3	14.2	14.6	15.9
37	1,841	.196	12.343	.107	1.333	9.6	10.1	10.4	10.8	11.5	12.3	13.2	13.7	14.1	14.7	15.1	16.2
38	4,762	.104	12.784	.096	1.241	10.1	10.6	10.9	11.3	12.0	12.8	13.6	14.0	14.4	15.0	15.3	16.0
39	7,318	−.069	12.989	.089	1.172	10.5	11.0	11.3	11.6	12.3	13.0	13.8	14.2	14.5	15.0	15.3	16.1
40	10,049	.154	13.233	.088	1.171	10.7	11.2	11.5	11.8	12.5	13.2	14.0	14.5	14.8	15.3	15.6	16.3
41	4,766	−.249	13.380	.086	1.172	10.8	11.4	11.6	12.0	12.6	13.4	14.2	14.6	14.9	15.4	15.8	16.4
42	867	−.142	13.487	.090	1.220	10.9	11.4	11.7	12.0	12.7	13.5	14.3	14.8	15.1	15.7	16.0	16.8