

Gestational Age - the Most Important Factor of Neonatal Ponderal Index

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Ponderal index (fetal weight in grams \times 100/ (fetal length in centimeters)³) (PI) is one of the anthropometric methods used to diagnose impaired fetal growth. Irrespective of the infant's position on the growth-weight-for-gestational age charts, PI is low in malnourished infants and high in obese ones. As fetal growth is affected by ethnicity, geographic location and socioeconomic status, we developed standards for neonatal PI, and assessed the effects of gestational age, sex and maternal parity.

Data on 5798 newborns from singleton pregnancies born in the Department of Gynecology and Obstetrics, Split University Hospital, were retrospectively analyzed. Over a 15-month period in 2000/2001, 5596 newborns from 24 to 42 weeks of gestation were born. The other 202 newborns, born from 24 to 34 weeks of gestation in the ten year period, 1990-1999, were added because of the small number of preterm infants; ensuring a minimum of 30 to fill up at least infants in each gestational week. All mothers were of Caucasian origin. Stillbirths and fetuses with congenital malformations were excluded.

The 10th, 50th and 90th percentiles, mean values with standard deviation of PI and the 10th, 50th, and 90th percentiles of birth weight and birth length are presented separately at weekly intervals. PI showed linear correlation with gestational age from 24 to 39 weeks, after which the data plateaued. Sex and parity had no impact on PI in infants born between 24 and 37 weeks. Analysis of variance revealed PI to be significantly higher in female than in male newborns, and in multiparous than in nulliparous infants after 37 weeks of gestation.

In conclusion, gestational age is the most important factor of neonatal PI. The effects of sex and parity on PI should only be considered in term neonates.

Key Words: Ponderal index, fetal growth, gestational age, newborn, anthropometry

INTRODUCTION

Fetal growth and development are determined by gestational age, and genetic and environmental factors.^{1,2} According to percentile curves of weekly weight gain, neonates are divided into hypotrophic (small for gestational age), eutrophic (appropriate for gestational age), and hypertrophic (large for gestational age).^{3,4} However, being small or large does not necessarily imply that the newborn is lean or obese. Therefore, this classification does not clearly define the clinical problem involved and cannot discriminate between impaired and normal fetal growth.⁵⁻⁸

In addition to birth weight, birth length is the most important anthropometric measurement in neonates. The curves of fetal weight and fetal length according to the weeks of gestation differ in their dynamics.^{4,9} In ponderal index (PI), the neonatal weight and length are inter-related ($\text{PI (g/cm}^3\text{)} = \text{weight(g)} \times 100 / \text{length(cm)}^3$).^{7,9} Neonates can be symmetrical or asymmetrical according to PI. Symmetrical fetal development includes an appropriate relationship between fetal weight and fetal length. The neonates with low PI are of asymmetrical constitution, i.e. they have a relatively greater length than weight, which is considered a measure of leanness.¹⁰ Asymmetrical neonates with high PI have a relatively greater weight than length, which is taken as a measure of obesity. Thus, the value of PI is supplementary

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to the data on fetal weight according to gestational age, and taken together these two measures provide complete information on the fetal growth pattern.^{9,11-13}

The objective of anthropometric measurements is to screen for newborns at risk, as fetal hypotrophy and hypertrophy are known factors of increased perinatal risk.^{5,6,14} Studies have demonstrated the association of inappropriate PI with acidosis, poor neonatal outcome, and neonatal neurologic disorders.^{6,9,15} Neonatal PI also impacts glucose tolerance in childhood, body mass index and overweight in young males, and blood pressure and risk of coronary heart disease in male adults, and influences the age of menopause.¹⁶⁻¹⁹ Standardization of PI values is a precondition for correct interpretation of results in clinical practice.

MATERIALS AND METHODS

Data on the 5,798 mothers and their infants born at 24 to 42 weeks of gestation from singleton pregnancies at the Department of Gynecology and Obstetrics, Split University Hospital, were retrospectively analyzed. The investigation included all mother-infant pairs born from January 1, 2000 to April 1, 2001 (N=5,596). Because of the small number of infants born from 24 to 34 weeks of gestation, the investigation period was extended with the addition of 202 newborns from the 10-year

period 1990-1999, in order to attain a minimum of 30 newborns for every week of gestation. Multiple pregnancies, and stillborn and malformed fetuses were excluded from the study. All neonates were weighed immediately upon birth on the same scale (Libela, Celje, Slovenia), whereas birth length was measured in the formation tub. Gestational age, expressed in completed weeks of gestation, was calculated according to the first day of the last menstruation and was corrected by ultrasonic assessment when a discrepancy exceeded one week. Data were grouped according to weeks of gestation. The preterm (24 to 36 weeks of gestation) and term (37 to 42 weeks of gestation) newborns were analyzed as two separate groups. Mothers were divided according to parity into primiparae and multiparae (irrespective of the number of previous deliveries).

RESULTS

A total of 5,798 Caucasian mothers and their offspring were analyzed. The lowest number (n=30) of neonates were born in week 25 of gestation, and there was no birth beyond week 42 of gestation. The mean neonatal PI was 2.69 ± 0.267 , standard deviation (SD) 3.5×10^{-3} , and median 2.71. The PI values showed a Gaussian distribution (Fig. 1). The neonatal sex distribution was identical across the weeks of gestation as well as

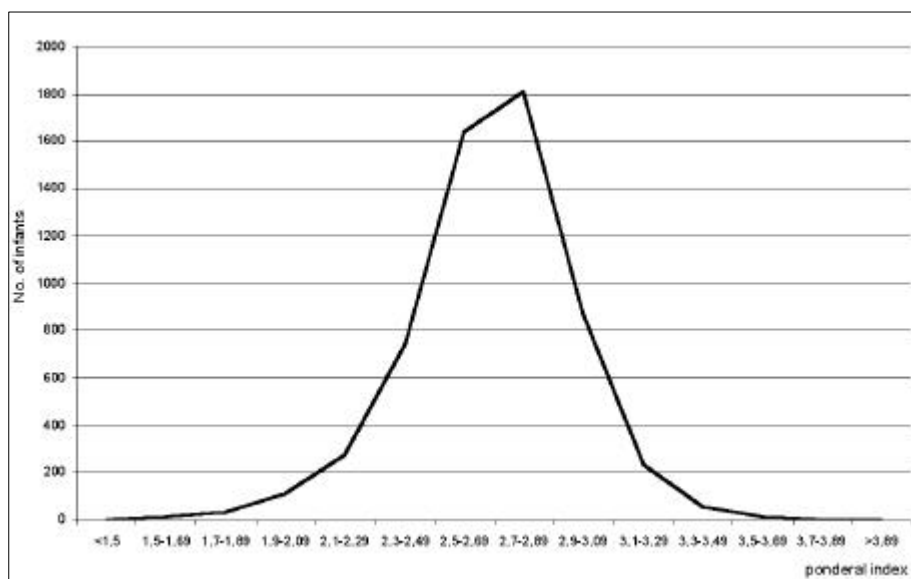


Fig. 1. Ponderal index value distribution.

in the groups of mothers divided according to parity ($p < 0.05$).

PI values were statistically, significantly different according to gestational age (ANOVA, $F=92.8$; $p=0.000$). Post hoc analysis (Duncan's test, significance: $p=0.05$) demonstrated that only between 39 to 42 weeks of gestation did PI values not differ, indicating that PI plateaued in week 39. From 24 to 39 weeks of gestation, PI values were growing significantly according to gestational age (Fig. 2). Therefore, Pearson's coefficient of correlation between PI and gestational age was calculated ($r=$

0.57; $p < 0.01$) and regression analysis of PI and gestational age between 24 and 39 weeks of gestation was performed (Fig. 3, Table 1). The values of PI, birth weight and birth length, according to weeks of gestation, are shown in Table 2.

Considering the sample in total, a significantly higher PI was recorded in children born to multiparae vs. primiparae (ANOVA, $F=45.00$; $p=0.000$) and in female vs. male infants (ANOVA, $F=4.17$; $p=0.041$); however, no such correlation was observed in preterm infants, either in relation to sex

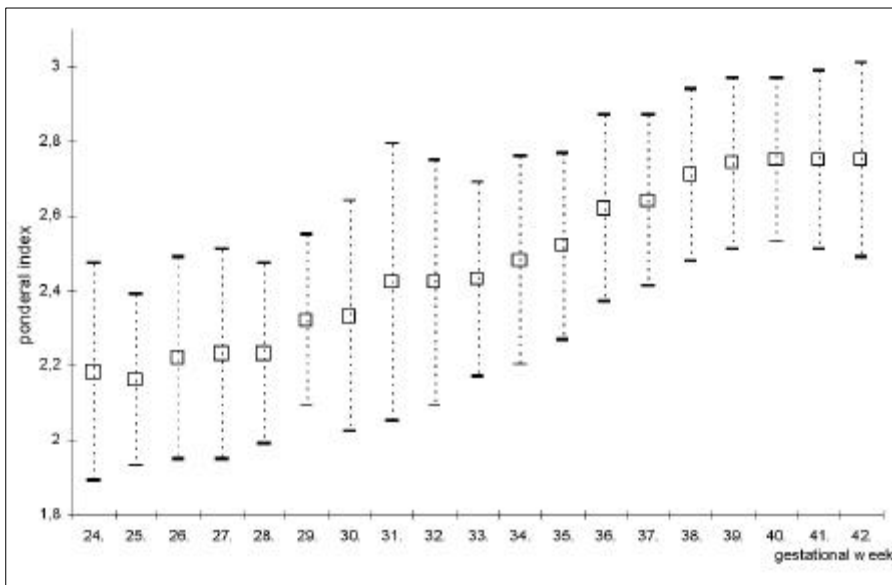


Fig. 2. Mean values and standard deviation of ponderal index according to gestational age from 24 to 42 weeks.

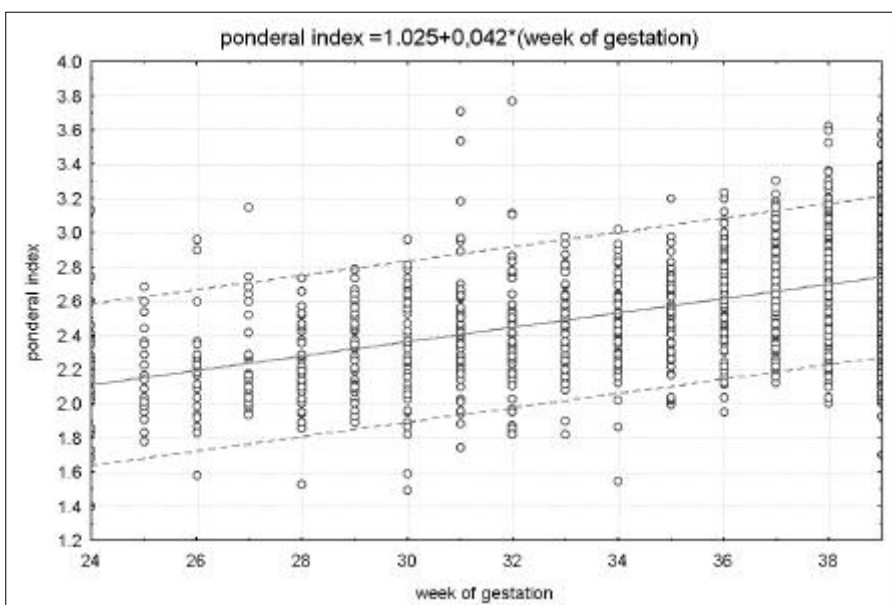


Fig. 3. Correlation of ponderal index with gestational age from 24 to 39 weeks (regression analysis).

Table 1. Summary of the Regression Analysis of Ponderal Index and Gestational Age from 24 to 39 Weeks

Regression summary for dependent variable: ponderal index R=0.53 R ² =0.28 Adjusted R ² =0.28						
N=3284	Beta	Standard Error of Beta	B	Standard Error of B	t(3282)	p-level
Intercept			1.102	0.043	25.591	0.00
Gestational age from 24 to 39 weeks	0.533	0.014	0.041	0.001	36.093	0.00

F(1,3282)=1302.8.

p<0.00.

Standard.Error of estimate: 0.24.

(ANOVA, F=2.39; $p=0.122$) or maternal parity (F=2.42; $p=0.120$). In contrast, PI was significantly higher in term female than term male newborns (ANOVA, F=3.94; $p=0.047$), and in term neonates born to multiparae than in those born to primiparae (ANOVA, F=35.00; $p=0.000$) (Table 3).

When the study sample was divided into four groups according to maternal parity and newborn sex (primipara-male, primipara-female, multipara-male, and multipara-female), there was no statistically significant difference in PI according to gestational age (ANOVA: total sample, F=0.01; $p=0.977$; preterm infants, F=0.51; $p=0.45$; and term infants, F=0.45; $p=0.475$).

DISCUSSION

Fetal growth is determined by gestational age, and by genetic and environmental factors. In ideal conditions, the fetus achieves the genetically determined growth potential using the growth support available. According to birth weight for gestational age, newborns are divided into small, appropriate, and large for gestational age. However, the dynamics of fetal growth in length differ from those of fetal weight gain.^{3,4} PI takes both of these anthropometric values into account. As defined, PI determines the nutritional status of the neonates. According to PI, newborn infants are divided into obese, malnourished, and normal.

Neonatal hypertrophy with normal PI usually is genetically determined, whereas its association with elevated PI frequently is due to pregnancy complicated with diabetes mellitus. Neonatal hypotrophy with low PI is associated with pre-

natal malnutrition, whereas its association with normal PI indicates that a genetically determined low growth potential has been accomplished. In such a way, genetically determined fetal growth impairments that do not imply an increased perinatal risk can be identified within particular groups of neonates with impaired fetal growth. PI is not an alternative to the methods of neonate classification exclusively according to body mass, but is an adjunct to these methods. As these measurements are aimed at screening for the neonates at risk, more data are obtained with the use of PI and the respective clinical practice is considerably upgraded. Considering the known geographic, racial, ethnic and socioeconomic effects on the anthropometric parameters involved, each institution should develop its own standard PI values and update them continuously because of biological variation between generations.²⁰⁻²²

Based on the authors' experience, stillbirths, cases of neonatal malformation, and children born from multiple pregnancies were excluded from the study.^{4,9,23} Children born from pregnancies complicated with diabetes mellitus, preeclampsia, or Rh immunization, early neonatal deaths, disproportionate children, and those delivered with breech presentation were not excluded. Although there are contradictory opinions on the inclusion of these groups of newborns in similar studies, we consider that newborns at risk should be considered part of the general population and should therefore be included in such a study.^{4,7,9,21,24-26}

Gestational age was determined according to the first day of last menstruation corrected by ultrasound finding when the discrepancy exceeded one week. Results are presented according

Table 2. Ponderal Index, Birth Weight and Birth Length According to Weeks of Gestation

Gestational age (completed weeks)	No. of infants	Ponderal index (g/cm ³)			SD*	Birth weight (g)			Birth length (cm)			
		10th percentile	50th percentile	90th percentile		Mean value	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
24	42	1.72	2.16	2.46	2.18	0.29	500	600	700	28	30	32
25	30	1.90	2.15	2.54	2.16	0.23	600	700	850	30	32	34
26	35	1.89	2.22	2.59	2.22	0.27	650	850	950	31	33	36
27	44	1.95	2.18	2.62	2.23	0.28	750	900	980	32	34	36
28	56	1.95	2.17	2.58	2.23	0.24	1000	1200	1350	36	38	41
29	52	1.98	2.27	2.63	2.32	0.23	1000	1320	1600	36	38	41
30	53	1.96	2.33	2.66	2.33	0.31	1150	1450	1800	37	40	43
31	56	2.01	2.34	2.78	2.42	0.37	1350	1680	1950	39	41	44
32	57	2.02	2.38	2.78	2.42	0.33	1350	1900	2300	39	43	45
33	61	2.11	2.41	2.77	2.43	0.26	1350	2000	2450	39	43	47
34	61	2.16	2.51	2.83	2.48	0.28	1600	2200	2800	41	45	48
35	70	2.21	2.53	2.82	2.52	0.25	1800	2450	2900	42	46	49
36	118	2.23	2.64	2.9	2.62	0.25	2200	2800	3350	45	47	50
37	269	2.32	2.64	2.95	2.64	0.23	2450	3050	3550	46	49	51
38	724	2.43	2.71	2.98	2.71	0.23	2700	3250	3900	47	50	52
39	1556	2.47	2.72	3.03	2.74	0.23	2900	3500	4100	48	50	53
40	1762	2.48	2.75	3.03	2.75	0.22	3050	3600	4200	48	51	53
41	652	2.45	2.75	3.05	2.75	0.24	3150	3700	4300	49	51	54
42	100	2.41	2.73	3.09	2.75	0.26	3150	3800	4550	49	52	55

*SD-standard deviation.

to completed weeks of gestation. In literature reports, the terms of 'current', 'completed', and 'nearest' weeks are used, which makes any objective comparison of the results quite difficult.^{4,9,24} With the exception of Chard et al., who included only preterm infants in their study, all other authors found the effect of gestational age on PI to be significant.^{9,11,20,27-29} Therefore, an accurate assessment of gestational age is the key for correct interpretation of the infant's anthropometric values.

Linear correlation between PI and gestational age has not yet been reported. A plateau of PI increase has invariably been reported to occur between 37 and 40 completed weeks.^{9,10,20,30} In our study, the values of PI underwent no major changes beyond week 39 of gestation. There was no linear correlation of fetal weight gain or fetal length increase (Table 1) with pregnancy duration, whereas the dynamics of their increase differed from the dynamics of PI increase. The linear PI dependence on gestational age allowed for calculation of the expected mean PI from 24 to 39 weeks of gestation (Fig. 3). The impact of gestational age on PI during this period was numerically evaluated by the coefficient of determination of 0.325 (32.5%).

Most of the studies in the field were conducted in the United States.^{7,9,20} In our study group, the absolute PI values were higher in all weeks of gestation than those reported elsewhere.^{9,10,20} This discrepancy of the results could in part be explained by the effect of geographic factors on anthropometric standards.⁹ With the exception of Miller et al., who noted different dynamics of PI increase in Black female term infants, other authors found no racial impact on PI.^{9,20,27} Neonatal sex and maternal parity were found to be significant factors of PI only in term infants; not in preterm ones. Female term infants had higher PI than male term infants. Also, children born to multiparae had higher PI than those born to primiparae. Similar results have been reported by Miller et al., whereas other authors do not consider maternal parity and neonatal sex to be of any major relevance for PI.^{9,20,27,31} When the infants were divided into four groups according to sex and maternal parity (primipara-male, primipara-female, multipara-male, and multipara-

female), PI showed no statistically significant difference. Therefore, the results are presented according to weeks of gestation, irrespective of sex and maternal parity.

Some authors decided to simplify PI standards and accept PI values from 2.2 to 3.0 as normal.^{32,33} We are inclined to believe that gestational age should not be neglected in the interpretation of PI values. The impact of sex and maternal parity on PI value is less pronounced and refers exclusively to term infants, when the rate of perinatal complications is lower. Accordingly, we consider that special standards for PI relative to neonatal sex and maternal parity are not necessary.

Gestational age was the most important factor of PI value. PI showed linear correlation with gestational age from 24 to 39 weeks of gestation, when it reached a plateau and remained unchanged until week 42 of gestation. Neonatal sex and maternal parity had a significant impact on PI exclusively in term newborns.

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