Catch-up growth among low birth weight infants:
Estimation of the time of occurrence
of compensatory events

Magdalena Kosińska,1 Bogumiła Stońska,2
Janusz Gadzinowski2

1 Institute of Anthropology, Adam Mickiewicz University, Fredry 10,
61-701 Poznań, Poland; E-mail: gdusia@amu.edu.pl
2 Chair and Department of Neonatology, University of Medical Sciences,
Polna 33, 60-535 Poznań

ABSTRACT The aim of this study was to estimate the time elapsed between
the birth and the occurrence of catch-up growth in the first 12 months of life,
in groups of infants born with low birth weight (less than or equal to 2500g).
Postnatal catch-up growth had occurred in 100 cases (60 boys and 40 girls).
There were no statistical differences between the sexes in the frequency of
growth compensation and in the time of the occurrence of the event. In the 2nd
and the 10th month of life the fewest number of compensational events were
observed, but there is no particular time which can be identified as having the
most rapid velocity. The category of birth body weight, gestational age and
occurrence of intrauterine growth retardation had a distinct influence on the
time distribution of growth compensation. Preterm delivery compounded the
effects on growth of small-for-gestational age births.

KEY WORDS newborns, growth compensation, growth velocity, gestational
age, intrauterine growth retardation

Introduction
It is well documented that birth weight
is one of the most significant predictors
of physical development throughout
infancy and childhood. In recent years,
due to advances in peri- and neonatal-
ogy, and particularly owing to progress
in medical care, the survival rate of
newborns with low birth weight has
significantly increased [CHRZĄSTEK-
SPRUCH et al. 1996, FURMAGA-JABŁOŃ-
SKA 1999]. These infants may experi-
ence a different pattern of physical
growth to those born with appropriate
birth weight [HARVEY et al. 1982,
CASEY et al. 1990, HEDIGER et al. 1998, KOSIŃSKA and SITEK 2003] and are more likely to remain underweight subsequently. Ideally, they should exhibit increased growth velocity which will allow them to reach the weight values adequate for their age. The achievement of constitutional growth after a reduction in growth rate associated with illness and malnutrition has been termed as catch-up growth [PRADER et al. 1963]. The relationship of low birth weight to subsequent growth and physical development has been a subject of much study in recent years [e.g., OUNSTED et al. 1982, 1984; STRAUSS 1997; McCOWAN et al. 1999]. However, existing studies have revealed inconsistent results with respect to both growth compensation and the time of the occurrence of this event. It has been found that infants that are born small generally show catch-up in the first year of life despite being at risk from poor postnatal growth and development [SCOTT et al. 1982, CASEY et al. 1990, ALBERTSSON-WIKLAND et al. 1993, HOKKEN-KOELEGA et al. 1995, S HETH et al. 1995, HEDIGER et al. 1998]. These contradictory results may be explained by the varying reasons for the occurrence of low birth weight. The deviation from the expected birth weight may be a consequence of preterm delivery or intrauterine growth retardation. In some cases both these factors are implicated [NORSKA-BORÓWKA 1986, KRAMER 1987].

The aim of this study was to estimate the time elapsed between the birth and the occurrence of catch-up growth within the first 12 months of life in groups of infants born with low birth weight (less than or equal to 2500g).

Materials and methods

The research cohort was selected from longitudinal studies of both infants born preterm and infants born with small birth weight. Data were collected on 231 singleton infants born in 1999-2000 in the Obstetrics and Gynaecology University Hospital in Poznań, whose birth body weights were less than or equal to 2500g. Qualified nursery staff measured the birth weight immediately after the birth, with a precision of up to 10g. The length of gestation was calculated in completed weeks from the mother’s last menstrual period (LMP). The occurrence of intrauterine growth retardation (IUGR) was estimated using the birth weight percentile position (below the 10th percentile) with reference to the data for the Wielkopolska Region (GADZINOWSKI et al. 2003).

Infants with well-defined causes for growth retardation, such as chromosomal disorders, syndromes, and severe malformations, were excluded from the studies. Finally, 181 infants (109 boys and 72 girls) were followed up to examine the consequences of low birth weight on growth in the first year of life.

The catch-up growth event is defined as the compensation of body weight values to values included between ±1SD in the reference system [CIEŚLIK et al. 1994]. In order to study the time that elapses between birth and the occurrence of catch-up growth within the first 12 months of life, the infants’ body weight was observed at monthly intervals. Data were analysed using the Product-Limit-Method (Kaplan-Meier) for description and the $\chi^2$ and the $F$-Cox test for comparison, as implemented...
in the survival analysis module of STATISTICA 6.0 (StatSoft. Inc.2004). These methods estimate and compare survival functions where the life history of every individual is known. Furthermore, they allow the inclusion of censored data, i.e. incomplete data from infants whose body weight was still lower than expected when the study ended or data of infants with whom contact had been lost before the end of the study [KLEINBAUM 1996, KOSIŃSKA and SZWED 2004].

The project was carried out with permission of the Bioethical Commission of the University of Medical Sciences in Poznań.

Results

The studied newborns were delivered with birth weight from 560-2450g (boys: $\bar{x} = 1655\pm489g$; $Me = 1620g$; girls: $\bar{x} = 1706\pm415g$; $Me = 1755g$), between the 24th and 40th week of gestation (boys: $\bar{x} = 31\pm3$; $Me = 31$; girls: $\bar{x} = 32\pm3$; $Me = 32$). Of 181 individuals, 162 (89%) were born preterm (below the 37th week of gestation) and 17 (9%) were born with birth weight less than or equal to 1000g (Tab. 1). Considering the percentile position, it was observed that 42 (23%) of infants were born with birth weight small-for-gestational age (below the 10th percentile). In 23 (13%) cases preterm delivery was coincident with intrauterine growth retardation.

Postnatal catch-up growth occurred in 100 cases (60 boys and 40 girls). In the remaining group there were infants who achieved the studied event over the entire study period ($N=49$) or with whom we had lost contact ($N=35$). Because there were no statistical differences between the sexes in the frequency of growth compensation ($\chi^2 = 0.005$, $p = 0.946$) and moreover, as there were no statistical differences in the time of the occurrence of this event ($F_{80,120} = 1.137$; $p = 0.260$) further analyses were carried out for both boys and girls together.

The slope of the Kaplan-Meier curve is regular (Fig. 1); there being no particular time which can be identified as the time of the most rapid velocity. Only in the 2nd and in the 10th month of life were the fewest number of compensational events observed. It is worth noting that 50% of infants who experienced catch-up growth in their weight had done so by the 9th month of life.

### Table 1. The frequency of birth weight and gestational age categories

<table>
<thead>
<tr>
<th>Categories of examined features</th>
<th>Boys</th>
<th></th>
<th></th>
<th>Girls</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight</td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x-1000g</td>
<td>13</td>
<td>11.9</td>
<td>4</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1001-1500g</td>
<td>29</td>
<td>26.6</td>
<td>18</td>
<td>25.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1501-2500g</td>
<td>67</td>
<td>61.5</td>
<td>50</td>
<td>69.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x:28th week</td>
<td>20</td>
<td>18.3</td>
<td>9</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29th-32nd week</td>
<td>49</td>
<td>45.0</td>
<td>32</td>
<td>44.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33rd-36th week</td>
<td>30</td>
<td>27.5</td>
<td>22</td>
<td>30.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>after 36th week</td>
<td>10</td>
<td>9.2</td>
<td>9</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Birth weight, the occurrence of intrauterine growth retardation and gestational age can be treated as predictors of the course of postnatal physical development. Therefore, in the further analysis, the time of the occurrence of catch-up growth was studied in the light of these variables. As expected, the category of birth body weight had a distinct influence on the distribution of the time of the growth compensation ($\chi^2 = 28.894; p < 0.001$) (Fig. 2). The probability of reaching the expected value of body weight increases with increasing birth body weight. Comparing three groups of infants it was found that the cumulative proportion of compensational events was significantly different (Fig. 2). Infants born with birth weight below 1000g attained the appropriate weight in only about 10% of cases and in nearly 80% of cases of infants with birth weight above 1500g.

Low birth weight may be a result of intrauterine growth retardation the consequence of which is a birth weight small for gestational age. According with common knowledge a higher probability of poor postnatal growth was observed in the group of infants with intrauterine growth retardation ($F$-Cox test: $F_{28,172} = 2.359; p < 0.001$) (Fig. 3). In the group of infants born as small-for-
gestational age, catch-up growth was found only in 50%. The highest number of compensational events was observed in the 4th and in the 12th month of life. Infants with appropriate birth weight equaled birth weight to expected values in 70% of cases.

The diverse distributions of the time of catch-up growth were also observed for different categories of gestational age ($\chi^2 = 17.821; p < 0.001$) (Fig. 4). As anticipated, the lowest probability of growth compensation within the studied period was observed in infants born before the 29th week of gestation. Within this group of infants compensation of body weight was observed in 38% of cases. The earliest occurrence of body weight increase was not observed in the most mature group (delivered above the 36th week) but in the group born within the 33rd-35th week of gestation. The difference between these two groups is statistically significant ($F$-Cox Test: $F_{68,14} = 2.349; p < 0.05$).

Preterm delivery compounded the effects on growth of being born small-for-

![Fig. 4. Kaplan-Meier curve for probabilities of compensational events in groups of infants distinguished by the category of gestational age (GA)](image)

![Fig. 5. Kaplan-Meier curve for probabilities of compensational events in groups of infants distinguished by the category of gestational age (GA) and the occurrence of intrauterine growth retardation](image)

gestational age ($\chi^2 = 25.269; p < 0.001$). In Fig. 5 the results of the analysis of time distribution on the dependence of the gestational age and the occurrence of intrauterine growth retardation are shown. Only one case of an infant born small-for-gestational age before the 29th week of gestation was observed. The weight of this infant was still lower than expected when the study terminated, so it wasn’t included in this analysis. Consistent with expectations, the poorest postnatal growth was recognized among infants with the lowest gestational age and with intrauterine growth retardation. Generally, infants having intrauterine growth retardation compensated their growth later and in fewer cases than those infants without this discordance. For the group of infants delivered with birth weights above the 10th percentile, only those born before the 29th gestational week showed a similar low probability of catch-up growth occurrence.
Discussion

Birth weight is one of the most important indicators of infant health. It can be treated as a predictor of mortality, morbidity and the course of postnatal physical development. The tendency of birth weight to determine growth status throughout childhood has been demonstrated in many studies [e.g., GARN et al. 1977; HACK et al. 1982, 1996; GARN 1985; BRODY 1995]. A vital aspect of the growth processes of infants with low birth weight is the compensation of growth to infants with appropriate birth weight.

Postnatal catch-up growth occurred in 68% of the infants that were studied for the whole examination period (12 months). The rest were likely to remain underweight up to the 2nd or even the 4th year of life, as has been found by other authors [FITZARDINGE and STEVEN 1972, ALBERTSSON-WIKLAND et al. 1993, LEGER et al. 1997]. Several investigators have shown that most catch-up growth occurs in the first 6 months after birth. [SCOTT et al. 1982, TENUOVO et al. 1987, FITZARDINGE and INGWOOD 1989]. In our studies, 50% of all infants which experienced catch-up growth had done so by the 9th month of life. The reason for this contradictory result may be explained by the fact that the research material included only infants with birth weight of less than, or equal to 2500g, alternatively, by the fact that the outcome and postnatal development of low birth weight infants varies between different countries. The slope of the Kaplan-Meier curve, drawn for all the studied infants, is regular, so no time could be identified as that of the most rapid velocity. The distinct slopes of the curves can be observed in those groups of infants distinguished by the category of birth weight, gestational age or the occurrence of intrauterine growth retardation. Only the curves drawn for infants with birth weight of 1501-2500g and for infants born after the 33rd gestational week allow it to be stated that the 6th month of life is the indication point for compensatory growth.

As mentioned above, birth weight, the occurrence of intrauterine growth retardation and gestational age can be treated as predictors of the course of postnatal physical development. By studying the time of the occurrence of catch-up growth in the dependence of these variables, this statement has been confirmed. The category of birth body weight had a distinct influence on the distribution of the time of growth compensation and on the cumulative proportion of compensational events. This diversity may undoubtedly be explained by the quantity of the remainder between the observed and expected values.

There are numerous reasons for the delivery of infants with birth weights less than or equal to 2500g [NORSKA-BORÓWKA 1986, KRAMER 1987]. One of such reasons is the occurrence of intrauterine growth retardation, of which a consequence is the birth weight small-for-gestational age. A higher probability of catch-up growth was observed in infants without intrauterine growth retardation. For the group of infants born small for gestational age, catch up growth was found only in 50%. Other authors have also shown that children who were small-for-gestational age at birth are more likely to remain underweight at one year of age than children
who were appropriately grown at birth [FITZHARDINGE and STEVEN 1972, ALBERTSSON-WIKLAND et al. 1993, LEGER et al. 1997].

A further factor responsible for low birth weight is preterm delivery. Thus, gestational age, rather than purely low birth weight, may be the correlate of the time of compensation of growth. For different categories of gestational age, diverse distributions of the time of catch-up growth were observed. The lowest probability of growth compensation within the study period was observed in infants born before the 29th week of gestation, but the increase of maturity is not equivalent to the increase of catch-up growth probability. The earliest occurrence of body weight gain was observed not in the most mature group but in the group delivered between the 33rd - 35th week of gestation. This may have been caused by the occurrence of intrauterine growth retardation in the whole group of infants born after the 36th week of gestation. Hence, it can be stated that preterm delivery compounds the effects on the growth of infants born small-for-gestational age. According to the results of other authors [ROSS et al. 1985, KARNISKI et al. 1987, CASEY et al. 1990], the poorest postnatal growth was recognized within infants having the lowest gestational age and exhibiting intrauterine growth retardation.

In this paper catch-up growth has been statistically defined. This depiction plays down the significance of genetic and environmental variability that, undoubtedly, has an influence on the time of growth compensation. This approach, however, was not the aim of this study as it was recognized that involving more factors would have decreased the homogeneity of the study cohort [FITZHARDINGE and STEVEN 1972]. Excluding infants with chromosomal disorders, syndromes and severe malformations rationalizes the cohort to infants apparently normal at birth except for their size.

**Conclusions**

The births of infants with birth weights less than or equal to 2500g are correlated to the risk of deficient postnatal growth. There are numerous, often compounded, causes for delivery of infants with birth weights less than or equal to 2500g. Depending on the cause for the occurrence of low birth weight, compensation of growth occurs at different times and with different degrees of probability.

**Acknowledgement**

This study was supported by interdisciplinary grant founded by Adam Mickiewicz University and the University of Medical Sciences in Poznań (No. 502-06-2-0003550 UAM-AM).

**References**


HACK M., I.R. MERKATZ, D. GORDON, P.K. GARN S.M., 1985,
Perinatal predictors of growth at six months in small for gestational age babies, Arch. Pediatr., 117(2), 298-307


FURMAGA-JABŁOŃSKA W., 1999, Długofalowa analiza rozwoju fizycznego dzieci urodzonych z małą masą ciała z uwzględnieniem wieku płodowego i chronologicznego, FOLIUM, Lublin

GADZINOWSKI J., M.D. KALISZEWSKA-DROZDOWSKA, M. KOSIŃSKA, J. MAZELA, B. STOŃSKA, 2003, Urodzeniowa masa ciała a wiek płodowy noworodków regionu Wielkopolski i Ziemi Lubuskiej, Gin. Pol., 74(3), 186-192


HARVEY D., J. PRINCE, J. BUNTON, C. PARKINSON, S. CAMPBELL, 1982, Abilities of children who were small-for-gestational-age babies, Pediatrics, 69, 296-300


MCCOWAN L., J. HARDING, S. BARKER, C. FORD, 1999, Perinatal predictors of growth at six months in small for gestational age babies, Early Hum. Develop., 56, 205-16


OUNSTED M., V. MOAR, A. SCOTT, 1982, Growth in the first four years: II. Diversity within groups of small-for-dates and large-for-dates babies, Early Hum. Dev., 7, 29-39

Streszczenie

Dzięki dynamicznemu rozwojowiperi- i neonatologii obniżeniu uległadolna granica wieku płodowego i urođeniowej masy ciała będąca wyznaczonym przeżywalności noworodków. Tym samym zwiększyła się liczba dzieci urodzonych z małą masy ciała, których rozwój może przebiegać w sposób odmienny od przyjętych norm. Odległość rokowania dotyczącego rozwoju dzieci urodzonych z małą masą ciała są niepewne a dotychczasowe badania wykazują sprzeczne wyniki dotyczące dalszego przebiegu procesów ontogenetycznych. Ważnym aspektem przebiegu wzrostania tej grupy dzieci jest wyrównywanie rozwoju fizycznego do grupy dzieci urodzonych z prawidłową masą ciała.

W przedstawionej pracy zawarto wyniki analiz czasu wyrównania masy ciała (zjawisko „catch-up growth”) przez dzieci urodzone z małą masą ciała (do 2500g) w zależności od stanu dojrzalości w momencie urodzenia określonego poprzez urodzeniową masę ciała, występowanie wewnątrzmaciczego zahamowania rozwoju oraz wiek płodowy. Dane, dotyczące urođeniowej masy ciała oraz masy ciała w kolejnych 12 miesiącach życia 181 noworodków zebrano w ramach długofalowych badań noworodków przedwcześni oraz noworodków urodzonych z małą masą ciała. Występowanie zjawiska wyrównania rozwoju określono na podstawie porównania z normami rozwojowymi. W celu określenia rozkładu w czasie występowania badanego zdarzenia zastosowano jedną metodę analizy przeżycia (metodę Kaplana-Meiera). Zróżnicowanie rozkładów wynikające z poziomu dojrzalości w momencie urodzenia oszacowano za pomocą testu F-Coxa oraz testu χ². Ze względu na brak istotnych różnic w częstości występowania oraz czasu występowania zjawiska „catch-up growth” pomiędzy grupą chłopców i dziewcząt, analizie poddano łącznie obie płcie.

Równomierny spadek krzywej Kaplana-Meiera nie pozwala na wskazanie momentu najbardziej charakterystycznego dla występowania zjawiska wyrównania. Spośród badanych noworodków 50% wyrównało poziom rozwoju do 10 miesiąca życia. Przeprowadzone analizy potwierdziły wpływ wartości urodzeniowej masy ciała (stopnia odczynienia tej cechy od wartości oczekiwanej), obecności wewnątrzmaciczego zahamowania rozwoju oraz wieku płodowego na czas wyrównania poziomu rozwoju. Wyraźnie widoczne jest nałożenie się na przebieg rozwoju postnatalnego badanych dzicy efektów wcześniactwa oraz występowania wewnątrzmaciczego zahamowania rozwoju.