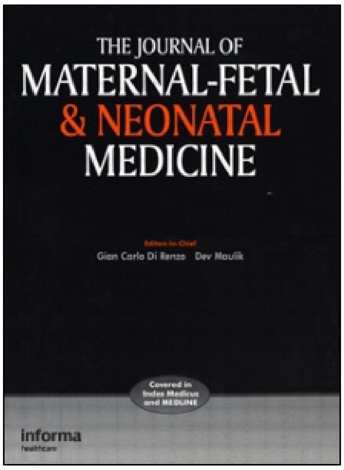

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The effect of intrauterine development and nutritional status on perinatal mortality

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The effect of intrauterine development and nutritional status on perinatal mortality

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Abstract

Objective. To study the influence of bodily development and nutritional status on perinatal mortality.

Methods. The authors developed a new method, the MDN system (MDN: Maturity, Development, Nutritional Status), to determine the development and nutritional status of newborns based on their weight and length standard positions. Using data of 680,947 neonates born in the 7 years from 1997 to 2003 in Hungary, they computed the perinatal mortality (PM) rate of each developmental groups of neonates.

Results. PM in the group of neonates of absolute average development was 7‰, 30‰ in the proportionally retarded group and it was 90‰ in the extremely overnourished group. The PM rate was the highest (191‰) in the extremely undernourished group.

Conclusions. Both bodily development and nourishment have a major impact on PM. The MDN system is a suitable method to differentiate the most endangered groups of neonates based on their development and nutritional status.

Keywords: *Perinatal mortality, birth weight and length standard, classification of neonates, intrauterine growth retardation, MDN-system*

Introduction

Obstetricians and neonatologists have made efforts for a long period to estimate the life chances of neonates precisely soon after their birth, but possibly in the delivery room. The objective is twofold: to diagnose possible diseases and recognise and differentiate the neonates who are highly endangered because of the deficiencies and disorders of their bodily development.

The most common method is still in use: by measuring the bodyweights of neonates, one can immediately differentiate the ones whose weights are below 2500 g, and who are regarded as being the most endangered newborns. Recently, however, specialists normally differentiate neonates of body weight below 1500 g, those less than 1000 g, as well as those who weigh less than 500 g at birth. At the same time, we have learned that body weight alone is not a reliable parameter to estimate the life chances of a neonate [1–5]. It has a series of reasons: (1) body weight depends on many factors; (2) each weight group is extremely heterogeneous when gestational age, body length and nutritional status (nourishment) are considered [6,7], however, scientific research needs heterogeneous groups to study; (3) because the average birth weights of neonate populations greatly differ by country and race [8], there is no practical chance to develop uniform weight criteria to be applicable in each country.

Another option is to determine the gestational ages of neonates in order to differentiate highly endangered or preterm babies. As the survival chance correlates with gestational age rather than with birthweight, in 1961 WHO declared, not the neonates of birth weight below 2500 g, but those born before the 37th week have to be considered prematured [1].

Lubchenco et al. [9] was the first to recognise that body weight and gestational age have to be considered simultaneously to determine bodily development of a neonate. On the basis of the birth standards developed by Battaglia and Lubchenco, it was recommended that newborns below the 10th

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weight percentile, or SGA (small for gestational age), were qualified as being highly endangered. Later on, SGA neonates were referred to as having intrauterine growth retardation (IUGR), because many newborns in the weight group under the 10th weight percentile were found to have retardation syndrome.

However, it was revealed later that the clinical picture of retardation is not a uniform syndrome taking into account its etiology, clinical picture and prognosis [10–19]. As a basic requirement, one has to be able to differentiate proportionally and disproportionally retarded (DPR) newborn babies. One can only do that if body length is considered apart from gestational age and birth weight [11,15,20,21]. Rohrer's Ponderal Index [20,22] was introduced for this purpose, but it was not commonly used, because the data base to calculate the index was limited and the proposed mathematical formula [(gram/cm^3) × 100] was not popular. Nevertheless, more and more authors underline the need for the consideration of nutritional status.

Recent scientific results confirm the recognition that the development and nutritional statuses of foetuses and neonates have a major impact on their viability, intrauterine and neonatal [23,24] morbidity, as well as on their morbidity in adulthood [18,25–27]. It also has been proven that development and nutritional status at birth influence the growth rate and bodily development, moreover the intellectual faculties of a child up until 18 years of age [28,29].

The authors firmly believe that all time exact estimations of the survival chances and the degree of endangeredness of neonates can be permitted of all the three important factors are simultaneously considered: (i) maturity (gestational age); (ii) bodily development (weight and length standard positions determined based on the appropriate weight and length standards); (iii) nutritional status depending upon the relative weight and length development. However, the question is how to consider all this at the same time, and more importantly, how to differentiate less endangered and highly endangered neonate groups identified in this complex system of classification. The authors developed a new method to achieve all this.

In the present study the authors describe their novel method, the MDN system (MDN: Maturity, Development, Nutritional status) [7] and its application:

- to determine the nutritional status of a neonate on the basis of its gestational age, length and weight development considered simultaneously;
- to differentiate the most viable and the most endangered neonates on the basis of their development and nutritional status;
- to demonstrate the influence of a neonate's nutritional status by the gestational age on its perinatal mortality (PM).

Method – the MDN system

The MDN system, integrating four important birth parameters, offers a method to decide to what extent a neonate is endangered on the basis of its bodily development and nutritional status. The four parameters are as follows: sex, gestational age, birth weight and birth length.

On the basis of gestational age, sex and birth weight the newborn's weight development (or its position to the weight standard percentiles) can be determined, and applying gestational age, sex and birth length its length development (or its position to the length standard percentiles) can be appointed. The weight and length development considered simultaneously will determine the nutritional status of a neonate. Calculation and description of nutritional status are obtained in a way described below.

The determination of weight and length standard positions

The weight and length development of a newborn is determined on the basis of its sex, gestational age, body mass and length at birth. To do this however, sex-specific national weight and length standards of reference value are needed. In Hungary, Joubert [30] prepared such standards on the basis of the birth data of babies born in this country between 1990 and 1996 (799,688 neonates). As is the case with the other commonly known standards, Joubert's standards apply seven percentile curves (percentiles 3, 10, 25, 50, 75, 90 and 97) to divide the entire weight and length ranges into eight weight zones and eight length zones. The field under percentile curve 3 makes zone 1; zone 2 is made by the area between percentile curves 3 and 10, whereas the area above percentile curve 97 gives zone 8 (Tables I–IV).

Using tabulated standards or a software designed specifically for the purpose, knowing the gestational age one can easily determine the weight zone (W) and length zone (L) of newborn baby on the basis of its weight and length at birth. Any neonate can be described with the letters (W and L) and numbers (1–8) of its weight and length zones. For example, if the birth weight of a newborn is in weight zone 6, that is between weight percentile curves 75 and 90, and its length is in length zone 2, that is between percentile curves 3 and 10, then the standard positions of this baby are W6 and L2.

Description of the nutritional status

The simplest way to describe the nutritional status of a person at any age is to give the person's height and body mass. The nutritional status (N) of a newborn

Table I. Weight standards for the Hungarian male neonates born between 1990 and 1996.

		Gestational weeks																								
Zones	Percentiles	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Percentiles
8																										
	97	705	775	845	925	1019	1129	1269	1425	1615	1825	2055	2285	2545	2787	3048	3325	3579	3819	4018	4193	4349	4495	4595	4627	97
7																										
	90	595	665	735	815	895	995	1119	1259	1435	1616	1828	2055	2277	2508	2755	3008	3276	3525	3729	3909	4075	4195	4295	4328	90
6																										
	75	525	585	645	718	795	888	995	1128	1295	1475	1649	1845	2048	2259	2488	2725	2976	3238	3458	3655	3795	3895	3955	3979	75
5																										
	50	455	501	555	621	705	781	881	1005	1155	1311	1481	1659	1851	2045	2255	2475	2721	2949	3161	3349	3495	3608	3655	3671	50
4																										
	25	385	422	475	533	595	685	782	895	1015	1152	1305	1455	1615	1805	2005	2211	2425	2663	2875	3055	3213	3305	3341	3352	25
3																										
	10	311	351	395	455	515	595	683	775	881	995	1123	1253	1395	1561	1745	1935	2164	2395	2623	2805	2925	3005	3035	3021	10
2																										
	3	245	275	315	361	422	482	561	643	725	833	935	1051	1182	1323	1493	1671	1872	2105	2322	2524	2672	2754	2762	2735	3
1																										

Table II. Length standards for the Hungarian male neonates born between 1990 and 1996.

		Gestational weeks																								
Zones	Percentiles	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Percentiles
8																										
	97	36.9	39.1	41.1	42.9	44.6	46.2	47.6	49.1	50.5	51.6	52.7	53.6	54.5	55.3	56.2	56.9	57.5	58.1	58.5	58.8	59.1	59.2	59.3	59.4	97
7																										
	90	34.1	36.2	38.3	40.2	41.9	43.5	44.9	46.5	47.8	49.1	50.3	51.3	52.3	53.3	54.2	54.9	55.7	56.4	56.9	57.4	57.6	57.8	57.9	57.9	90
6																										
	75	31.8	33.9	35.8	37.7	39.4	40.9	42.5	43.9	45.3	46.6	47.9	49.1	50.2	51.3	52.3	53.1	53.8	54.5	55.1	55.4	55.6	55.8	55.9	55.9	75
5																										
	50	29.5	31.4	33.3	35.1	36.9	38.6	40.1	41.6	42.9	44.3	45.7	46.9	48.1	49.3	50.4	51.3	52.1	52.7	53.2	53.5	53.7	53.9	53.9	54.1	50
4																										
	25	27.1	29.1	30.8	32.7	34.3	36.1	37.6	39.1	40.7	42.1	43.5	44.7	46.1	47.2	48.4	49.5	50.3	50.9	51.4	51.8	52.1	52.2	52.2	52.3	25
3																										
	10	24.4	26.5	28.3	30.2	31.9	33.5	35.1	36.7	38.3	39.9	41.3	42.7	44.1	45.4	46.5	47.8	48.6	49.3	49.9	50.2	50.4	50.4	50.5	50.5	10
2																										
	3	21.6	23.4	25.2	27.2	28.9	30.7	32.3	33.9	35.4	36.9	38.5	40.1	41.8	43.2	44.8	46.1	47.1	47.8	48.2	48.6	48.8	48.9	48.9	49.1	3
1																										

Table III. Weight standards for the Hungarian female neonates born between 1990 and 1996.

		Gestational weeks																								
Zones	Percentiles	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Percentiles
8																										
	97	675	725	801	895	995	1118	1269	1438	1638	1845	2055	2295	2545	2775	3015	3239	3466	3669	3855	4025	4176	4315	4368	4355	97
7																										
	90	595	635	689	765	849	965	1096	1245	1417	1605	1796	2005	2235	2455	2685	2917	3155	3375	3568	3747	3898	4005	4055	4049	90
6																										
	75	529	555	601	668	755	855	968	1097	1255	1425	1615	1805	2018	2225	2438	2655	2885	3098	3296	3475	3619	3725	3775	3798	75
5																										
	50	461	479	521	582	655	749	852	967	1101	1255	1425	1602	1803	1998	2201	2402	2617	2835	3035	3202	3329	3415	3475	3497	50
4																										
	25	395	415	451	501	573	651	751	855	975	1105	1245	1402	1581	1765	1952	2145	2355	2565	2773	2945	3075	3161	3202	3205	25
3																										
	10	335	352	382	425	481	562	643	735	843	953	1072	1201	1355	1525	1701	1891	2103	2325	2525	2703	2835	2912	2943	2951	10
2																										
	3	282	295	323	355	405	465	531	614	702	791	885	1003	1132	1283	1455	1645	1845	2052	2255	2455	2614	2701	2725	2732	3
1																										

Table IV. Length standards for the Hungarian female neonates born between 1990 and 1996.

		Gestational weeks																								
Zones	Percentiles	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Percentiles
8																										
	97	37.5	39.3	41.3	43.1	44.8	46.4	47.9	49.3	50.5	51.7	52.7	53.5	54.5	55.2	55.9	56.5	57.1	57.5	57.8	58.1	58.3	58.4	58.5	58.6	97
7																										
	90	34.8	36.5	38.5	40.2	41.8	43.5	45.2	46.7	48.1	49.2	50.3	51.3	52.2	53.1	53.7	54.4	55.1	55.6	56.1	56.4	56.6	56.8	56.9	56.9	90
6																										
	75	32.1	33.9	35.6	37.3	39.1	40.8	42.5	43.9	45.4	46.8	47.9	49.1	50.1	51.1	51.9	52.7	53.3	53.9	54.4	54.7	54.9	55.2	55.3	55.4	75
5																										
	50	28.8	30.8	32.9	34.7	36.5	38.1	39.6	41.1	42.6	43.9	45.3	46.5	47.7	48.7	49.7	50.5	51.3	51.9	52.4	52.9	53.2	53.4	53.5	53.5	50
4																										
	25	26.1	28.1	30.1	32.1	33.9	35.8	37.5	39.1	40.4	41.9	43.2	44.4	45.7	46.9	47.9	48.9	49.7	50.3	50.8	51.1	51.3	51.5	51.6	51.6	25
3																										
	10	23.1	25.3	27.2	29.3	31.3	33.1	34.9	36.6	38.1	39.6	41.1	42.4	43.8	44.9	46.2	47.2	47.9	48.5	49.1	49.4	49.6	49.8	49.9	49.9	10
2																										
	3	20.1	22.1	24.1	26.1	28.1	30.1	31.9	33.7	35.3	36.8	38.3	39.8	41.2	42.6	43.9	45.2	46.2	46.8	47.4	47.7	47.9	48.1	48.2	48.3	3
1																										

is defined by the weight development and length development according to the gestational age.

The authors prepared a matrix comprising eight horizontal lines for the weight standard zones and eight columns for the length standard zones, which seems a useful tool to determine the nutritional status of neonates. This 64-cell matrix is referred to as the MDN Table (see Figure 1 where the neonate mentioned earlier [W6, L2] is positioned in the grey cell). Any newborn can be positioned in this table, no matter what weight or length zone it belongs to. Each cell is identified by the letter and number of the weight zone and those of length zone in the intersection of which the cell is located in the Table.

To describe nutritional status (N) of a neonate, one has to know its weight standard position (weight zone number, W) and length standard position (length zone number, L). The calculation of the nutritional index, or nourishment status: $N = W - L$. In case the number of the weight zone is higher than that of the length zone, then N will be a positive number, which means that the baby is born with a relative overweight (overnourished). When N is a negative number, the baby is relatively underweight for its length.

Figure 2 demonstrates the nutritional statuses (N value) of neonates in each cell of the 64-cell of the MDN Table. The N value, representing nutritional status as rated according to the Table, can range from $+7$ to -7. Obviously, exteremely overnourished neonates are positioned in the cell marked as $+7$, whereas extremely undernourished ones will be positioned in the cell marked as -7. In an ideal case, a neonate is positioned in the weight zone and length zone having identical numbers when its N value $= 0$. Neonates with $N = 0$, $N = +1$ or $+2$ and those with $N = -1$ or -2 are regarded as being normally (or proportionally) nourished.

For better understanding, the four corners of the MDN Table are marked with letters to indicate the typical differences in the development and nutritional statuses of neonates positioned in the cells nearest to the corners of the Table.

Classification of neonates according to the degree of nourishment

Figure 3 demonstrates the most typical groups of newborns according to their nourishment. This figure also demonstrates the incidence rates of neonates with specific development and nutritional status in the neonate population born between 1997 and 2003 (680,947 newborn babies as recorded by the Hungarian Statistical Office).

Overnourished	ON	$N = +3$ to $+7$
Moderately overnourished	MON	$N = +3, +4$
Extremely overnourished	EON	$N = +5, +6, +7$
Normally nourished	NN	$N = -2$ to $+2$
Absolute average	AA	W 4, 5; L 4, 5
Proportionally retarded	PR	W 1, 2; L 1, 2
Proportionally overdeveloped	POD	W 7, 8, L 7, 8
Undernourished (disproportionally retarded)	UN(DPR)	$N = -2$ to -7
Moderately undernourished	MUN	$N = -3, -4$
Extremely undernourished	EUN	$N = -5, -6, -7$

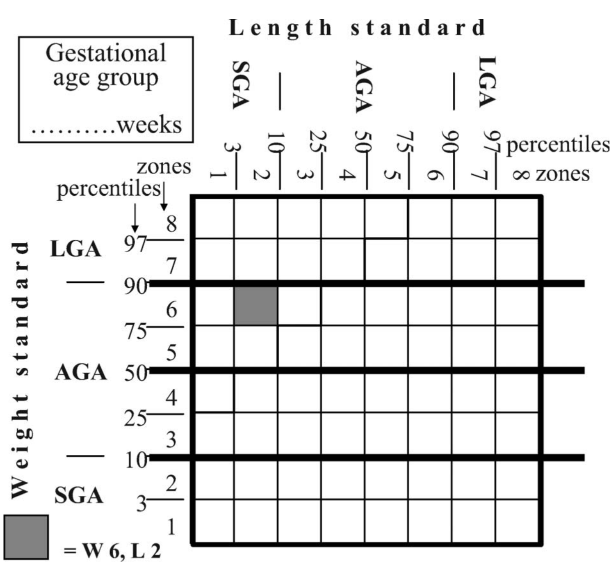

Figure 1. MDN Table for the simultaneous representation of weight and length standard positions of neonates. Neonates in cell W6-L2 belong to weight standard zone 6 (between percentile curves 90 and 97) and to length standard zone 2 (between percentile curves 3 and 10).

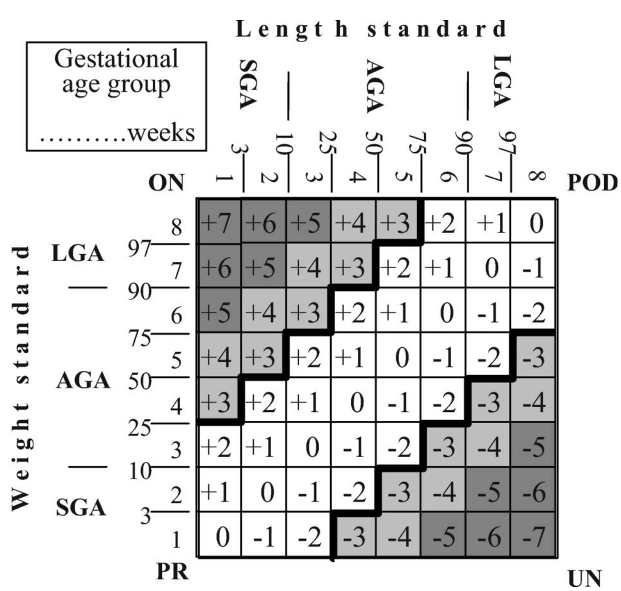

Figure 2. The weight and length standard positions (W and L) and N values (W-L) of neonates with different nutritional statuses in the MDN Table. The corners of the MDN Table: PR (proportionally retarded), POD (proportionally overdeveloped), ON (overnourished), UN (undernourished).

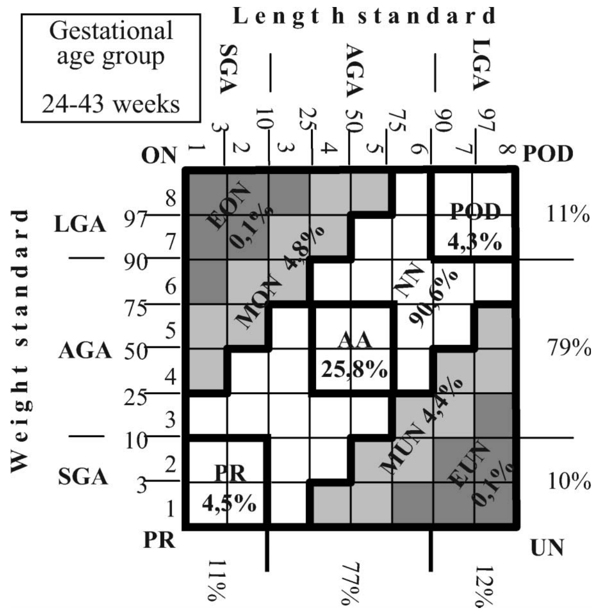

Figure 3. The classification (and percentage distribution) of Hungarian neonates born between 1997 and 2003 by bodily development and nourishment. NN, normally nourished; AA, absolute average; PR, proportionally retarded; POD, proportionally overdeveloped; MUN, moderately undernourished; EUN, extremely undernourished; MON, moderately overnourished; EON, extremely overnourished.

On an MDN Table the gestational age-group should be always indicated to which data of the Table relates.

The numerical representation of neonates by their maturity, weight and length with the help of the MDN index

As is explained earlier, the MDN method is a tool to describe the maturity, bodily development and nutritional status of any neonate numerically. The **MDN-index** = GA/*W*/*L*/*N*, where GA = gestational age in weeks; *W* = weight standard zone (position); *L* = length standard zone (position); *N* = nutrition index calculated from the previous parameters [7,18]. Examples: (a) MDN index = GA = 38/*W* = 6/*L* = 2/*N* = +4; (b) MDN-index = GA = 38/*W* = 2/*L* = 6/*N* = −4.

Results

By processing the birth data of the entire neonate population, gestational age 24–43 weeks, born in the years from 1997 to 2003 in Hungary, the authors studied the PM rate of the neonates in each cell of the MDN Table (Figure 4). The four cells in the centre of the table represent the neonates considered an absolute average (AA) or etalon group on the basis of their weight and length. PM rates printed in boldface type indicate the values, which are at least

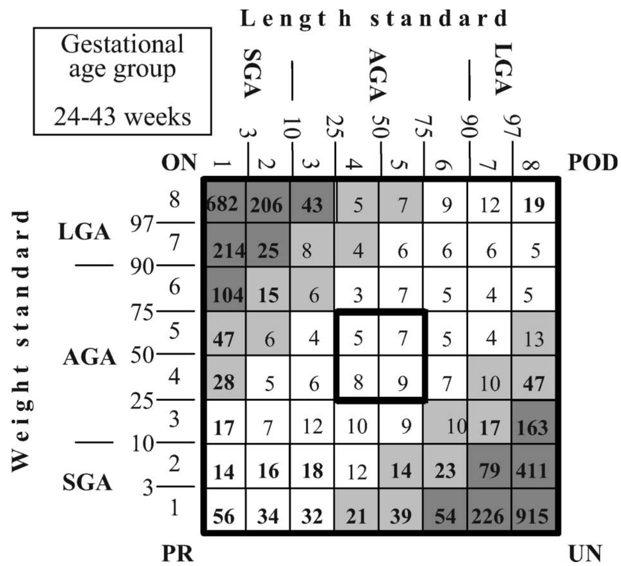

Figure 4. PM rates (‰) of the entire Hungarian neonate population (gestational age 24–43 weeks) born between 1997 and 2003, as represented by the cells of the MDN Table.

twice as high as in any of the four cells in the centre of the table.

It must be also perceived that the most favourable values of PM are out of the absolute AA. All of this is in relationship with the tendency observed in the matrix: in the zone between −2 and +3 PM diminishes toward the zones of higher weights except giant babies, of course.

Identification of the most endangered neonates with the MDN Table on the basis of their bodily development and nutritional status

Relying on the birth data of neonates born between 1997 and 2003, the authors find PM rate to be 8.9‰ in Hungary in that period of time. For comparison, this rate in the AA group, which is necessary to determine for comparative studies, was 7‰ in the same period of time. The highlighted sectors of the MDN Table in Figure 5 represent the most endangered neonate groups.

The major groups of highly endangered foetuses and neonates

1. *Undernourished (UN) group:* They are those who were born with insufficient weight and often show the syndrome of classic *disproportional retardation*. The PM rate is rather high, 21‰ in the large group of undernourished neonates. The group comprises the moderately undernourished subgroup with a PM rate of merely 16‰. The cells creating the triangle of *extremely undernourished* neonates in the UN corner of the

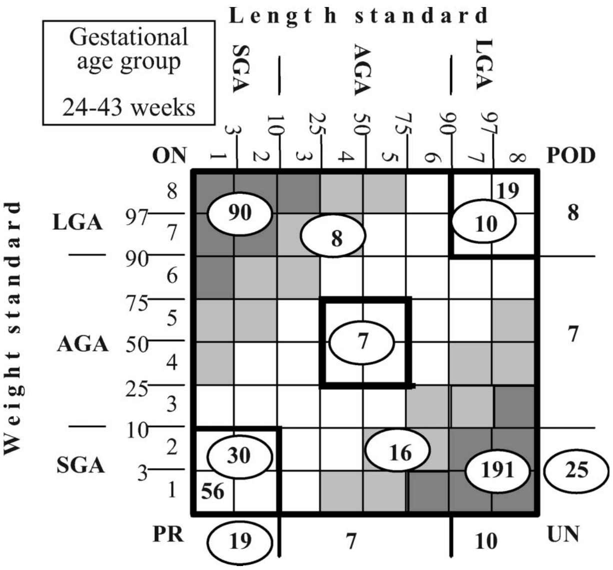

Figure 5. PM rates (‰) in the major groups of the Hungarian neonate population (gestational age 24–43 weeks) born between 1997 and 2003.

table has a conspicuously high, 191‰ PM rate. The MDN Table clearly shows that disproportional retardation, which causes a high mortality rate, can be found not only among the neonates under weight percentile 10, but also among those over weight percentile 10, as two thirds of the studied cases show.

2. *Overnourished (ON) group:* PM rate is 10‰ in the *overnourished group*. This group includes the moderately overnourished subgroup where PM rate is only 8‰. PM rate is 90‰ in the triangle of the *extremely overnourished* group in the ON corner of the MDN Table.
3. *Proportionally retarded (PR) group:* Proportionally retarded babies are positioned in the four bottom left cells (in the PR corner) giving the field bordered by weight percentile 10 and length percentile 10. PM rate in this group is 30‰. However, the smallest DPR neonates, being under percentile 3 by both weight and length, have an even higher, 56‰, PM rate.
4. It should not be forgotten, however, about the group of extremely *proportionally overdeveloped* or giant babies positioned in the POD corner of the table being both their weight and length in the 8th percentile zone. They are also highly endangered as is shown by the 19‰ PM rate of this cell.
5. *SGA group by weight:* PM rate in the weight group under the 10th percentile (heterogeneous SGA by length and nutritional status) is 25‰ (that in average for gestational age (AGA) group is 7‰, and 8‰ in the large for gestational age (LGA) group, that is over the 90th percentile). A very high, 43‰, PM rate is found in the weight group under the 3rd percentile.
6. *SGA group by length:* PM rate in the length group under the 10th percentile (heterogeneous by weight and nutritional status) is 19‰ including a PM rate of 34‰ in the group under the 3rd length percentile.

Discussion

Relying on the empirical fact that the degree of nourishment and the status of development have a high influence on the life prospects of neonates, the authors developed a method, the MDN system including an MDN matrix to study and qualify the nutritional status at birth.

The MDN system can be applied when gestational age, birth weight and length are known and when reliable weight and length standards are available for reference.

The MDN system with an integrated MDN matrix where maturity (gestational age), development (weight and length standard positions) and nutritional status are considered simultaneously allows the identification the most endangered neonate groups on the basis of bodily development and nutritional status. Having processed the data of almost half a million Hungarian neonates, the authors describe the most endangered groups of this population.

The MDN system offers a novel method to identify and differentiate proportionally retarded, DPR and mixed retarded newborns below the 10th weight percentile, as well as DPR ones over the 10th weight percentile.

The MDN system as a method can be applied in any country. Preferably, the development of neonates born in the studied country has to be determined first according to country-specific (or preferably race-specific) weight and length percentile standards. Then, each neonate will be rated by and positioned in its nation-specific MDN matrix. The morbidity and mortality rates of different national neonate groups having equivalent positions in their national MDN matrices can be compared with this method. This also makes possible the comparison of neonatal morbidity and mortality data of countries, even if average birth weights are significantly different. The MDN system offers a tool to make more accurate and more reliable national and international comparative studies.

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