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Level, Causes and Risk Factors of Neonatal Mortality, in Jordan: Results of a National Prospective Study

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Abstract *Objective* The present study aimed at assessment of the magnitude of neonatal mortality in Jordan, and its causes and associated factors. *Methods* Through a multistage sampling technique, a total of 21,928 deliveries with a gestational period ≥20 weeks from 18 hospitals were included in the study. The status of their babies 28 days after birth, whether dead or alive, was ascertained. Extensive data were collected about mothers and their newborns at admission and after 28 days of birth. Causes of death were classified according to the neonatal and intrauterine death classification according to etiology. Preventability of death was classified according to Herman's classification into preventable, partially preventable, and not preventable. *Results* Neonatal mortality rate, overall and for subgroups of the study was obtained. Risk factors for neonatal mortality were first examined in bivariate analyses and finally by multivariate logistic regression models to account for potential confounders. A total of 327 babies ≥20 weeks of gestation died in the neonatal period (14.9/1000 LB). Excluding babies <1000 g and <28 weeks of gestation to be consistent with the WHO and UNICEF's annual neonatal mortality reports, the NNMR decreased to 10.5/1000 LB. About 79 % of all neonatal deaths occurred in the first week after birth with over 42 % occurring in the first day after birth. According to NICE hierarchical classification, most neonatal deaths were due to congenital anomalies (27.2 %), multiple births (26.0 %), or unexplained immaturity (21.7 %). Other important causes included maternal disease (6.7 %), specific infant conditions (6.4 %), and unexplained asphyxia (4.9 %). According to Herman's classification, 37 % of neonatal deaths were preventable and 59 % possibly preventable. An experts' panel determined that 37.3 % of neonatal deaths received optimal medical care while the medical care provided to the rest was less than optimal. After adjusting for socio-demographic characteristics, type of the hospital, and clinical and medical history of women, the following variables were significantly associated with neonatal mortality: male gender, congenital defects, inadequate antenatal visits, multiple pregnancy, presentation at delivery, and gestational age. *Conclusion* The present study showed the level, causes, and risk factors of NNM in Jordan. It showed also that a large proportion of NNDs are preventable or possibly preventable. Providing optimal intrapartum, and immediate postpartum care is likely to result in avoidance of a large proportion of NNDs.

Keywords Antenatal · Gestation · Mortality · Maternal · Newborn · Prematurity

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Significance of the Study

Accurate measurement of NNM is essential for assessment of progress towards the Millennium Development Goal (MDG) 4's target of a two-thirds reduction in under-five mortality from 1990 to 2015. Identification of causes and risk factors is a first step in formulating a national strategy for prevention and control of NNM. Available data on NNM in Jordan come from two sources: first, the periodic JFS which measures NNM over the past 10 years on a relatively small sample that doesn't permit accurate assessment of causes and risk factors of NNM. Second is the vital registration system which grossly underestimates NNM. The present study used a prospective design to collect extensive information on a large sample of women at entry to hospital and 28 days after birth. The study provides detailed information on level, causes, and risk factors of NNM in Jordan which can be used to formulate a national strategy in Jordan and can be of great benefit for similar developing countries in their efforts to prevent NNM.

Introduction

In the late 1990s, the neonatal mortality rate (NNM) in Jordan fell from 19 to 15/1000 live births (LB) and remained relatively constant as Jordan transitioned into the new millennium [19]. The Jordan Fertility and Family Health Survey (JFS), 2007 [2], reflecting mortality in the preceding 10 years showed a neonatal mortality rate of 15/1000 LB. To achieve the Millennium Development Goal (MDG) 4's target [5] of a two-thirds reduction in under-five mortality from 1990 to 2015, particular emphasis must be placed on reducing neonatal mortality. This will require effective planning and monitoring of health services and, most importantly, accurate measures of mortality.

Available data on NNM in Jordan come from the periodic JFS surveys repeated every 2–3 years or from the national vital registration statistics. The JFS collects retrospective data over the preceding 10 years from a random sample of the population. Thus, the data reflect past mortality pattern. Although the sample is relatively large (around 8000 women in their child bearing age), the number of neonatal deaths is relatively small and doesn't permit robust analysis of causes of death and associated factors. The other source of data, namely, the national vital statistics grossly underestimates neonatal mortality. Registration of births and deaths is based on reporting by a family member without incentives for early or penalties for late reporting. Most neonates dying within the first 28 days after birth are unlikely to get registered neither as births nor as deaths, i.e. they tend to be completely missed by the system.

Recognizing the need for accurate contemporary data on the magnitude and risk factors of neonatal mortality, United Nations Children's Fund (UNICEF) in collaboration with the Higher Population Council (HPC), Ministry of Health and other health sectors decided to support the present study. The John Snow Inc. (JSI) implemented the study with funding from the UNICEF.

The study was expanded to cover perinatal mortality as well, because of the strong link with NNM.

Information on perinatal and neonatal mortality is important to contribute to the effort towards reducing infant mortality. In this study we assessed the magnitude of neonatal and perinatal mortality, its causes and associated factors, as well as accuracy of the national vital registration system. Findings of the study were envisaged as the basis for the development of a national strategy to reduce perinatal mortality. The study collected extensive qualitative and quantitative data for this purpose. The present report deals exclusively with quantitative data on neonatal mortality.

Methods

Study Sample

The aim was to recruit a total of 24,000 women giving birth during the study period in any of the 18 selected hospitals. This number was considered sufficient to estimate differences in neonatal mortality among the main subgroups of the study as small as 0.002 with a 90 % power and 90 % confidence.

Selection of Hospitals

The following criteria for selection of hospitals were set and agreed upon by the Technical Committee which consisted of representatives from the different health sectors in Jordan, UNICEF, and WHO. According to these criteria, seven hospitals in the Middle, six hospitals in the North, and five hospitals in the South were selected. Selection criteria included:

1. Representation of the three regions in Jordan, namely, the South, Middle, and North.
2. Representation, within the three regions, of the three health sectors, MOH, private, and military.
3. Inclusion of at least one university hospital; and,
4. Consideration of the workload of the hospitals (number of deliveries) as well as the geographic distribution

which is likely to be related to the socioeconomic status of clients and the quality of services provided.

A fixed number of deliveries were set for each hospital proportional to the annual number of deliveries taking place in the past year in that hospital.

Duration of the Study

The study period started March 1, 2011 and ended April 30, 2012 covering a period of 14 months.

Eligibility Criteria

All consenting women ≥20 weeks of gestation delivering in any of the selected hospitals during the study period were consecutively included in the study, until the predetermined number from each hospital was reached. Over 99 % consented to participate in the study.

Exclusion Criteria

Any woman delivering outside the hospital (at home or in any other non-participating hospital) and reporting to the hospital thereafter was excluded.

Number of Women Actually Included in the Study

A total of 21,928 women were actually included in the study. In some hospitals, the targeted number of women was not reached before termination of the recruitment period because of the low number of deliveries taking place. However, in all participating hospitals the number of women recruited exceeded 90 % of the targeted number. Ethical considerations: The study was solicited by the High Population Council in Jordan. The study was approved by the National Institutional Review Board. A written informed consent was obtained from each participating woman. All ethical standards were strictly adhered to.

Data Collection

Initial Sata

A structured data form was prepared for the purpose of this study. It involved extensive socio-demographic and obstetric data on the woman, as well as data on the newborn. This form was initially completed by the midwife under the supervision of the obstetrician who was required to sign each form. The midwife passed the form to the pediatric nurse who was charged in completing the neonatal form thereafter under the supervision of the neonatologist/pediatrician who was also required to sign each form. Completion of the form was carried out before discharge of the mother and/or her newborn from hospital. If the newborn died in hospital before discharge, the cause of death was recorded and a special form was completed.

Follow Up Data

Newborns discharged alive from hospital were followed up at 30 days after birth to determine their status, whether alive or dead. Each participating woman, at the time of recruitment, was required to provide contact information including her mobile number, home number, and the telephone number of her husband and any close relatives. Participating women were informed that they will be contacted 30 days after birth to inquire about their health and the health of their newborns. A special form was prepared for this purpose. Calls were made by the pediatric nurses. If the newborn died within 28 days of birth, the mother was asked about the place of death. If death occurred at home, a visit was arranged to perform verbal autopsy. If the death occurred in another hospital, the hospital was contacted to provide the cause of death and other relevant information.

The data collection team was trained by the same group of trainers which consisted of a gynecologist, a neonatologist, an epidemiologist, and a biostatistician.

Causes of Death

Causes of death were classified according to the Neonatal and Intrauterine Death Classification according to Etiology (NICE) [18] which classifies causes of death into 13 categories including one for unclassifiable causes. Preventability of death was classified according to Herman's classification into preventable [7], partially preventable, and not preventable. Furthermore, an expert panel reviewed all the available clinical and other information on each woman and her newborn, ascertained the hospital diagnosis, and then assigned the direct, underlying, and contributing causes of death for each neonatal death. The expert panel consisted of a neonatologist, a gynecologist, an epidemiologist, and a biostatistician.

Data Management and Statistical Analysis

IBM SPSS Statistics 20 [9] was used for data entry and analysis. The data were checked for data entry errors by performing range and logical checks. Detected errors were corrected by returning back to original study forms. Neonatal mortality rate, overall and for subgroups of the study was obtained. Risk factors for neonatal mortality were first examined in bivariate analyses and the statistical significance was assessed using the Chi square test for categorical factors, and the *t* test or F-test for continuous factors as appropriate. Frequency distributions of causes of death were obtained according to NICE classification, as well as according to the Expert Panel assigned cause of death. Considering the hierarchical complexity of predictor variables, we used the hierarchical model proposed by Mosley and Chen [14] to identify determinants of neonatal mortality. Data were further analyzed using generalized linear mixed models (multilevel models) and traditional logistic regression analysis, considering the hierarchical complexity of predictor variables. In the generalized linear mixed models, one intercept-only random effect with 'hospital' as the subject field was used to account for correlation between subjects within the same hospital. Based on the information criteria and likelihood ratio test, the binary logistic regression final model was preferred over the generalized linear mixed final model. In the binary logistic regression analysis, the variables, region and sector, defining the selected hospitals were included in the model. A P value of <0.05 was considered statistically significant.

Results

Our results are based on a total of 21,928 women admitted in any one of the 18 selected hospitals from March 1, 2011 to April 30, 2012, giving birth to 22,330 LB. LB were followed up until 28 days of life. Of those, 21,634 survived the neonatal period, 327 died in the neonatal period, and 369 births were lost to follow up.

Maternal Characteristics

The maternal age ranged between 14 and 55 years with a mean (SD) of 27.8 years (6.0). About 6.2 % were younger than 20 years and 12.3 % were older than 35 years. Approximately 2 % of the women were illiterate and 13.5 % of them were employed. Almost 3.3 % of women reported smoking at least one cigarette daily. About 28 % of women were primiparas. The overall multiple pregnancy rate was 28.3/1000. About 25.5 % of women were married to a first degree relative, 11.5 % of women were married to a second degree relative, and 67.9 % of them were not married to a relative.

Neonatal Mortality

Using the gestational age cutoff value of ≥20 weeks, the neonatal mortality rate was 14.9/1000 LB. The rate generally decreased as the gestational period increased to reach 11.6/1000 LB for gestational age ≥28 weeks. Excluding babies <1000 g and <28 weeks of gestation to be consistent with the WHO and UNICEF's annual neonatal mortality reports, the NNMR decreased to 10.5/1000 LB. For the purpose of further analysis, the cutoff value of ≥20 weeks of gestation will be used.

The highest NNMR was observed in the Middle region (16.9/1000 LB), followed by the North (12.6/1000 LB) and lastly the South (11.7/1000 LB) ($P = 0.02$). The NNMR was highest in the military sector (27/1000 LB) and lowest in the private sector (6.2/1000 LB).

Timing and Place of Neonatal Deaths

About 79 % of all neonatal deaths occurred in the first week after birth with over 42 % occurring in the first day after birth. The vast majority of neonatal deaths occurred in the same hospital in which the neonate was born, with 83.4 % occurring before discharge and 9.8 % occurring after readmission. Transferred babies to other hospitals constituted 4.9 % of all neonatal deaths, while deaths occurring at home after discharge accounted for only 1.8 % of neonatal deaths.

Main Causes of Neonatal Death

Table 1 shows that, according to NICE hierarchical classification, most neonatal deaths are due to congenital anomalies (27.2 %), multiple births (26.0 %), or unexplained immaturity (21.7 %). Other important causes included maternal disease (6.7 %), specific infant conditions (6.4 %), and unexplained asphyxia (4.9 %).

The specific causes within the NICE classification categories are shown in Table 2. The most common congenital anomalies were congenital heart disease and multiple congenital anomalies, accounting for 25.8 and 19.1 % of all congenital causes of death respectively. Pre-eclampsia accounted for over three quarters of the category of "maternal diseases". Over 70 % of neonatal deaths caused by "specific infant conditions" was due to sepsis, and 50 % of the "unclassifiable cases" were due to milk aspiration.

To further elucidate on the causes of neonatal death, a committee of experts thoroughly reviewed all available data on each neonatal death including the cause of death provided by the attending physician and made its judgment on the cause of death. As shown in Table 3, respiratory distress syndrome (RDS) was the leading cause of death (53.3 %), followed by congenital anomalies (13.8 %), sepsis (16.2 %) with or without RDS, and asphyxia (10.1 %).

Since more than one cause is usually involved in a neonatal death and the causes are commonly interlinked, the frequency of the individual causes of death was explored. The most frequently mentioned causes were prematurity (72.5 %) followed by respiratory distress

Table 1 Causes of neonatal deaths (≥20 weeks of gestation) according to the NICE cause of death classification, Jordan, 2012

Cause of death	Early neonatal deaths		Late neonatal deaths		Neonatal deaths (early and late)	
	N	(%)	N	(%)	N	(%)
Congenital anomalies	73	27.4	16	26.2	89	27.2
Multiple births	73	27.4	12	19.7	85	26.0
Maternal disease	18	6.8	4	6.6	22	6.7
Specific fetal conditions	1	0.4	0	0.0	1	0.3
Unexplained small-for-dates infants	1	0.4	2	3.3	3	0.9
Placental abruption	3	1.1	1	1.6	4	1.2
Obstetric complications	7	2.6	2	3.3	9	2.8
Specific infant conditions	17	6.4	4	6.6	21	6.4
Unexplained asphyxia	13	4.9	3	4.9	16	4.9
Unexplained immaturity	56	21.1	15	24.6	71	21.7
Unclassifiable cases	4	1.5	2	3.3	6	1.8
Total	266	100	61	100	327	100

NICE neonatal and intrauterine death classification according to etiology

syndrome (60.1 %), multiple births (28.7 %), congenital anomalies (27.2 %), sepsis (18.7 %), asphyxia (18.3 %), and pulmonary hemorrhage (14.4 %).

Preventability of Neonatal Deaths

The experts panel judged that 30 % of all neonatal deaths were preventable and that 44.3 % were possibly preventable with optimal care. According to Herman's classification, 37 % of neonatal deaths were preventable and 59 % possibly preventable.

Using the Neonatal Care Clinical Guidelines for Physicians, Jordan (Ministry of Health and Health System Strengthening, Jordan, 2007), to assess the appropriateness or optimality of the care, the experts' panel determined that 37.3 % of neonatal deaths received optimal medical care while the medical care provided to the rest was less than optimal.

Risk Factors for Neonatal Mortality (Bivariate Analysis)

Table 4 shows the rate of neonatal deaths according to mothers' characteristics, region, and hospital of birth which were significantly related to neonatal mortality. Newborns of teenage mothers (24.2/1000 LB) were significantly ($P = 0.009$) at higher risk of dying than newborns of older mothers. Significantly higher NND rates were found in women living in the middle region of the country compared to those living in the North and South (16.9, 12.6, and 11.7/1000 LB, respectively, $P = 0.019$). Neonatal deaths were less likely to take place in private hospitals and public hospitals compared to military and teaching hospitals ($P < 0.001$).

Other variables such as education of the mother, income, consanguinity, and smoking were assessed and showed no significant association with neonatal mortality.

The rate of neonatal deaths among primiparas (21.7/1000 LB) was significantly higher than that among women who gave birth two or more times ($P < 0.001$). The rate was significantly higher among babies born to women who had a history of low birth weight or preterm delivery (25.2 vs. 14.0/1000 LB) and women who had a history of neonatal death/stillbirth (35.4 vs. 13.8/1000 LB). Of the medical illnesses, preeclampsia was the strongest predictor of neonatal death. The rate was significantly higher for women who had preeclampsia compared to women who had no preeclampsia (97.5 vs. 13.8/1000 LB).

Babies born to women who did not utilize antenatal services had higher rates of mortality compared to babies born to mothers who utilized antenatal care services, and the rate decreased for babies born to women who utilized the services more frequently. A number of newborn and delivery characteristics were also found to be significantly related to neonatal mortality (Table 5). As expected, male gender, multiple pregnancy, lower gestational duration, low birth weight, and presence of congenital defects were significantly associated with higher neonatal mortality. Birth orders one (21.7/1000 LB) and two (14.2/1000 LB) were more likely to die than other birth orders. Transverse (56.6/1000 LB) and breech (53.3 %) presentations were significantly associated with higher neonatal death com-

Table 2 Proportion of specific causes of neonatal death within the main NICE categories, Jordan 2012

Category/subcategory	Early neonatal deaths (N/%)[a]	Late neonatal deaths (N/%)[a]	Neonatal deaths (N/%)[a]
Congenital anomalies	73	16	89
Congenital heart disease	17 (23.3)	6 (37.5)	23 (25.8)
Multiple congenital anomalies	16 (21.9)	1 (6.3)	17 (19.1)
Hydrocephalus	6 (8.2)	1 (6.3)	7 (7.9)
Diaphragmatic hernia	6 (8.2)	0 (0.0)	6 (6.7)
Microcephalus	4 (5.5)	0 (0.0)	4 (4.5)
Down syndrome	3 (4.1)	0 (0.0)	3 (3.4)
Severe metabolic disorder	2 (2.7)	1 (6.3)	3 (3.4)
Tracheoesophageal fistula/intestinal fistula	2 (2.7)	1 (6.3)	3 (3.4)
Edwards syndrome	1 (1.4)	1 (6.3)	2 (2.2)
Lung hypoplasia	2 (2.7)	0 (0.0)	2 (2.2)
Bilateral polycystic kidney disease	2 (2.7)	0 (0.0)	2 (2.2)
Spina bifida with hydrocephalus	1 (1.4)	0 (0.0)	1 (1.1)
Congenital muscle dystrophy	0 (0.0)	1 (6.3)	1 (1.1)
Other potentially fatal malformation	9 (12.3)	3 (18.8)	12 (13.5)
Unspecified	2 (2.7)	1 (6.3)	3 (3.4)
Multiple births	73	12	85
Quadruplets	6 (8.2)	1 (8.3)	7 (8.2)
Triplets	24 (32.9)	4 (33.3)	28 (32.9)
Twin	43 (58.9)	7 (58.3)	50 (58.8)
Maternal disease	18	4	22
Preeclampsia	15 (83.3)	2 (50.0)	17 (77.3)
Pre-gestational diabetes mellitus	2 (11.1)	1 (25.0)	3 (13.6)
Epilepsy	1 (5.6)	1 (25.0)	2 (9.1)
Obstetric complications	7	2	9
Placenta previa	2 (28.6)	1 (50.0)	3 (33.3)
Cephalopelvic disproportion	2 (28.6)	0 (0.0)	2 (22.2)
Fetal blood loss	2 (28.6)	0 (0.0)	2 (22.2)
Malpresentation	1 (14.3)	1 (50.0)	2 (22.2)
Specific infant conditions	17	4	21
Sepsis	11 (64.7)	4 (100.0)	15 (71.4)
Accidental birth trauma	3 (17.6)	0 (0.0)	3 (14.3)
Term infant with respiratory distress syndrome	2 (11.8)	0 (0.0)	2 (9.5)
Sudden infant death syndrome	1 (5.9)	0 (0.0)	1 (4.8)
Unclassifiable cases	4	2	6
Milk aspiration	2 (50.0)	1 (50.0)	3 (50.0)
Meconium aspiration	1 (25.0)	0 (0.0)	1 (16.7)
Severe dehydration	0 (0.0)	1 (50.0)	1 (16.7)
Unknown	1 (25.0)	0 (0.0)	1 (16.7)

[a] Proportions for specific causes within each main category of the NICE cause of death classification

pared to cephalic presentation (12.2/1000 LB). Cesarean delivery was associated with a higher risk of neonatal mortality compared to vaginal delivery (26.1 vs. 10.1/1000 LB, $P = 0.00$). A low Apgar score at one and at 5 min was strongly and significantly associated with higher neonatal mortality.

Risk Factors for Neonatal Mortality (Multivariate Analysis)

Table 6 shows the multivariate analyses of factors associated with neonatal mortality. Three different regression models were developed to consider the hierarchical nature of

Table 3 Causes of neonatal mortality according to the judgment of the expert committee, Jordan 2012

Main causes	Early neonatal deaths		Late neonatal deaths		Neonatal deaths	
	N	(%)	N	(%)	N	(%)
Respiratory distress syndrome	150	56.4	25	41.0	175	53.5
Congenital anomaly	39	14.7	6	9.8	45	13.8
Asphyxia	28	10.5	5	8.2	33	10.1
Sepsis/not combined with RDS	19	7.1	11	18.0	30	9.2
Sepsis/combined with RDS	15	5.6	8	13.1	23	7.0
Intraventricular hemorrhage	2	0.8	2	3.3	4	1.2
Renal failure	3	1.1	0	0.0	3	0.9
Severe dehydration	2	0.8	1	1.6	3	0.9
Pulmonary hemorrhage	1	0.4	1	1.6	2	0.6
Placenta abruption	1	0.4	0	0.0	1	0.3
Electrolyte imbalance	1	0.4	0	0.0	1	0.3
Hydrops fetalis	1	0.4	0	0.0	1	0.3
Severe metabolic acidosis	1	0.4	0	0.0	1	0.3
Sudden infant death syndrome	1	0.4	0	0.0	1	0.3
No visible reason	2	0.8	2	3.3	4	1.2

predictor variables. Model 1 included all socio-demographic and hospital variables (distal variables) significant at alpha level of <0.10. The model shows the overall effect of socio-demographic variables and is not adjusted for mediating factors. Only three variables showed significant association with neonatal mortality at alpha level of <0.05: mother's age, region, and type of the hospital (health sector). Babies born to mothers younger than 20 years of age were at a higher risk of death in the neonatal period compared to babies born to mothers aged between 20 and 35 years. Mother's age >35 years was not significantly associated with increased risk of neonatal mortality. In the second model (Model 2), the intermediate variables (history of preterm or low birth weight delivery, history of neonatal death or stillbirth, preeclampsia, hospitalization during pregnancy, and number of deliveries) were added and their effects were adjusted for the effects of the socio-demographic variables and the type of the hospital. Region and type of hospital had an effect on neonatal mortality not mediated through the medical history of the mother and parity. After adjusting for employment and age of the mother, region, and type of hospital, mother's clinical and medical variables were significantly associated with increased risk of neonatal mortality. History of preterm or low birth weight delivery (OR 1.7) and history of neonatal death or stillbirth (OR 2.1) were significantly associated with an increased risk of neonatal mortality. Preeclampsia (OR 4.5) and mother's hospitalization during the current pregnancy (OR 4.0) were associated with a four times increased risk of neonatal mortality. Babies who were born to primiparas (OR 2.7) or Para 2 women (OR 1.8) were at a higher risk of dying in the neonatal period.

In Model 3, child characteristics (proximal variables) were added. The Model shows that the type of the hospital, but not age of mother or the region, has an effect that is not mediated through intermediate and proximal variables. All intermediate variables, except history of preterm or low birth weight delivery, have an effect on neonatal mortality that is not mediated by the baby's characteristics. After adjusting for socio-demographic characteristics, type of the hospital, and clinical and medical history of women, the following variables were significantly associated with neonatal mortality: gender of the baby, congenital defects, number of antenatal visits, number of fetuses, presentation at delivery, and gestational age. Males were at a higher risk of dying in the neonatal period compared to females (OR 1.5). Newborns who had congenital defects were at much higher risk of neonatal mortality compared to newborns who had no congenital defects (OR 61.6). Compared to babies born to women who had frequent antenatal care visits (>8 visits), babies born to women who did not use antenatal care services (OR 4.1) or had $\leq$8 antenatal care visits (OR 1.9) were more likely to die in the neonatal period. Compared to singletons, multiple births were at higher risk of neonatal mortality (OR 1.7). Breach presentation compared to cephalic presentation was associated with higher risk of neonatal mortality (OR 1.5). Preterm births were almost 24 times more likely to die during the neonatal period compared to full term babies. When gestational age was replaced by birth weight in Model 3, low birth weight babies were 22 times more likely to die in the neonatal period compared to normal birth weight babies (OR 22.1; 95 % CI 16.2, 30.1).

Table 4 Rate of neonatal deaths by region, type of hospital in which birth occurred, and mothers' characteristics, Jordan 2012

Variables	Total	Neonatal death		P value
Region				0.019
North region	7553	95	12.6	
Middle region	12,095	205	16.9	
South region	2313	27	11.7	
Type of the hospital				<0.001
Private hospital	6572	41	6.2	
Public hospital	10,335	152	14.7	
Military hospital	4180	113	27.0	
Teaching hospital	874	21	24.0	
Mother's age (years)				0.009
<20	1362	33	24.2	
20–35	17,917	251	14.0	
>35	2660	43	16.2	
Parity				0.000
1	6167	134	21.7	
2	5218	74	14.2	
3–4	6772	75	11.1	
≥5	3784	44	11.6	
History of low birth weight or preterm delivery				0.000
No	20,186	283	14.0	
Yes	1745	44	25.2	
History of neonatal death/stillbirth				0.000
No	20,830	288	13.8	
Yes	1101	39	35.4	
Maternal anemia				0.021
No	18,162	255	14.0	
Yes	3785	72	19.0	
Preeclampsia				0.000
No	21,670	300	13.8	
Yes	277	27	97.5	
Antenatal care visits				0.000
None	224	12	53.6	
1–8	6192	146	23.6	
>8	15,339	169	11.0	
Mother transferred from another hospital				0.000
No	21,512	296	13.8	
Yes	435	31	71.3	

Discussion

Our data on neonatal mortality are unique since they were collected prospectively from a large sample of 22,330 live newborns, representing over 12 % of all births in Jordan during the study period. All live births ≥20 weeks of gestation taking place in any of the 18 selected hospitals during the study period were followed up for 28 days to ascertain their status whether dead or alive. Only 369 neonates were lost to follow up (1.6 %). Available data on neonatal mortality in Jordan are usually obtained from the National Vital Registration system and the periodic Demographic Health Surveys. Neonatal mortality is grossly underestimated by the National Vital Registration system; neonates dying in the first month of their life are very likely to be completely missed by the system both as births and as deaths. The Demographic Health Surveys collect retrospective data on neonatal mortality in the past 10 years based on interviewing a sample of women in their reproductive age. Thus, Demographic Health Surveys measure past neonatal mortality and is very prone to recall bias. Therefore, comparison of our data with that provided

Table 5 Neonatal death rates by newborns' characteristics, Jordan, 2012

Variables	Total	Neonatal death		*P* value
	N	Deaths	Rate/1000 LB	
Baby's gender				0.041
Male	11,255	186	16.5	
Female	10,695	141	13.2	
Number of fetuses				0.000
Single	20,728	233	11.2	
Multiple	1233	94	76.2	
Gestational age				0.000
≤31	308	178	577.9	
32–36	1405	59	42.0	
≥37	20,239	90	4.4	
Birth weight				0.000
<1500	285	162	568.4	
1500–<2500	1717	91	53.0	
≥2500	19,950	74	3.7	
Birth weight				0.000
≥2500	19,950	74	3.7	
<2500	2002	253	126.4	
Birth rank				0.000
1	6167	134	21.7	
2	5218	74	14.2	
3	3943	42	10.7	
4	2829	33	11.7	
≥5	3784	44	11.6	
Presentation				0.000
Cephalic	20,506	250	12.2	
Breech	994	53	53.3	
Transverse	424	24	56.6	
Mode of delivery				0.000
Vaginal	15,283	154	10.1	
Cesarean	6617	173	26.1	
Congenital defects				0.000
Yes	215	77	358.1	
No	21,738	242	11.1	
Apgar score at 1 min				0.000
Poor (0–3)	147	72	489.8	
Intermediate (4–7)	9575	228	23.8	
Normal (8–10)	11,809	27	2.3	
Apgar score at 5 min				0.000
Poor (0–3)	48	42	875.0	
Intermediate (4–7)	1173	175	149.2	
Normal (8–10)	20,297	110	5.4	

by the Demographic Health Surveys should be carried out with caution. The neonatal mortality rate observed in our study is close to that reported by the demographic health surveys. However, it is not clear what gestational age was used to define NNM in the demographic health surveys while in our study a gestational age of ≥20 weeks was used. Because of the relatively small number of NNDs, the demographic health surveys lacked the power to provide data on causes and risk factors of NNM in Jordan.

Infant and neonatal mortality rates are often used as indicators of the level of health care in countries. Neonatal deaths, in fact, account for the majority of infant deaths. Inter-country comparisons using these rates should be carried out with caution. The period of gestation defining a live birth differs among countries and has a substantial effect on corresponding neonatal mortality rates. For example, including babies delivered alive at 20 weeks of gestation who are very likely to die soon after birth will result in higher estimates of neonatal mortality rate than in situations when live births are included when the gestational period is ≥28 weeks. The US used to rank badly on infant mortality as compared to many European countries. Rather than the level of health care, inclusion of all births that show evidence of life is a common practice in the US but is not the case in many European countries showing better estimates of neonatal and infant mortality [10]. The present study clearly shows that changing definition can markedly affect neonatal mortality which decreased from 14.9 to 10.5/1000 LB (about 30 % change) when we excluded live births ≤28 weeks of gestation and <1000 g birth weight.

Using NICE classification, the most common causes of NNM in our study from highest to lowest were congenital anomalies, multiple births, unexplained immaturity, maternal diseases, specific infant conditions, and unexplained asphyxia. This is not consistent with the global estimates of causes of death provided by the World Health Organization (WHO) showing that infections (36 %, which includes sepsis/pneumonia, tetanus and diarrhea), pre-term (28 %), and birth asphyxia (23 %) are the major causes of NNM [12]. However, variation between countries depending on their level of health care was acknowledged [20]. When causes of death were classified by the Expert Committee, respiratory distress syndrome was the commonest cause followed by congenital anomalies, sepsis, and asphyxia. Sepsis accounted for 16.2 % of all deaths in our study. In agreement with available literature, over three-fourths of NNDs in our study are either preventable or possibly preventable. According to a WHO fact sheet [20], effective care can prevent three-fourths of NNDs. The package of essential care includes antenatal care, obstetric care and birth attendant's ability to resuscitate newborns at birth. Most of the infection-related deaths could be avoided by treating maternal infections during pregnancy, including antibiotics for preterm prelabor rupture of membranes ensuring a clean birth, care of the umbilical cord and immediate, exclusive breast-

Table 6 Risk factors for neonatal mortality due to all causes in the multivariate analysis, Jordan 2012

Variable	Model 1		Model 2		Model 3	
	OR (95 % CI)	*P* value	OR (95 % CI)	*P* value	OR (95 % CI)	*P* value
Age						
20–35	1.0		1.0		1.0	
<20	1.6 (1.1, 2.4)	0.013	1.2 (0.8, 1.8)	0.326	1.3 (0.8, 2.0)	0.232
>35	1.2 (0.9, 1.7)	0.284	1.4 (0.9, 2.0)	0.109	1.1 (0.7, 1.6)	0.817
Region						
North	1.0		1.0		1.0	
Middle	1.4 (1.1, 1.8)	0.007	1.6 (1.2, 2.0)	0.001	1.1 (0.8, 1.5)	0.407
South	0.7 (0.5, 1.1)	0.162	0.8 (0.5, 1.2)	0.228	0.6 (0.3, 1.0)	0.072
Health sector						
Private	1.0		1.0		1.0	
Public	2.4 (1.6, 3.5)	0.000	2.5 (1.8, 3.6)	0.000	2.6 (1.7, 4.0)	0.000
Military	4.8 (3.3, 6.9)	0.000	3.9 (2.7, 5.6)	0.000	3.3 (2.1, 5.1)	0.000
Teaching	3.8 (2.2, 6.5)	0.000	2.1 (1.2, 3.7)	0.009	2.5 (1.3, 4.9)	0.007
History of preterm or low birth weight delivery			1.7 (1.1, 2.4)	0.009	1.1 (0.7, 1.8)	0.533
History of neonatal death or stillbirth			2.1 (1.4, 3.2)	0.000	2.0 (1.3, 3.2)	0.004
Preeclampsia			4.5 (2.9, 6.9)	0.000	2.5 (1.5, 4.3)	0.001
Hospitalization during pregnancy			4.0 (3.1, 5.3)	0.000	1.3 (1.0, 1.9)	0.076
Number of deliveries						
1			2.7 (1.8, 4.1)	0.000	2.9 (1.8, 4.7)	0.000
2			1.8 (1.2, 2.7)	0.009	2.0 (1.3, 3.3)	0.004
3–4			1.3 (0.8, 1.9)	0.272	1.7 (1.0, 2.6)	0.033
≥5			1.0		1.0	
Gender of the baby (males vs. females)					1.5 (1.1, 1.9)	0.003
Congenital defects					61.6 (40.6, 93.5)	0.000
Number of antenatal visits						
None					4.1 (1.7, 9.7)	0.001
1–8					1.9 (1.5, 2.5)	0.000
>8					1.0	
Number of fetuses (multiple vs. single)					1.7 (1.2, 2.4)	0.002
Presentation						
Cephalic					1.0	
Breech					1.5 (1.0, 2.3)	0.038
Other					1.5 (0.9, 2.7)	0.139
Gestational age (≥37 weeks vs. <37)					23.8 (17.4, 32.5)	0.000

feeding. Low birth weight babies need to maintain body temperature through skin-to-skin contact with the mother [20]. Continuous positive airway pressure to manage babies with RDS and use of surfactant to prevent RDS in preterm babies are essential interventions for newborns.

The observed low NNM rate in the private sector can be explained by the known practice in Jordan, of referring high risk deliveries to the public sector. However, our data showed consistently a strong association between the hospital in which the delivery took place and the NNM rate. Since hospitals code for quality of care, it becomes evident that improving the quality of neonatal care in hospitals is a key for reducing NNM to meet the fourth millennium development goal in Jordan. This is further supported by our data showing that only 37.3 % of neonatal deaths had received optimal medical care as defined by the Neonatal Care Clinical Guidelines for Physicians, Jordan [10]. A thorough assessment of the quality of medical care in all hospitals included in the study was carried out and will be presented in a separate report.

The study also has shown a number of maternal and neonatal risk factors of NNM. Consistent with available literature, maternal age <20 years [11] was a significant risk factor for neonatal mortality in the bivariate analysis, but lost its significance in multivariate analysis because of its strong correlation with parity. In agreement with a number of previous studies, history of NND or stillbirth [4], Maternal disease particularly preeclampsia [6], parity [4], inadequate antenatal care [16], prematurity [12, 15], low birth weight [15], male gender [4, 15, 20], congenital anomalies [3], multiple pregnancy [17], malpresentation [1] and gestational age ≤37 weeks [8] were among the most prominent risk factors observed in this study. For the sake of brevity, we refrained from discussing the proposed mechanisms by which each of these factors contributes to NNM.

The major study limitation was the inability to follow all women. However, the follow up rate was very high (>98 %). Only 369 births out of 21,928 women were lost to follow. Another limitation is that home deliveries were not included in the study. However, home deliveries account for about 1 % of total deliveries in Jordan.

In conclusion, the present study showed the level, causes, and risk factors of NNM in Jordan. It showed also that over three-fourths of NNDs are preventable or possibly preventable. Optimal intrapartum, and immediate postpartum care were provided to only 37.3 % of NNDs leaving ample room for avoidance of a large proportion of NNDs through improvement of medical care provided in Jordanian hospitals. The study provides a basis for developing a national strategy to combat NNM in order to progress toward achieving the millennium development goal 4 regarding child survival.

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Compliance with Ethical Standards

Conflict of interest None.

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