Jordan Journal of Nursing Research, Volume **4**, No. **4**, **2025**
DOI: https://doi.org/10.14525/JJNR.v4i4.03

Jordan Journal of Nursing Research

https://jjnr.just.edu.jo/jjnr

Did the COVID-19 Pandemic Influence Neural Tube Defects Incidence in Jordan?

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ARTICLE INFO

Article History:
Received: July 24, 2025
Accepted: September 25, 2025

ABSTRACT

Background: Neural tube defects (NTDs), mostly folate-dependent, are congenital anomalies. COVID-19 increased obesity in Jordanian women and reduced prenatal care, potentially affecting NTD prevention and screening. ***Purpose*****:** This study investigates the impact of the COVID-19 pandemic on NTD incidence in Jordan, considering reduced antenatal care, limited folic acid supplementation, and increased obesity among women during lockdowns. ***Methods*****:** A comparative observational study was conducted on two groups of live births. The first group included babies conceived before the pandemic and born between March 2019 and November 2020 (N = 65,455), while the second group included babies conceived during the pandemic and born between December 2020 and August 2022 (N = 68,363). All recorded NTD cases from 12 hospitals in Northern Jordan were classified into these two groups: conceived before (n = 72) and during (n = 88) the pandemic. Descriptive statistics, Chi-square, and student independent t-test were performed. Incidence rates were compared, and data on socio-demographic, medical, antenatal, anthropometric, and nutritional factors was collected from medical records and parental interviews. ***Results*****:** NTD incidence was 1.3 per 1,000 births during the pandemic *versus* 1.1 before, with no statistically significant difference (P=0.3217). Myelomeningocele was the most common sub-type (61.4%), with a slight female predominance (51.1%). Case fatality was significantly higher during the pandemic (29.5% *vs*. 13.9%, P = 0.0183), and in non-spina bifida cases (87.5% *vs*. 23.7%, P = 0.0007). Family history had less impact on spina bifida (5%) compared to other NTDs (37.5%, P = 0.0149). Despite the pandemic, 84.1% of mothers attended antenatal clinics and 61.4% took folic acid. A higher BMI (≥ 29 kg/m²) was noted in 37.1% of mothers, up from 30.6% pre-pandemic. ***Conclusion*****:** Reducing NTDs requires identifying key risk factors and reassessing maternal health programs, with further national studies needed to guide prevention efforts. ***Implications for Nursing*****:** Nurses educate, support, and advocate for maternal health, emphasizing folic acid, antenatal care, nutrition, and emotional support.

Keywords: Antenatal care, COVID-19 pandemic, Folic acid, Incidence, Neural tube defects.

What does this paper add?

1. It shows that, even during the challenges of the COVID-19 pandemic, many women in Jordan continued to access antenatal care and take folic acid, helping keep neural tube defect rates steady.
2. It reveals a rise in maternal obesity and higher rates of severe outcomes for affected babies during the pandemic, highlighting the need for more personalized nutrition support and early risk screening for pregnant women.

Introduction

Neural tube defects (NTDs) are congenital anomalies resulting from the incomplete closure of the neural tube during early embryonic development. The major forms include anencephaly, encephalocele and spina bifida (NICHD, 2017). The impact of NTDs depends on their type. Anencephaly, unfortunately, is incompatible with life and usually results in stillbirth or death shortly after birth. Spina bifida, on the other hand, allows survival, but often brings significant lifelong challenges, such as paralysis, difficulties with bowel or bladder control, hydrocephalus, and learning difficulties, which can greatly affect the quality of life for both the child and the family (Shaikh et al., 2025). The global prevalence of NTDs is approximately two cases per 1,000 births, affecting around 214,000-322,000 pregnancies annually, with higher incidence and mortality rates in low- and middle-income countries, particularly in Asia and Africa (Kancherla, 2023; Yacob et al., 2021).

In Jordan, the most recent incidence of NTDs was reported as 1.4 per 1,000 births before the COVID-19 pandemic (Al-Qudah et al., 2010). While insufficient folate levels are a primary cause of NTDs and can be prevented (De-Regil et al., 2015; Kancherla, 2023), the Jordanian government introduced wheat flour fortification with folic acid in 2002 and folic acid supplementation in antenatal care centers in 2004 (MOH, 2004; Serdula et al., 2014). These initiatives reduced NTDs frequency by about 70%, but 30% of cases remain folate-independent, linked to other factors, such as maternal diabetes, exposure to valproic acid, race, socio-economic status and maternal obesity (Agopian et al., 2013; Finnell et al., 2021; Parker et al., 2013; Shaikh et al., 2025; Tanoshima et al., 2015).

Maternal obesity before pregnancy is a well-established risk factor for NTDs in babies, and the likelihood of these defects rises as a mother's body mass index increases (Vena et al., 2022). With reference to the preceding, the COVID-19 pandemic led to increased obesity rates, with 68.5% of Jordanian females affected and a global decline in antenatal and prenatal care visits by 38.6%, potentially impacting NTDs prevention and screening (Al-Domi et al., 2021; Kotlar et al., 2021; Townsend et al., 2021). Based on this, we hypothesized that the pandemic increased NTDs risk due to reduced prenatal care and/or weight gain during lockdown. The study aims to investigate and compare the pandemic's effect on NTDs incidence, types of NTDs, case fatality rate and to provide an overview of the associated risk factors.

Methods

Study Design, Settings and Target Population

A comparative observational study was conducted on two groups of infants born with NTDs at 12 hospitals (Governmental: Princess Rahmeh, Princess Raya, Al-Yarmouk, Al-Mafraq, Al-Eyman, Jerash, Moath Ben Jabal, Aby Obaideh; Military: Prince Rashed, King Talal, Princess Haya; and University: King Abdullah) in Northern Jordan over two time periods.

Since the COVID-19 pandemic, lockdown began in Jordan in March 2020 and considering that NTDs develop in the first trimester, we included in this study all infants born with NTDs in Northern Jordan and divided them into two groups as follows: the first group (pre-pandemic group) included infants conceived before the pandemic and born between March 2019 and November 2020, while the second group (pandemic group) included infants conceived during the pandemic and born between December 2020 and August 2022.

The study excluded infants born in private hospitals in Northern Jordan and in Northern Badia hospitals, as these cases are typically referred to the selected hospitals if they survive the first 24 hours. Additionally, all infants born without NTDs and those born outside Northern Jordan were excluded.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki ethical principles for medical research involving human subjects. Prior to data collection, the study proposal was submitted to three Institutional Review Boards (IRBs): The Jordanian Ministry of Health (IRB number: MBA/IRB/12068), Jordanian Royal Medical Services (IRB number: TF3/1/IRB/16058), and King Abdullah University Hospital (IRB number: 67/149/2022). Since the research did not involve blood sample collection, verbal consent was obtained from participating parents *via* telephone calls, as permitted by all three IRBs.

Sampling

The estimated sample size was calculated based on a previously reported incidence rate of 1.4 per 1,000 births (Al-Qudah et al., 2010) and 54,565 live births recorded in Northern Jordan in 2020 (JDOS, 2020). This yielded

an expected 76 cases (1.4 × 54,565 ÷ 1,000 ≈ 76). To enhance the power of the analysis and account for potential exclusions, the sample size was increased by 10%, resulting in a final total of 88 infants.

To conduct this comparative study, we included all live birth infants conceived during the pandemic (N = 68,363) and born with NTDs (n = 88) between December 2020 and August 2022 in 12 selected hospitals in Northern Jordan, in addition to all live birth infants conceived before the pandemic (N = 65,455) and born with NTDs (n = 72) between March 2019 and November 2020 in the same selected hospitals.

Data Collection

Data was initially collected through multiple visits to neonatal intensive care units (NICUs) and by reviewing medical records to calculate and compare the incidence of NTDs across both study periods. From the medical records, information was extracted on each baby's NTD type, gestational age, sex, and birth status (live or deceased), as well as parental details, including mother's and father's names, mother's national identification number, area of residence, and contact telephone numbers. Maternal health information, including parity, gravidity, chronic diseases, and medications taken during pregnancy, was also recorded.

Later, telephone interviews with parents were conducted to gather socio-demographic, medical, antenatal, anthropometric and nutritional information only for the group conceived during the pandemic using a validated questionnaire.

The questionnaire was reviewed by a panel of neonatologists and nutrition specialists to ensure content validity, and a pilot study with 15 participants was conducted to assess reliability before finalizing the instrument. It included questions covering socio-demographic, medical, antenatal, anthropometric, and nutritional aspects.

Questionnaire forms were administered directly to participating parents *via* telephone interviews. During the interviews, parents were asked about the baby's age at death, sex, twin or single pregnancy, previous history of spontaneous abortion, any prenatal consultations, and attendance at antenatal care (ANC) clinics during the first trimester. For mothers who did not attend ANC clinics, reasons for non-attendance were recorded. Additional questions focused on first-trimester screenings, gestational age at the first ANC visit, patterns of folic acid supplementation (prenatal and/or first trimester), and the gestational age at which folic acid intake began. Mothers were also asked about symptoms of folic acid deficiency.

Furthermore, the questionnaire collected information to determine maternal BMI before the pandemic and during the first trimester, as well as to assess nutritional habits and knowledge before and during the pandemic. This included the use of antenatal vitamins and minerals, recognition of folic acid as an essential prenatal vitamin, understanding of its importance, dietary sources, foods rich in folic acid, and the impact of cooking on folic acid content.

Statistical Analysis

The data was coded and entered into Microsoft Excel, then analyzed using SPSS, version 25.0. Descriptive statistics, including frequencies and percentages, were used for categorical variables, while means and standard deviations described continuous variables. Pearson's Chi-square ($\chi 2$) and Fisher's exact tests were performed to assess the associations between categorical variables, while the student t-test for independent variables was performed to detect any significant differences between the means of the normally distributed continuous variables. $P < 0.05$ was considered statistically significant.

Results

Out of the 335 participants initially evaluated, only 72 (conceived before the pandemic) and 88 (conceived during the pandemic) met the study's inclusion criteria. Many were excluded due to being born outside Northern Jordan, being misdiagnosed with NTDs, or being born outside the two specified study periods. Cases were identified in only nine of the 12 hospitals, with 50% of the pandemic group and 27.7% of the pre-pandemic group coming from Princess Rahma Children's Governmental Hospital.

Socio-demographic Data

The average maternal age for the pandemic group (N=88) at conception was around 29 years, with families averaging five members. Most babies were the third among siblings and forth in pregnancy order, with a slight female majority (51%). Notably, 77.3% of the participants had no first-degree consanguinity between parents, although 66.7% of encephalocele cases did.

Most of the families resided in Irbid, where most babies were also born. Additionally, most mothers had a high school education or less, were unemployed during pregnancy and 89% of the families had a monthly income under 500 Jordanian Dinar. 87.5% of mothers had health insurance. However, many were exposed to smoking, either directly or passively, but most of them did not smoke during pregnancy (Table 1).

Table 1. Socio-demographic characteristics of the pandemic group study participants (N = 88)

Variable	NTD N (%) 88 (100.0)	Spina bifida n (%) 80 (90.9)	Anencephaly n (%) 5 (5.7)	Encephalocele n (%) 3 (3.4)
Sex				
-Male	43 (48.9)	39 (48.7)	2 (40.0)	2 (66.7)
-Female	45 (51.1)	41 (51.3)	3 (60.0)	1 (33.3)
First degree consanguinity between parents				
-Yes	20 (22.7)	17 (21.3)	1 (20.0)	2 (66.7)
-No	68 (77.3)	63 (78.7)	4 (80.0)	1 (33.3)
Order according to pregnancies				
-Baby was the first or second pregnancy	28 (31.8)	27 (33.8)	0 (0.0)	1 (33.3)
-Baby was the third pregnancy or more	60 (68.2)	53 (66.2)	5 (100.0)	2 (66.7)
Residence				
-Irbid	50 (56.8)	47 (58.8)	2 (40.0)	1 (33.3)
-Jerash	6 (6.8)	6 (7.5)	0 (0.0)	0 (0.0)
-Ajloun	10 (11.4)	8 (10.0)	1 (20.0)	1 (33.3)
- Al-Mafraq	18 (20.5)	16 (20.0)	1 (20.0)	1 (33.3)
-Amman	4 (4.5)	3 (3.7)	1 (20.0)	0 (0.0)
Birthplace				
-Irbid	64 (72.8)	60 (75.0)	3 (60.0)	1 (33.3)
-Jerash	4 (4.5)	4 (5.0)	0 (0.0)	0 (0.0)
-Ajloun	4 (4.5)	3 (3.8)	0 (0.0)	1 (33.3)
-Al-Mafraq	16 (18.2)	13 (16.2)	2 (40.0)	1 (33.3)
Mother's education				
-high school or less	61 (69.3)	56 (70.0)	4 (80.0)	1 (33.3)
-more than high school	27 (30.7)	24 (30.0)	1 (20.0)	2 (66.7)
Mother employment during pregnancy				
-Yes	7 (8.0)	6 (7.5)	0 (0.0)	1 (33.3)
-No	81 (92.0)	74 (92.5)	5 (100.0)	2 (66.7)
Family's income during mother's pregnancy	78 (88.6)	73 (91.2)	5 (100.0)	0 (0.0)
-Less than 500 JOD	10 (11.4)	7 (8.8)	0 (0.0)	3 (100.0)
-500 JOD or more				
Mother and child insurance				
-Yes	77 (87.5)	70 (87.5)	4 (80.0)	3 (100.0)
-No	11 (12.5)	10 (12.5)	1 (20.0)	0 (0.0)
Smoker or passive smoker mother				
-Yes	74 (84.1)	67 (83.8)	4 (80.0)	3 (100.0)
-No	14 (15.9)	13 (16.2)	1 (20.0)	0 (0.0)
Mother smoked during pregnancy				
-Yes	11 (12.5)	10 (12.5)	1 (20.0)	0 (0.0)
-No	77 (87.5)	70 (87.5)	4 (80.0)	3 (100.0)
Variable	**Mean ± SD**			
	NTD N=88	**Spina bifida n=80**	**Anencephaly n=5**	**Encephalocele n=3**
Family members number	5.0 ± 2	5.4 ± 1.8	7.0 ± 2.4	4.5 ± .7
Order according to siblings	3.0 ± 2	3 ± 1.8	5.0 ± 2.4	2.0 ± 1.4
Order according to pregnancies	4.0 ± 3	3.9 ± 2.4	6.8 ± 4.5	2.5 ± 2.1
Mother's age at pregnancy (years)	28.8 ± 6	28.6 ± 6.2	34 ± 5.4	26 ± 7

Data is presented as frequencies (n) and percentages (%) unless otherwise stated. NTD: Neural tube defect.

Antenatal Care Data

Most of the pandemic group mothers (N=88) (93.2%) did not seek prenatal consultations with a doctor, but 84.1% visited an antenatal care clinic (ANC) during the first trimester, typically around seven weeks of gestation. Only 6.8% took folic acid prenatally, 61.4% began taking it regularly during the first trimester, starting at an average of 4.7 weeks of gestation.

Figure 1 shows the patterns of taking folic acid among the interviewed mothers. Reasons for not taking folic acid included mothers' inability to visit the ANC due to lockdown (8.1%), lack of money or insurance (6.5%), forgetting to take it (9.7%) and experiencing side effects (6.5%). Additionally, 69.4% of the mothers reported experiencing symptoms of folic acid deficiency, such as fatigue, numbness and early graying of hair, before or during the first trimester.

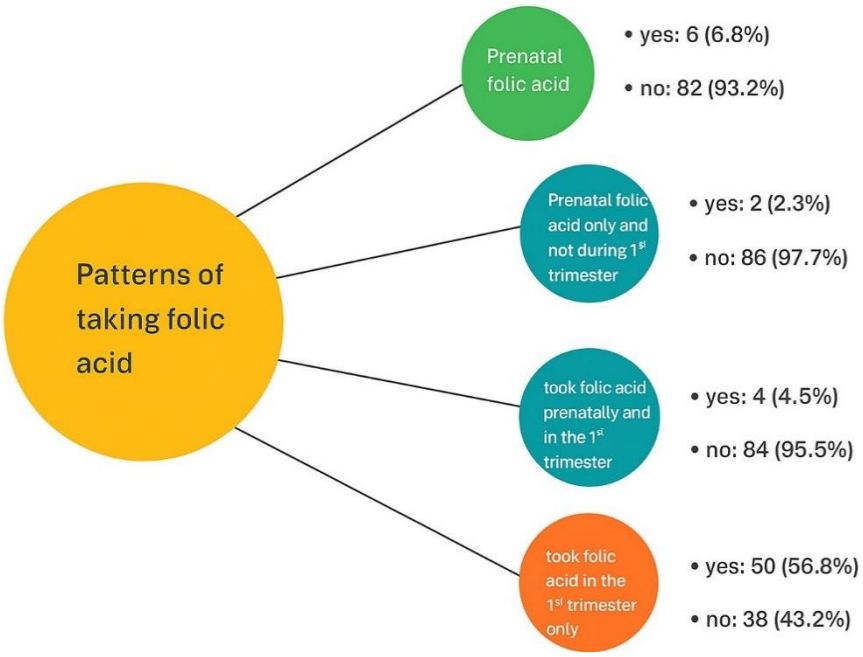

Figure 1. Frequency distribution of patterns of taking folic acid among the interviewed mothers of the pandemic group (N = 88)

Anthropometric and Nutritional Data

Before the pandemic, the average BMI of the interviewed mothers (N=88) was 26.4 kg/m², increasing slightly to 26.5 kg/m² during the first trimester. There was a 6.5% rise in the number of mothers with a BMI of 29 kg/m² or higher during the first trimester (37.1%) compared to before the pandemic (30.6%). Regarding dietary knowledge, 14.8% of mothers could not identify any vitamins or minerals, although 80.7% recognized folic acid as an important prenatal supplement. However, only 8% had excellent knowledge of its role. 54.6% could not identify food sources of folic acid. Additionally, 44% reported a decrease in folic acid-rich food intake during the pandemic, citing lockdown, financial issues and pregnancy cravings as reasons.

NTDs Incidence

The study sample represented about 70% of the population, as there were 54,565 births in Northern Jordan in 2020, with 38,052 occurring in the selected hospitals (Jordanian Department of Statistics, 2020).
38052 ÷ 54565 × 100 = 69.7%.

Between December 2020 and August 2022, 88 cases of neural tube defects (NTDs) were reported in these hospitals, out of 68,363 total births during the same period, resulting in an incidence rate of 1.3 per 1,000 births among those conceived during COVID-19.

88 × 1000 ÷ 68363 = 1.3 per 1000 births.

The incidence rate of NTDs among the total births at the same selected hospitals among those conceived prior to COVID-19 was 1.1 per 1,000 births.
72 × 1000 ÷ 65455 = 1.1 per 1000 births.

Results of comparison showed that there is no statistically significant (P = 0.3217) difference between the incidences prior to and during COVID-19, although the incidence during COVID-19 is slightly higher (Table 2).

Table 2. Incidence and case fatality rates of cases conceived prior to and during the COVID-19 pandemic among births in the selected hospitals

	Prior to COVID-19 n (%)	During COVID-19 n (%)	P-value
Diagnosis after birth			
-NTDs	72 (0.1)	88 (0.1)	0.3217
-Free of NTDs	65383 (99.9)	68275 (99.9)	
Incidence rate	1.1/1000 births	1.3/1000 births	
Evaluation after 4 months of birth			
-Alive	62 (86.1)	62 (70.5)	**0.0183**
-Deceased	10 (13.9)	26 (29.5)	
Case fatality rate	13.9%	29.5%	

Data is presented as frequencies (n) and percentages (%).
P-value < 0.05 is statistically significant for Chi-square test.
NTDs: Neural tube defects.

Medical Data

Among the pandemic group cases (N=88), the most common sub-type of NTDs was myelomeningocele (MMC) which accounted for 61.4% of cases, while meningocele accounted for 9.1%, unspecified spina bifida for 12.5%, spina bifida occulta for 7.9%, encephalocele for 3.4% and anencephaly for 5.7%. In general, spina bifida cases accounted for 90.9% compared to non-spina bifida cases (9.1%). 8% of the pandemic NTDs cases had a family history of NTDs, 0% among encephalocele and 60% among anencephalic cases.

The average gestational age at birth was 37.6 weeks, pre-term births occurred in 14.8% of all cases and 60% of anencephalic cases. Twin pregnancies, which comprised 6.8% of the total, only involved spina bifida, making up 7.5% of those cases. While most mothers had free medical history, 20.5% had chronic conditions, such as (diabetes mellitus, iron deficiency anemia, inflammatory bowel disease, hypertension, hypothyroidism, and chronic H. pylori), all of which were associated with spina bifida cases. A history of spontaneous abortions was present in 27.3% of mothers, with a higher proportion among those with anencephalic babies (60%). By the time of interviews, 37.5% of the babies had died, including all anencephalic and two-thirds of encephalocele cases. To calculate the case fatality rate, we evaluated the babies' status after four months of birth and found that 29.5% of them were dead, which means that 8% died after four months of birth. Consequently, the case fatality rate among the pandemic group was 29.5% (Table 3).

Table 3. Medical history of the pandemic group study participants (N = 88)

Variable	NTD N (%) 88 (100.0)	Spina bifida n (%) 80 (90.9)	Anencephaly n (%) 5 (5.7)	Encephalocele n (%) 3 (3.4)
NTD family history				
-Yes	7 (8.0)	4 (5.0)	3 (60.0)	0 (0.0)
-No	81 (92.0)	76 (95.0)	2 (40.0)	3 (100.0)
Term of the baby				
-Full-term	75 (85.2)	70 (87.5)	2 (40.0)	3 (100.0)
-Pre-term	13 (14.8)	10 (12.5)	3 (60.0)	0 (0.0)

Single or twin pregnancy				
-Single pregnancy	82 (93.2)	74 (92.5)	5 (100.0)	3 (100.0)
-Twin pregnancy	6 (6.8)	6 (7.5)	0 (0.0)	0 (0.0)
Mother's medical history				
-Free medical history	70 (79.5)	62 (77.5)	5 (100.0)	3 (100.0)
-Has a chronic disease	18 (20.5)	18 (22.5)	0 (0.0)	0 (0.0)
Mother's history of previous spontaneous abortions				
-Yes	24 (27.3)	20 (25.0)	3 (60.0)	1 (33.3)
-No	64 (72.7)	60 (75.0)	2 (40.0)	2 (66.7)
Baby's status				
-Alive	55 (62.5)	54 (67.5)	0 (0.0)	1 (33.3)
-Deceased	33 (37.5)	26 (32.5)	5 (100.0)	2 (66.7)
Evaluation after 4 months of birth				
-Alive	62 (70.5)	61 (76.3)	0 (0.0)	1 (33.3)
-Deceased	26 (29.5)	19 (23.7)	5 (100.0)	2 (66.7)
Variable	**Mean ± SD**			
	NTD N=88	**Spina bifida n=80**	**Anencephaly n=5**	**Encephalocele n=3**
GA at birth (weeks)	37.6 ± 2.2	37.6 ± 2.2	36 ± 1.4	39 ± 1.4

Data is presented as frequencies (n) and percentages (%) unless otherwise stated.

NTD: Neural tube defect. GA: Gestational age.

In comparison, the case fatality rate among those conceived prior to the COVID- 19 pandemic was 13.9% with a significant (P = 0.0183) difference observed between the two study periods (Table 2). Additionally, a highly significant (P = 0.0007) difference was observed in case fatality rates between spina bifida and non-spina bifida cases within the pandemic group (N=88). Specifically, the case fatality rate for spina bifida cases was 23.7%, while for non-spina bifida cases, it was markedly higher at 87.5% (Table 4).

Table 4. Comparing the spina and non-spina bifida NTD babies according to selective socio-demographic data and medical history among the pandemic group study participants (N = 88)

Variable	**NTD N (%) 88 (100.0)**	**Spina bifida n (%) 80 (90.9)**	**Non-spina bifida NTD n (%) 8 (9.1)**	**P-value**
Sex				
-Male	43 (48.9)	39 (48.7)	4 (50.0)	1.000
-Female	45 (51.1)	41 (51.3)	4 (50.0)	
First degree consanguinity between parents				
-Yes	20 (22.7)	17 (21.3)	3 (37.5)	0.3748
-No	68 (77.3)	63 (78.7)	5 (62.5)	
Order according to pregnancies				
-Baby was the first or second pregnancy	28 (31.8)	27 (33.8)	1 (12.5)	0.4272
-Baby was the third pregnancy or more	60 (68.2)	53 (66.2)	7 (87.5)	
Smoker or passive smoker mother				
-Yes	74 (84.1)	67 (83.8)	7 (87.5)	1.000
-No	14 (15.9)	13 (16.2)	1 (12.5)	
Mother smoked during pregnancy				
-Yes	11 (12.5)	10 (12.5)	1 (12.5)	1.000
-No	77 (87.5)	70 (87.5)	7 (87.5)	
NTD family history				
-Yes	7 (8.0)	4 (5.0)	3 (37.5)	**0.0149**
-No	81 (92.0)	76 (95.0)	5 (62.5)	

History of previous spontaneous abortions				
-Yes	24 (27.3)	20 (25.0)	4 (50.0)	0.2060
-No	64 (72.7)	60 (75.0)	4 (50.0)	
Term of the baby				
-Full-term	75 (85.2)	70 (87.5)	5 (62.5)	0.0917
-Pre-term	13 (14.8)	10 (12.5)	3 (37.5)	
Evaluation after 4 months of birth				
-Alive	62 (70.5)	61 (76.3)	1 (12.5)	**0.0007**
-Deceased	26 (29.5)	19 (23.7)	7 (87.5)	
	Mean ± SD			**P-value**
Mother's age at pregnancy (years)	28.8 ± 6	28.8 ± 6.3	29.8 ± 6.6	0.695

Data is presented as frequencies (n) and percentages (%) unless otherwise stated.
P-value < 0.05 is statistically significant for Chi-square test or independent student t-test.
NTD: Neural tube defect.

Table 4 also shows that there is a significant (P = 0.0149) difference between the presence of family history in the spina bifida (5%) and the non-spina bifida NTDs cases (37.5%), indicating that family history may have a lesser influence on the development of spina bifida compared to other NTDs.

Discussion

This study examined the impact of the COVID-19 pandemic on the incidence of NTDs in Jordan, focusing on socio-demographic and medical characteristics, case fatality rate, NTDs sub-types and the nutritional habits and antenatal care of Jordanian mothers. The study found no statistically significant difference in the incidence of NTDs before and during the pandemic. However, case fatality rate was significantly higher during the pandemic and among non–spina bifida cases. Myelomeningocele was the most common sub-type, with a slight female predominance. Family history appeared to have less influence on spina bifida compared to other NTDs. Despite the challenges of the pandemic, most mothers continued to attend antenatal clinics, and more than half of them reported taking folic acid. Additionally, over one-third of mothers had a BMI ≥ 29 kg/m² during the pandemic.

The NTDs incidence in Northern Jordan during the pandemic was 1.3 per 1,000 births, only slightly higher than the pre-pandemic rate of 1.1 per 1,000 births. This relative stability is likely due to the high rate of antenatal care attendance (84.1%) and folic acid intake (61.4%) during the pandemic, leading to the rejection of the study's initial hypothesis. Jordan's NTDs rate remains lower than in Riyadh (1.7 per 1,000) (Al Rakaf et al., 2015) and significantly lower than in Ethiopia (20.24 per 1,000) (Mohamed et al., 2023), likely due to the country's fortification and supplementation programs implemented in 2002 and 2004 (Ministry of Health, 2004; Serdula et al., 2014). Myelomeningocele (MMC) was the most prevalent NTD sub-type (61.4%), consistent with findings from Saudi Arabia (Al-Wassia et al., 2023), but differing from Morocco, where anencephaly was more common (Forci et al., 2021), suggesting potential genetic and environmental influences.

In this study, the average maternal age at pregnancy was around 29 years, similar to findings in Saudi Arabia and Morocco (Al-Wassia et al., 2023; Forci et al., 2021). Mothers of anencephalic babies had a higher mean age of 34 years, compared to 25.3 years in Brazil, likely due to differences in genetic, nutritional and social factors (Machado et al., 2012). The gender distribution of NTDs cases was nearly equal (51.1% female), aligning with Moroccan data (Forci et al., 2021), though this contrasts with most available literature, such as in Saudi Arabia, where females predominated (Al-Wassia et al., 2023). Birth order also played a role, as 68.2% of cases were the third pregnancy or more and the average pregnancy order was fourth, suggesting a link between gravidity and NTDs, as also noted in Ethiopia where birth order three and four had a strong significant association with NTDs (Berihu et al., 2019). First-degree consanguinity was present in 22.7% of cases, especially in encephalocele (66.7%), similar to Moroccan findings. However, the overall consanguinity rate in Morocco (80%) was higher, likely due to more frequent cousin marriages (Forci et al., 2021).

According to the Virginia Department of Health, 95% of anencephaly cases lack a family history, but having one affected child increases the risk to one in 25 (Virginia Department of Health Fact Sheet, 2016). In

this study, 60% of anencephalic cases had a family history, likely due to higher birth rates in Jordan, where the average pregnancy order for these cases was the seventh. Additionally, 8% of all NTD cases had a first-degree family history, which is higher than the 3.1% reported in Alabama, USA (Dupépé et al., 2017), likely due to Jordan's higher birth rates, consanguinity and larger family sizes.

Twin pregnancies were found only in spina bifida cases (7.5%) in this study, while an Australian study reported 13 twin pregnancies with discordant NTDs, including eight with anencephaly, three with encephalocele and two with spina bifida (Ross et al., 2018). Pre-term deliveries occurred in 14.8% of NTD cases and 60% of anencephaly cases, which is lower than the 27.3% for NTDs in Morocco (Forci et al., 2021) and the 85% for anencephaly in Brazil (Machado et al., 2012), suggesting relatively strong antenatal care in Jordan.

In this study, 27.3% of mothers with NTD-affected pregnancies had a history of spontaneous abortions, lower than the 48% reported by Carmi et al. (1994). Among mothers of anencephalic babies, 60% had experienced prior miscarriages, consistent with a Mexican study that found that women with a history of miscarriages had 4.58 times higher risk of having an anencephalic child (Blanco-Muñoz et al., 2006). Additionally, maternal exposure to smoking or passive smoking doubles the risk for NTDs (Suarez et al., 2011) and 84.1% of mothers in this study were smokers or passive smokers.

Mothers with higher BMI values are at a higher risk for fetal NTDs (Vena et al., 2022). In our study, 37.1% of mothers had a BMI $\geq$ 29 kg/m², showing a 6.5% increase during the first trimester compared to pre-pandemic levels. This finding is based on mothers' subjective recall of their weight, which may be affected by societal standards to report lower weights. As a result, it's expected that in our study we have a higher percentage of women with BMI $\geq$ 29 kg/m^2. Our study's case fatality rate was 29.5%, lower than Morocco's 38.6% (Forci et al., 2021), likely due to Morocco's higher proportion of anencephaly cases.

While our sample represented about 70% of the Northern Jordanian population, it excluded Northern Badia and private hospitals and did not cover all Jordanian regions. The study's comparative observational design limited the establishment of clear causality and generalizability. Additionally, relying on mothers' recall for dietary intake and BMI introduced further limitations.

Implications for Policy Makers, Future Research and Nursing

Although NTD incidence did not change during the pandemic, the higher case fatality rate highlights gaps in maternal and neonatal care. Policy makers should prioritize uninterrupted access to antenatal services, folic acid supplementation, and maternal nutrition support, even in times of crisis. Future research is needed to establish a national birth defects registry and to explore ways of improving care pathways, so that affected children and their families receive the support that they need.

Nurses play a crucial role in preventing neural tube defects and supporting maternal health. Educating women about taking folic acid before and during early pregnancy is essential, as it greatly reduces NTD risk. Nurses also help ensure continued access to antenatal care, especially during crises like the COVID-19 pandemic. With rising obesity rates among pregnant women, they provide supportive guidance on healthy nutrition and weight management. By assessing family history, nurses can identify high-risk pregnancies and offer appropriate referrals. In cases of poor outcomes, they provide emotional support and grief counseling, helping families cope with loss. Beyond clinical settings, nurses engage in community outreach, promoting awareness about the importance of prenatal care and healthy pregnancy practices. Through education, compassion, and advocacy, nurses help improve outcomes for both mothers and babies, ensuring that they receive the care and support that they need for a healthier start to life.

Conclusion

The incidence of NTDs in our study remained consistent with pre-pandemic levels, indicating that antenatal care was effectively maintained during the lockdown. To reduce NTDs incidence, it's important to identify and address key contributing factors. The findings could help the government reassess programs for pregnant women to lower disability and mortality rates. Therefore, further national studies are recommended to better understand NTDs incidence and its contributing factors.

Author Contributions

Study Design: **MH**. Data Collection: **MH, AA** and **EZ**. Data Analysis: **MH** and **N.A-B**. Study Supervision: **NA-B**. Manuscript Writing: **MH**. Critical revisions for important intellectual content: **MH**, **NA-B**, **AA** and **EZ**.

Acknowledgements

The authors express their gratitude to Dr. Shibani Ghosh from Tufts University, Professor Hiba Bawadi from Qatar University, the participating mothers, and the healthcare professionals for their support in completing this research.

Funding or Sources of Financial Support

This research was funded by the Jordan Nutrition Innovation Lab (JNIL) Research Fellowship from the Friedman School of Nutrition at Tufts University and Cooperative Agreement No. 72027820LA00003 from the United States Agency for International Development (USAID) in accordance with JNIL Branding and Marking Guide.

Conflict of Interests

The authors have no conflict of interests to declare.

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