Determinants of Infant Mortality in Bhutan: Evidence from the 2012 National Health Survey Data

Tashi Dendup[1]*, I Gusti Ngurah Edi Putra[1], Tashi Tobgay[2], Sonam Wangdi[3], and Ugyen Wangchuk[3]

[1] School of Health and Society, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, Australia
[2] Institute of Health Partners, Thimphu, Bhutan
[3] World Health Organization Country Office, Kawang Jangsa, Thimphu, Bhutan
* Tashi Dendup, corresponding author. Email: taseedee@gmail.com
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Abstract

This study examined the bio-demographic, socioeconomic, environmental, and health-related determinants of infant mortality in the Kingdom of Bhutan. The nationally representative dataset of the 2012 National Health Survey (NHS), Ministry of Health of Bhutan, was used. Cox proportional hazards regression from survival analysis, accounting for the complex study design of the NHS, was performed using a stepwise approach to identify the determinants associated with infant mortality. The weighted infant mortality rate from November 2009 to October 2011 was 34 per 1,000 live births. Children born to uneducated mothers (aHR=2.27; 95%CI=1.16-4.47) and mothers who experienced domestic violence during pregnancy (aHR=4.24; 95%CI=1.45-12.41) were more likely to die before reaching their first birthday. Those infants born in households that used solid fuel were 2.16 times (95%CI=1.21-3.85) more likely to die than their counterparts. Relative to those born in the central region, children born in western (aHR=6.13; 95%CI=2.84-13.20) and the eastern (aHR=5.13; 95%CI=2.81-9.35) regions had a greater risk of dying. The results showed that education, domestic violence experience, solid fuel use, and region of residence are the key determinants of infant mortality in Bhutan. Policies that facilitate education and empowerment of women, prevent domestic violence, reduce solid fuel use, and equitable regional socioeconomic development policies may help accelerate the reduction of child mortality.

Keywords

Bhutan; domestic violence; education; infant mortality; solid fuel

Introduction

Infant mortality rate (IMR) is regarded as a sound indicator of wellbeing and health since it reflects the socioeconomic, living, and environmental conditions for the health of mothers and newborns (Reidpath & Allotey, 2003). Infant mortality is defined as the death of a child before reaching their first birthday (WHO, 2016). Globally, the IMR had declined from 65 per 1,000 live births in 1990 to 29 per 1,000 live births in 2018 (WHO, 2020). However, disparities still exist between regions and countries. The burden is markedly high in sub-Saharan Africa and South Asia (Black et al., 2003; Sartorius & Sartorius, 2014; United Nations Children's Fund, 2017). Infant mortality, therefore, remains a significant public health problem, particularly in developing countries (United Nations Children's Fund, 2017).

Bhutan, a small country in South Asia, has made significant strides in improving its population's health over the last decades. The rates of infant mortality decreased significantly by 75%, i.e., from 102.8 per 1,000 live births in 1984 to 30 in 2012 (Ministry of Health, 2014), and to 25 per 1,000 live births in 2018 (United Nations Children's Fund, 2017). Similarly, neonatal mortality rates have declined from 21 per 1,000 live births in 2012 to 18 in 2015 (Ministry of Health, 2016), and to 16 per 1,000 live births in 2018 (United Nations Children's Fund, 2017). Nevertheless, the current IMR is higher than some countries in the region, such as Thailand (8 per 1,000), Indonesia (21 per 1,000), Maldives (7 per 1,000), and Sri Lanka (6 per 1,000) (United Nations Children's Fund, 2017).

A range of proximal (e.g., health-related factors), intermediate (e.g., water and sanitation), and distal (e.g., education and income) determinants are thought to predict infant and child mortality (Mosley & Chen, 2003). These determinants include breastfeeding (Iram & Butt, 2008; Lamichhane et al., 2017; Reno & Hyder, 2018), baby's birth size and weight (Lamichhane et al., 2017; Memiah et al., 2020; Vidal e Silva et al., 2018), and place and type of delivery (Iram & Butt, 2008; Lamichhane et al., 2017; Memiah et al., 2020). Poor health of newborn (Vidal e Silva et al., 2018), prenatal and postnatal care (Iram & Butt, 2008; Reno & Hyder, 2018), multiple births (Dwomoh et al., 2019; Vidal e Silva et al., 2018), and birth interval (Dwomoh et al., 2019; Lamichhane et al., 2017; Reno & Hyder, 2018) are also found to be associated with infant mortality. Maternal age and health (Iram & Butt, 2008; Reno & Hyder, 2018; Vidal e Silva et al., 2018), maternal substance use (Reno & Hyder, 2018), education (Andriano & Monden, 2019; Dutta et al., 2020; Iram & Butt, 2008; Reno & Hyder, 2018), poor socioeconomic status (Ezeh et al., 2015; Iram & Butt, 2008; Reno & Hyder, 2018), rural residence and region (Ezeh et al., 2015; Lamichhane et al., 2017), area disadvantage (Reno & Hyder, 2018; Vidal e Silva et al., 2018), and female labor participation or employment (Akinyemi et al., 2018; Scharber, 2014) also predicted child and infant mortality. Other maternal factors include intimate partner violence (Ahmed et al., 2006; Koenig et al., 2010), tetanus immunization (Iram & Butt, 2008), mass media use, and body mass index (Memiah et al., 2020). Furthermore, environmental determinants such as unsafe drinking water, poor sanitation and hygiene, solid fuel use, electricity availability, urbanization, and pollution are found to have a significant impact on infant mortality (Bassani et al., 2010; Dutta et al., 2020; Iram & Butt, 2008; Reno & Hyder, 2018; Rinne et al., 2007; Sartorius & Sartorius, 2014). National-level indicators such as health expenditure and GDP per capita are also shown to be associated with IMR (Dutta et al., 2020). Identifying factors predicting child mortality can contribute to designing effective policies and interventions to save children's lives. Bhutan aims to reduce the neonatal mortality rate to <13 per 1,000 live births in 2023 from that of 16 in 2018. The 2012 National Health Survey (NHS) showed that around 70% of the infant deaths occurred within the first 28 days of birth (Ministry of Health, 2014).

There is a lack of data on the factors influencing infant mortality in the Kingdom of Bhutan. A case-control study found that children who were born premature and had low birth weight had higher odds of dying. In contrast, children of mothers who attended antenatal and postnatal care were less likely to die before reaching their first birthday (Pokhrel et al., 2019). More than 50% of the deaths were found to occur at home. This study by Pokhrel et al. (2019) was conducted in one district that prohibits generalizability and did not examine the influence of some important factors such as solid fuel use, water and sanitation, education of husband and household head, domestic violence, and rural residence. Another study showed that the mother's age, parity, region of residence, household size, and access to electricity and sanitation were factors predicting under-five-year-old mortality in Bhutan (Dendup et al., 2018). Neonatal deaths, pneumonia, and diarrhea were identified as the leading causes of under-five-year-old deaths based on routine data collected (Ministry of Health, 2016).

With the improvement in socioeconomic, environmental conditions, and child health, mortality in children is expected to be concentrated among infants and neonates (Wang et al., 2014). Thus, understanding the determinants influencing mortality among children during the early period of life becomes more relevant, given Bhutan's potential improvement in child survival. A better understanding of the multifaceted causes of infant mortality can help accelerate the progress in improving child health and survival (Black et al., 2003). This study examined the determinants associated with infant mortality in Bhutan using nationally representative data.

Methods

Study data and sample

This study used the latest available dataset of the 2012 National Health Survey (NHS), conducted by the Ministry of Health of Bhutan, in collaboration with the National Statistical Bureau of Bhutan (Ministry of Health, 2014). A two-stage sampling design stratified by urban-rural areas was used to collect data in 20 districts from November 2012 to February 2013. Urban and rural areas in each district were the primary sampling strata. Villages in rural areas and blocks in the urban areas were initially selected, followed by the selection of households systematically from identified sampling units. This survey successfully documented data from 13,256 households and achieved a response rate of 97%.

Further information related to the survey method mentioned above can be found elsewhere (Ministry of Health, 2014). The Bhutan Research Ethics Board of Health provided ethical clearance for the present study (REBH/Approval/2020/014).

The present study used the birth history records within the two years prior to the survey to increase sample size and outcomes given the small number of infant mortalities recorded in the previous year (just 30 infant deaths). The period used to extract births (November 2009 to October 2011) enabled all infants to reach their first year of life at the commencement of the survey in November 2012. We also included all births without information on the month of birth by assuming that those births occurred in the middle of the corresponding year. Meanwhile, births that occurred earlier than three years or more before the survey (i.e., before November 2009) were not included to reduce recall bias. For this analysis, only singleton births were included, which led to the final sample size of 2,179 for the study.

Study variables

Infant mortality as a dependent variable was defined as deaths of children that occurred before reaching their first birthday (365 days), which was recorded as 1 (died) and 0 (survived). Independent variables were selected according to the framework proposed by Mosley and Chen (2003) and based on the availability of data in the NHS dataset.

There were four main groups of independent variables that included: (1) bio-demographic determinants (e.g., mother's current age, age when first married, age when first pregnant, marital status, child's sex, birth interval, birth order, total births, and household head's sex); (2) socioeconomic determinants (e.g., education of mother, husband's education, household head's education, household size, working status of the mother and household head, wealth index, domestic violence, and domestic violence during pregnancy); (3) environmental determinants (e.g., safe drinking water, safe sanitation facilities, solid fuel use, electricity availability, place and region of residence); and (4) health-related determinants (e.g., contraceptive use, place of delivery, skilled delivery, antenatal care, postnatal care, and colostrum intake). Health-related variables were only collected for those births that occurred in the year preceding the survey (Ministry of Health, 2014). The wealth index was constructed by the principal components analysis method using household assets that include possession of goods (i.e., television and radio); household facilities (i.e., electricity and toilet type); housing conditions (i.e., the main floor and walls materials); and ownership of transportation (i.e., motorcycle and car or truck) (Ministry of Health, 2014).

Statistical analysis

Descriptive analysis using cross-tabulations were carried out to assess the distribution of infant mortality by the independent variables. The complex sample analysis was performed to take into account the sampling weight and clustering effects. The weighted number of samples and percentage, and weighted infant mortality rates (IMRs) were reported. The IMR was calculated using the direct method by dividing the number of infant deaths under one year of age in the study period by the number of live births in the same year and then multiplied by 1,000. A weighting adjustment, wherein underrepresented groups are assigned weights greater than one and those overrepresented smaller than one, was used to estimate the IMR. This helps to account for unequal probability selection common in population studies and provide more accurate parameter estimates. Weighted values were provided in the dataset, and we used the survey command [svy] in STATA to calculate the proportion of infant deaths.

Furthermore, bivariate and multivariate analyses were performed using the Cox proportional hazards regression model from survival analysis. This model expresses the hazard at time t as a function of the values of explanatory variables ($X_1, X_2, \ldots, X_p$) as presented below (Iddrisu et al., 2019).

$$h(t) = h_0(t)exp\left(\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p\right)$$

Where $\beta_1, \beta_2, \ldots, \beta_p$ represent parameter estimates of explanatory variables, and h_0 is the baseline hazard when all explanatory variables have zero value. One primary assumption of this model is a constant hazard ratio. From this equation, the hazard ratio (HR) can be calculated as presented below.

$$HR(t, X_1, X_0) = exp(\beta_1(X_{1-}X_0))$$

The time variable represents how many days infants survived that was observed from the birth date (start point) until their first birthday (365 days – endpoint). For those infants who died during the observation period, the survival time was generated based on the age of death, recorded as the day and month of death within the one-year period of life. When the month of death was the only available information in the dataset, we calculated the days of survival by multiplying the number of months by 30 days. The unadjusted and adjusted HRs, along with 95% confidence intervals (CI), were generated by regression analysis.

Due to a small number of infant deaths in this study (64 cases), infant mortality determinants were identified using multiple regression analysis with a stepwise elimination method. All independent variables, irrespective of the level of the *p*-value from the bivariate analysis, were included in the multivariate model to minimize the risk of missing essential determinants. Other variables that were not significant, and eliminated from the multivariate model before, were again included in the final model to re-examine their influence. The final model consisted of variables with a *p*-value of less than 0.05. The potential multicollinearity between the independent variables was assessed using correlation and variance inflation factor (VIF). All statistical analyses were performed using the STATA version 14 package.

Results

During the 2-year period (November 2009 to October 2011), there were 2,179 singleton births and 64 infant deaths. Table 1 presents the distribution of infant mortality by the explanatory variables. The overall weighted IMR was 34 per 1,000 live births. The proportion of infant mortality was significantly higher among infants born to uneducated mothers, mothers who experienced domestic violence during pregnancy, born in households that used solid fuel for cooking, western and eastern regions, as well as infants who were delivered at home, delivered by unskilled birth attendants, and not given colostrum. Figure 1 (a) presents the Kaplan-Meier curve, which shows that 97.33% of the infants survived until the first birthday. More than half of the infant deaths (n=41) occurred within the first month of life.

Table 1: Characteristics and Distribution of Infant Mortality in Bhutan

Variables	n	n* (%*)	IM (IMR*)	*p*-value#
Total samples	2,179	2,114	64 (34)	
a) Bio-demographic determinants				
Mother's age (years)				0.962
<25	605	611 (28.90)	16 (35)	
≥25	1,574	1,503 (71.10)	48 (34)	
Mother's age when first married (years)				0.805
<18	648	659 (31.18)	22 (33)	
≥18	1,463	1,388 (65.64)	40 (35)	
Not reported/missing	*68*	*67 (3.18)*	*2 (15)*	
Mothers age when first pregnant (years)				0.903
<20	892	906 (42.84)	28 (35)	
≥20	1,194	1,117 (52.82)	32 (34)	

Variables	n	n* (%*)	IM (IMR*)	*p*-value#
Not reported/missing	*93*	*92 (4.34)*	*4 (31)*	
Mother's marital status				0.209
Married	1,961	1,906 (90.13)	60 (36)	
Not married	217	108 (9.83)	4 (16)	
Not reported/missing	*1*	*1 (0.04)*	*0*	
Sex of the child				0.177
Girl	1,100	1,045 (49.45)	27 (26)	
Boy	1,079	1,069 (50.55)	37 (42)	
Total births				0.322
≤2 births	1,247	1,215 (57.49)	31 (29)	
>2 births	932	899 (42.51)	33 (41)	
Sex of the household head				0.388
Female	898	792 (37.49)	29 (40)	
Male	1,281	1,322 (62.51)	35 (31)	
Birth order				0.953
First or second	1,315	1,288 (60.91)	38 (34)	
≥ Third	864	826 (39.09)	26 (34)	
Birth interval				
<33 months	1,199	1,101 (52.09)	26 (23)	
≥33 months				
Not reported/missing	980	1,013 (47.91)	38 (47)	
b) Socioeconomic determinants				
Mother's education				0.001
No education	1,013	965 (45.66)	37 (52)	
With education	1,154	1,138 (53.82)	27 (19)	
Not reported/missing	*12*	*11 (0.51)*	*0*	
Education of the husband				0.685
No education	780	743 (35.13)	28 (36)	
With education	1,331	1,303 (61.63)	34 (32)	
Not reported/missing	*68*	*68 (3.23)*	*2 (56)*	
Education of the household head				0.744
No education	1,230	1,165 (55.08)	37 (36)	
With education	947	949 (44.88)	27 (32)	
Not reported/missing	*2*	*1 (0.03)*	*0*	
Household size				0.063
<5	646	654 (30.96)	31 (50)	
≥5	1,533	1,459 (69.04)	33 (27)	
Mother's working status				0.768
Not working	1,488	1,437 (67.97)	45 (33)	
Working	655	651 (30.80)	18 (37)	
Not reported/missing	*36*	*26 (1.22)*	*1 (23)*	
Household head's working status				0.842
Not working	711	648 (30.65)	23 (36)	
Working	1,464	1,463 (69.21)	40 (33)	
Not reported/missing	*4*	*3 (0.13)*	*1 (211)*	
Wealth index				0.792
Poorest/second/middle	1,336	1,286 (60.82)	47 (35)	
Fourth/richest	843	828 (39.18)	17 (32)	

Variables	n	n* (%*)	IM (IMR*)	*p*-value#
Domestic violence				0.485
Yes	285	284 (13.45)	10 (44)	
No	1,892	1,829 (86.52)	54 (33)	
Not reported/missing	*2*	*1 (0.03)*	*0*	
Domestic violence during pregnancy				0.004
Yes	58	53 (2.53)	7 (128)	
No	2,064	2,007 (94.92)	56 (32)	
Not reported/missing	*57*	*54 (2.55)*	*1 (8)*	
c) Environmental determinants				
Safe drinking water				0.340
Yes	2,131	2,062 (97.53)	64 (35)	
No	48	52 (2.47)	0	
Safe sanitation facilities				0.737
Yes	1,419	1,357 (64.20)	36 (35)	
No	759	756 (35.76)	27 (31)	
Not reported/missing	*1*	*1 (0.04)*	*1 (100)*	
Electricity availability				0.408
Yes	1,953	1,918 (90.74)	8 (47)	
No	225	195 (9.24)	56 (33)	
Not reported/missing	*1*	*1 (0.02)*	*0*	
Use of solid fuel				0.019
Yes	549	582 (27.52)	23 (53)	
No	1,630	1,532 (72.48)	41 (27)	
Place of residence				0.947
Urban	509	497 (23.53)	10 (33)	
Rural	1,670	1,617 (76.47)	54 (34)	
Region of residence				0.033
Western	817	549 (25.96)	15 (13)	
Central	610	852 (40.30)	17 (42)	
Eastern	752	713 (33.74)	32 (41)	
d) Health-related determinants				
Contraceptive use				0.570
Ever used	287	255 (12.08)	17 (50)	
Never used	370	374 (17.69)	10 (37)	
Not reported/missing	*1,522*	*1,485 (70.23)*	*37 (30)*	
Place of delivery				0.041
Institutional	761	780 (36.91)	16 (27)	
Home	341	330 (15.60)	18 (65)	
Not reported/missing	*1,077*	*1,004 (47.49)*	*30 (29)*	
Skilled delivery				0.033
Yes	773	322 (15.24)	18 (67)	
No	329	788 (37.27)	16 (27)	
Not reported/missing	*1,077*	*1,004 (47.49)*	*30 (29)*	
Antenatal care				0.074
<4	200	200 (9.46)	5 (16)	
≥4	842	853 (40.35)	27 (42)	
Not reported/missing	*1,137*	*1,061 (50.19)*	*32 (31)*	
Postnatal care				0.075

Variables	n	n* (%*)	IM (IMR*)	*p*-value#
Yes	777	792 (37.48)	18 (30)	
No	325	318 (15.03)	16 (60)	
Not reported/missing	*1,077*	*1,004 (47.49)*	*30 (29)*	
Fed colostrum				0.003
Yes	975	962 (45.48)	26 (31)	
No	61	81 (3.84)	5 (140)	
Not reported/missing	*1,143*	*1,071 (50.68)*	*33 (29)*	

*Note: n=number of samples; IM=number of infant mortality; IMR=infant mortality rate (per 1000 live births); *weighted values; #p-value from Chi-square test by excluding the not reported/missing category*

Table 2 provides the unadjusted HR. Based on bivariate analysis, none of the variables from the bio-demographic group was associated with infant mortality. Meanwhile, infants born to uneducated mothers and mothers who experienced domestic violence during pregnancy had a higher risk of death. The risk of mortality was also higher among babies born in households that used solid fuel for cooking and born in the western and eastern regions. In addition, those babies who did not receive postnatal care and were not given colostrum had an increased risk of dying than their counterparts.

Table 3 presents the multivariate models (Models 1 to 4) that examined the adjusted associations between each group of determinants (bio-demographic, socioeconomic, environmental, and health-related determinants) and infant mortality. Due to a small number of infant deaths, the final model (Model 5) was developed using a stepwise elimination method. The findings showed that infants born to uneducated mothers (aHR=2.27; 95%CI=1.16-4.47) and mothers who experienced domestic violence during pregnancy (aHR=4.24; 95%CI=1.45-12.41), born in households that use solid fuel (aHR=2.16; 95%CI=1.21-3.85), western (aHR=6.13; 95%CI=2.84-13.20) and eastern regions (aHR=5.13; 95%CI=2.81–9.35) had increased risk of dying before reaching their first birthday. The bio-demographic determinants, number of births, and birth order significantly associated with infant mortality when assessed by a group of determinants were individually not found significant in the final Model 5.

Figure 1 presents the Kaplan-Meier curve comparing survival probabilities for infants born to uneducated relative to educated mothers (b), infants of mothers who experienced domestic violence during pregnancy relative to those who did not (c), infants born in households that used solid fuel relative to households that did not use solid fuel (d), and infants born in different regions (e). None of the independent variables were highly correlated (r<0.5), and all VIFs were <5, suggesting that multicollinearity was not a problem in the analysis.

Table 2: Unadjusted Associations Between Determinants and Infant Mortality in Bhutan

Variables	HR (95%CI)	*p*-value
a) Bio-demographic determinants		
Mother's age *(ref: <25 years)*		
≥25	0.88 (0.29 – 2.60)	0.808
Mother's age when first married *(ref: <18 years)*		
≥18	1.10 (0.58 – 2.09)	0.770

Variables	HR (95%CI)	*p*-value
Mothers age when first pregnant *(ref: <20 years)*		
≥20	0.84 (0.39 – 1.81)	0.652
Mother's marital status *(ref: married)*		
Not married	0.58 (0.14 – 2.33)	0.437
Sex of the child *(ref: girl)*		
Boy	1.94 (0.89 – 4.22)	0.093
Total births *(ref: ≤2 births)*		
>2 births	1.26 (0.58 – 2.75)	0.550
Sex of the household head *(ref: female)*		
Male	0.90 (0.44 – 1.81)	0.768
Birth order *(ref: first or second)*		
≥ Third	0.76 (0.31 – 1.83)	0.541
Birth interval *(ref: <33 months)*		
≥ 33 months	N/A	
b) Socioeconomic determinants		
Mother's education *(ref: with education)*		
No education	2.44 (1.27 – 4.66)	0.008
Education of the husband *(ref: no education)*		
With education	0.84 (0.42 – 1.71)	0.633
Education of the household head *(ref: no education)*		
With education	1.20 (0.60 – 2.40)	0.593
Household size *(ref: <5)*		
≥5	0.65 (0.34 – 1.24)	0.187
Mother's working status *(ref: working)*		
Not working	1.04 (0.48 – 2.23)	0.925
Household head's working status *(ref: working)*		
Not working	0.91 (0.42 – 1.98)	0.817
Wealth index *(ref: poorest/second/middle)*		
Fourth/richest	0.82 (0.39 – 1.80)	0.622
Domestic violence *(ref: no)*		
Yes	1.58 (0.56 – 4.44)	0.379
Domestic violence during pregnancy *(ref: no)*		
Yes	4.09 (1.18 – 14.17)	0.027
c) Environmental determinants		
Safe drinking water *(ref: yes)*		
No	NA	
Safe sanitation facilities *(ref: yes)*		
No	0.79 (0.41 – 1.54)	0.485
Electricity availability *(ref: yes)*		
No	1.62 (0.56 – 4.65)	0.366
Use of solid fuel *(ref: no)*		
Yes	2.24 (1.24 – 4.06)	0.008
Place of residence *(ref: urban)*		
Rural	1.42 (0.52 – 3.88)	0.488
Region of residence *(ref: Central)*		
Western	4.58 (1.98 – 10.63)	0.001
Eastern	4.27 (2.42 – 7.54)	<0.001
d) Health-related determinants		

Variables	HR (95%CI)	*p*-value
Contraceptive use *(ref: never used)*		
Ever used	0.66 (0.20 – 2.22)	0.495
Place of delivery *(ref: institutional)*		
Home	2.24 (0.94 – 5.36)	0.069
Skilled delivery *(ref: yes)*		
No	2.32 (0.97 – 5.54)	0.058
Antenatal care *(ref: <4)*		
≥4	2.62 (0.82 – 8.38)	0.102
Postnatal care *(ref: yes)*		
No	2.52 (1.11 – 5.76)	0.028
Given colostrum *(ref: yes)*		
No	5.68 (1.84 – 17.54)	0.003

Note: HR=hazard ratio; CI=confidence interval

Table 3: Adjusted Associations Between Determinants and Infant Mortality in Bhutan

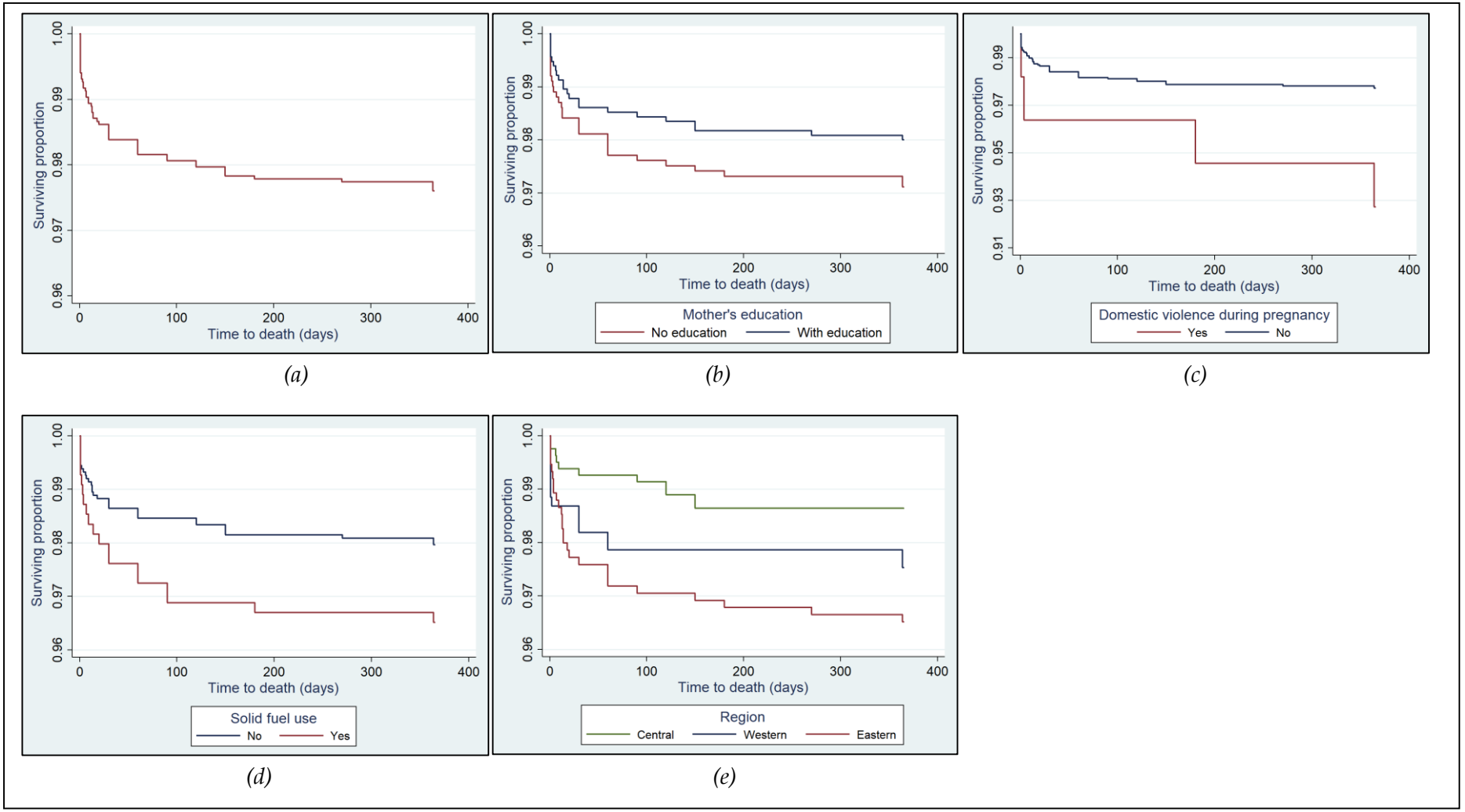
Variables	Model 1 (n=2,016)		Model 2 (n=2,069)		Model 3 (n=2,171)		Model 4 (n=288)		Model 5 (2,106)	
	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value
a) Bio-demographic determinants										
Mother's age *(ref: <25 years)*										
≥25	0.84 (0.34 – 2.08)	0.699								
Mother's age when first married *(ref: <18 years)*										
≥18	1.59 (0.79 – 3.20)	0.190								
Mothers age when first pregnant *(ref: <20 years)*										
≥20	0.65 (0.29 – 1.43)	0.276								
Mother's marital status *(ref: married)*										
Not married	0.75 (0.15 – 3.81)	0.728								
Sex of the child *(ref: girl)*										
Boy	1.96 (0.95 – 4.07)	0.069								
Total births *(ref: ≤2 births)*										
>2 births	5.71 (2.01 – 16.19)	0.001								
Sex of the household head *(ref: female)*										
Male	0.83 (0.38 – 1.79)	0.629								
Birth order *(ref: first or second)*										
≥ Third	0.20 (0.06 – 0.69)	0.012								
Birth interval *(ref: <33 months)*										
≥ 33 months	N/A									
b) Socioeconomic determinants										
Mother's education *(ref: with education)*										
No education			3.13 (1.54 – 6.37)	0.002					2.27 (1.16 – 4.47)	0.018
Education of the husband *(ref: no education)*										
With education			0.85 (0.29 – 2.48)	0.760						

Variables	Model 1 (n=2,016)		Model 2 (n=2,069)		Model 3 (n=2,171)		Model 4 (n=288)		Model 5 (2,106)	
	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value
Education of the household head *(ref: no education)*										
With education			1.88 (0.76 – 4.67)	0.170						
Household size *(ref: <5)*										
≥5			0.61 (0.30 – 1.25)	0.176						
Mother's working status *(ref: working)*										
Not working			0.87 (0.40 – 1.89)	0.716						
Household head's working status *(ref: working)*										
Not working			1.08 (0.53 – 2.21)	0.831						
Wealth index *(ref: poorest/second/middle)*										
Fourth/richest			0.84 (0.37 – 1.90)	0.666						
Domestic violence *(ref: no)*										
Yes			1.18 (0.41 – 3.40)	0.762						
Domestic violence during pregnancy *(ref: no)*										
Yes			3.76 (1.13 – 12.56)	0.032					4.24 (1.45 – 12.41)	0.009
c) Environmental determinants										
Safe drinking water *(ref: yes)*										
No					N/A					
Safe sanitation facilities *(ref: yes)*										
No					0.69 (0.39 – 1.21)	0.190				
Electricity availability *(ref: yes)*										
No					1.35 (0.48 – 3.82)	0.567				
Use of solid fuel *(ref: no)*										
Yes					2.47 (1.38 – 4.43)	0.003			2.16 (1.21 – 3.85)	0.010
Place of residence *(ref: urban)*										
Rural					1.27 (0.43 – 3.70)	0.654				
Region of residence *(ref: Central)*										

Variables	Model 1 (n=2,016)		Model 2 (n=2,069)		Model 3 (n=2,171)		Model 4 (n=288)		Model 5 (2,106)	
	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value	aHR (95%CI)	*p*-value
Western					5.76 (2.41 – 13.79)	<0.001			6.13 (2.84 – 13.20)	<0.001
Eastern					4.59 (2.51 – 8.38)	<0.001			5.13 (2.81 – 9.35)	<0.001
d) Health-related determinants										
Contraceptive use *(ref: never used)*										
Ever used							1.23 (0.26 – 5.80)	0.787		
Place of delivery *(ref: institutional)*										
Home							N/A			
Skilled delivery *(ref: yes)*										
No							N/A			
Antenatal care *(ref: <4)*										
≥4							7.49 (0.61 – 91.57)	0.112		
Postnatal care *(ref: yes)*										
No							1.41 (0.26 – 7.54)	0.683		
Given colostrum *(ref: yes)*										
No							4.48 (0.97 – 20.62)	0.054		

Note: aHR=adjusted hazard ratio; CI=confidence interval; Models 1 to 4 were developed to examine adjusted associations between each group of determinants and infant mortality: Model 1 (bio-demographic characteristics); Model 2 (socioeconomic determinants); Model 3 (environmental determinants); Model 4 (health-related determinants); Model 5 is the final model developed using a stepwise elimination method.

Figure 1: Kaplan-Meier curve showing the surviving proportion of the infants in Bhutan **(**a**),** and by mother's education **(**b**)**, domestic violence during pregnancy **(**c**)**, solid fuel use **(**d**)**, and region **(**e**)**



Discussion

This is perhaps the first study that examined the determinants influencing infant mortality in Bhutan using a nationally representative dataset. The weighted infant mortality rate (IMR) was 34 per 1,000 live births in 2012. The findings show that education, domestic violence, the region of residence, and solid fuel use were associated with infant mortality in Bhutan. The IMR estimated in this study is slightly higher than the rate of 30 per 1,000 live births in the 2012 NHS report (Ministry of Health, 2014). The difference in the period used to extract birth history and mortality, and inclusion of those births with missing information for the month of birth in this study could have led to this difference. Given the small number of events and to facilitate computation, this study included births that occurred two years prior to the NHS to estimate the IMR, whereas the 2012 NHS considered births that occurred one year before the survey.

The results showed that infants born to uneducated mothers had more than twice the odds of dying than their counterparts. The effect of maternal education on child health and mortality is well-established. Studies show that even a one-year increase in maternal education is associated with a significant decrease in child mortality (Andriano & Monden, 2019; Makate, 2016). Maternal education has been shown to influence child mortality through reducing financial barriers to care, rejection of domestic violence, a better attitude towards and access to health services, and greater health knowledge (Andriano & Monden, 2019). Better health knowledge would also mean improved sanitation and hygienic practices and the use of health services. Besides, educated mothers may be more likely to invest in their children's health (Prickett & Augustine, 2016), have better jobs, and are financially sound.

Our study found that children born to mothers who experienced domestic violence during pregnancy had a higher likelihood of infant mortality. This finding aligns with other studies that showed a greater risk of infant mortality among children whose mothers experienced domestic violence (Koenig et al., 2010; Memiah et al., 2020) and experienced domestic violence during their last pregnancy (Ahmed et al., 2006). In Bhutan, the lifetime prevalence of violence against women by intimate partners was reported to be high at 44.6%, and around one in three experienced violence in the last 12 months (National Commission for Women and Children, 2017). Furthermore, more than 53% of the Bhutanese women accepted that a man was justified in hitting his wife (National Commission for Women and Children, 2017). Several mechanisms have been posited through which domestic violence may influence childhood mortality. One possible way is the effect of blunt trauma to the fetus and the associated outcomes, including death (Jasinski, 2004; Omer & Everly, 1988). Another conceivable pathway is the impact of increased maternal stress due to domestic violence, which is shown to influence low birth weight and premature delivery (Omer & Everly, 1988). Domestic violence may also impact the mother’s physical health, which can affect child health and mortality (Koenig et al., 2010). Finally, exposure to violence may prevent women from using health services during pregnancy, delivery, and after birth (Dietz et al., 1997). In Bhutan, women who reported experiencing physical and sexual violence were more likely to have had their previous pregnancy end in a miscarriage (National Commission for Women and Children, 2017).

The issue of violence against mothers, especially during pregnancy, seems to have mostly remained outside the scope of the maternal and child health programs in Bhutan, potentially due to inadequate evidence. This study suggests that the prevention of domestic violence can

potentially help reduce child mortality and provide avenues to further inter-sectorial collaborations. Interventions to address domestic violence against women, such as education and awareness and legal reforms, can provide health and human rights benefits for women and present opportunities to improve child survival (Koenig et al., 2010; Memiah et al., 2020).

Consistent with findings from other developing countries (Bassani et al., 2010; Naz et al., 2018; Rinne et al., 2007), our results showed that children born in households that use solid fuel for cooking had higher odds of dying before reaching their first birthday. Exposure to indoor smoke that contains health-damaging substances and particles can cause lower respiratory infections (Bassani et al., 2010; Rinne et al., 2007), and indoor smoke is among the top environmental determinants impacting child health and mortality worldwide (Naz et al., 2018; Smith & Mehta, 2003). Children, especially those under one year of age, spend a considerable amount of time indoors breathing the indoor air when their mothers carry them. Furthermore, they are much more vulnerable to the impacts of exposure to indoor smoke since their respiratory system is still being developed. Strategies to reduce solid fuel use through other socioeconomic programs may complement strategies such as expanded case management for respiratory infections and effective vaccination programs. Future studies may benefit by examining differences by regions with different climatic conditions and residence, given that colder and rural areas may potentially use more solid fuels than warmer regions. The small number of events and non-availability of climatic variables precluded such an analysis in this study.

This study also showed that infants born in the eastern region had higher odds of dying than those born in the central region. This supports the findings in our previous study that showed higher rates of child mortality in the eastern region (Dendup et al., 2018). The higher levels of poor socioeconomic conditions, greater prevalence of malnutrition, low health utilization, poor sanitation, and low health literacy in the eastern region might be some possible explanations for the greater mortality among infants born in this region (National Statistics Bureau, 2013a, 2013b, 2014). The results also showed that children born in the western regions had higher odds of infant mortality. On the contrary, our previous results indicate that children within the western region had lower odds of under-five-year-old mortality (Dendup et al., 2018). The small number of infant deaths could have influenced the results in the present study. Furthermore, >80% of the infant deaths in the western region were from lower wealth quintiles suggesting that those from low socioeconomic backgrounds may be more vulnerable, even in regions with better services and infrastructure.

When assessed by the individual group of determinants, the number of birth and birth order factors under the bio-demographic group was significantly associated with infant mortality. However, the influence of these determinants did not emerge to be statistically strong in the final model, suggesting that the socioeconomic and environmental determinants found significant may be more important in influencing infant mortality than these bio-demographic determinants in Bhutan.

Strengths and limitations

This study's strengths include the sizeable nationally representative sample, the high response rate, and the application of complex sample analysis. These strengths lend the findings to be widely applicable in the Bhutanese context. There are, however, a few limitations that need to be taken into account while interpreting the results. The use of cross-sectional data prevents drawing causal associations. Owing to the large number of missing

information for health-related variables, these variables could not be examined adequately. Health-related factors are proximal to infant health outcomes and are more important in influencing child mortality. Furthermore, the 2012 NHS interviewed only surviving mothers that might have underestimated the IMR. The NHS data is also prone to recall bias, which could have potentially distorted the findings to some extent.

Conclusions

Based on the 2012 NHS data, the weighted IMR was 34 per 1,000 live births in 2012. This study shows that education, domestic violence, the region of residence, and solid fuel use are the key determinants of infant mortality in Bhutan. The findings suggest that interventions aimed to educate women, prevent domestic violence, and reduce the use of solid fuel for cooking can reduce infant mortality in Bhutan. Equitable regional socioeconomic development programs can also indirectly impact child survival. Policy intervention needs to be developed and undertaken in collaboration with related agencies such as the education sector and those working for the welfare of women and children. Future studies are required to examine infant mortality trends and health-related factors, including those not assessed in this study due to the non-availability of data such as birth weight. Focused intensified efforts can help Bhutan accelerate the reduction of child mortality.

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