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From parental education to under-5 mortality: how antenatal care and hand hygiene mediate the pathway mechanisms

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Abstract

Background Reducing the under-5 mortality rate (U5MR) to as low as 25/1000 live births globally by 2030 to reach the sustainable development goal (SDG) 3.2.1 appears to be a race against time. Amidst this situation, Bangladesh experienced stagnancy in U5MR at the beginning of the SDG era. While a comprehensive understanding of this stagnancy is crucial, research on stagnancy is scant and limited to investigating the direct effects of the key predictors. Therefore, building on the existing evidence, this research investigated the effect of one of the key predictors, parental education, on under-5 mortality (U5M) mediated through antenatal care (ANC) and the availability of hand washing stations.

Methods This study conducted weighted mediation analyses using the Bangladesh Demographic and Health Survey data from 2011, 2014 and 2017–18, with sample sizes 4,658, 4,367, and 4,826, respectively, and estimated a generalised structural equation model. The "nlcom" post-estimation command of STATA was used to obtain the direct effects (coefficients), which were then multiplied to estimate the indirect effects for the indirect parallel and sequential pathways. The indirect effects were added to obtain the total indirect effect, which was added to the direct effect of education to estimate the total effect of education.

Results This study reveals inconsistent parallel and sequential mediation of parental education's effect across the three surveys. The direct effect of education on U5M reduced over time. The total (parallel and sequential combined) mediated effects of either parent's education on U5M were negative (reduced U5M risk). While the mediated effect of mother's education on U5M was not significant, the mediated effect of father's education was significant in 2011. The total effect of education (direct and indirect combined) on U5M was negative (reduced U5M risk) and significant in 2011. However, the effect reduced over time and changed direction in 2017-18. Since 2011, the effects decreased and changed direction to become positive (increased U5M risk) in 2017-18. Due to the weakening direct effect of education and the opposite nature of the indirect effect, the indirect effect of education appeared to be greater than the total effect in 2014 and 2017–18. In 2011, approximately 50% of the total effect of either parent's education was mediated. However, in 2014 and 2017–18, the proportions were greater than 100%, except for the proportion of the mediated effect of father's education in 2014.

Conclusions This study reports a weakening and inconsistent mediated effect of both parents' education on U5M. Using existing literature, it also justifies that improving the quality of education and ANC could more effectively reduce U5M to achieve SDG 3.2.1. To improve the quality of education, this study recommends updating the school

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curriculum with a greater emphasis on maternal and child health education. To improve the quality of ANC, it is recommended that the mandatory use of ANC cards be strictly monitored.

Keywords Under-5 mortality, Stagnancy, Education, Antenatal care, Handwashing, Mediation analysis

Background

Collective global health initiatives reduced the under-5 mortality rate (U5MR) by 59% from 93/1000 live births in 1990 to 37.7/1000 live births in 2019. Still, reducing the U5MR to as low as 25/1000 live births globally by 2030 to reach the sustainable development goal (SDG) 3.2.1 appears to be a race against time [1, 2]. Contrastingly, as a country in the South Asian region, Bangladesh has performed comparatively better in reducing the U5MR. The 5-year period U5MR decreased by 67% between 1993–94 and 2017–18 to reach 45/1000 live births, however, the reduction rate has not been consistent [3]. Furthermore, the proportion of death caused by the leading causes have remained the same for almost a decade since 2011; pneumonia, birth asphyxia, prematurity and possible serious infections claimed almost 60% of the total U5M in 2011 and in 2017–18 [3].

Returning to the topic of inconsistent mortality reduction rate, the Bangladesh Demographic and Health Survey (BDHS) reported a 19% reduction in 1999–2000 as opposed to a 6.4% reduction reported in the subsequent survey (BDHS 2004). A similar inconsistency in the U5M reduction rate was reported in the following decade; a 13% reduction in the 2014 survey contrary to a sluggish 2% reduction in the 2017–18 survey [3, 4]. Such inconsistencies, primarily dragging reductions in U5MR, are threats to the achievement of SDG 3.2.1 [2]. Therefore, it is fundamental to understand these sluggish reductions or stagnancies and take appropriate actions to prevent future stagnancies for an effective under-5 mortality (U5M) reduction.

We did not find any Bangladesh-specific study that analysed indirect effects of U5M predictors to explain the recent stagnancy in U5M. Overall, the foci of the recent studies were causes of U5M, effect of sociodemographic and health-related factors, such as parental education, early marriage, desire for children, C-section and birth interval on U5M [5–13]. Mazumder et al. examined the stagnancy reported in BDHS 2017–18 using two different approaches [14, 15]. One study investigated how the direct effects of the key predictors like mother's age at childbirth, parental education, availability of hand washing stations in the household, or utilisation of antenatal care on all-cause U5M changed between the 2011 and 2017–18 survey periods [15]. The other study investigated the trend in the interplay of the aforementioned predictors with the top four causes of U5M in Bangladesh during the same period [14]. While these two studies explained how the change in the direct effects of these key predictors might have been associated with the sluggish reduction of U5M, these studies did not shed light on the possible contribution of change in the indirect effects on U5M [14, 15].

Acknowledging the indirect effects of the factors of interest is no less important than acknowledging their direct effects to develop effective health interventions. It is evident in the literature that the interplay of sociodemographic factors related to health is complex, and the effect of one factor can influence health outcomes indirectly or through another factor/s too [16–18]. Notably, the indirect effect, also known as the mediated effect, has often been reported to be larger than the direct effect of predictors of interest [16, 19]. Therefore, examining the indirect effects of the key predictors identified in the studies conducted by Mazumder et al. can help further explain the stagnancy reported in BDHS 2017–18 [3, 14, 15].

To elaborate, in the context of the stagnancy reported in BDHS 2017–18, analysing the pathway mechanisms between the key predictors identified by Mazumder et al. and U5M could provide a deeper understanding of the stagnancy by determining the underperforming factors on the pathway leading to U5M. Moreover, as supported by studies that used mediation analysis, knowledge gained by investigating these pathways and the change in their effects over time can help tailor interventions for a more effective U5MR reduction leading to the achievement of SDG 3.2.1 [20]. However, uncovering such a pathway's theoretical and practical evidence-based framework is critical before investigating one, and that can start with further validating the key predictors of U5M reported by Mazumder et al. and the potential associations among these [14, 15].

While the majority of U5 (under-5) deaths can be prevented with vaccines or other low-cost interventions, parental education also plays a significant role in U5M reduction due to its multifaceted influence on the society. Accordingly, a study of 175 countries reported that more than 50% of the global U5 deaths prevented between 1970 and 2009 were attributable to increased maternal education [21, 22]. Although the effect size was smaller than that of maternal education, each additional year of paternal education significantly reduced the risk of U5M, too: 3.04% for mother's education and

1.57% for father's education [21, 23]. Owing to the multifaceted role of education, the literature also supports the association of parental education with antenatal care (ANC) and handwashing, two well-established interventions for U5M prevention [24–28]. It is evident that quality ANC and proper handwashing can avert a significant proportion of U5 deaths [29–34]. Research conducted in the Bangladeshi context, including the two studies conducted by Mazumder et al., altogether also supports such associations among education, ANC, handwashing and U5M [14, 15, 24–26].

Therefore, it is logical that ANC and handwashing lie on the path between education and U5M in the Bangladeshi context, too; parental education improves ANC uptake and handwashing practice by improving health awareness and literacy. Standard ANC provides counselling on hand washing to pregnant women and, in turn, can improve handwashing practices in the household of pregnant women [35]. Hence, the effect of parental education on child mortality can be mediated sequentially through ANC uptake and then the availability of handwashing stations in households. It can also be mediated parallelly: parental education through ANC to child mortality; and parental education through hand washing station to child mortality. However, in instances where the quality of education, ANC services or handwashing practices are substandard, the mediated effect of parental education on U5M may not exist or may become inconsistent.

Undeniably, the pathway from education to U5M through ANC and handwashing cannot be the only mechanism with the potential to offer significant knowledge for bolstering the U5M prevention initiatives. However, among the few Bangladesh-specific studies on child health that investigated mediated effect, only one considered U5M as the outcome variable using nationally representative data and used maternal autonomy as the exogenous variable [16, 17, 36]. Therefore, in a context of scant studies on the mediated effect of key predictors on U5M, investigating the pathway from education to U5M through ANC and handwashing is relevant. Moreover, the impact of parental education, ANC and handwashing on U5M, as evident in the current literature, adequately justifies investigating the pathway [21, 23, 32, 34]. Furthermore, knowledge generated from studying this pathway will also guide the testing of other potential pathways (e.g., ANC through facility delivery to perinatal survival) in the Bangladeshi context [37]. Most importantly, investigating the mediation pathway between parental education and U5M can deepen the understanding of the stagnancy of U5MR in Bangladesh that surfaced in the 2017–18 survey. This knowledge will help strengthen the initiatives to achieve SDG 3.2.1, while no such studies exist, and the SDG deadline is nearing [2, 3].

At the global level, the findings of this study will provide new knowledge with the potential to accelerate the reduction of U5MR by tailoring interventions related to parental education, ANC and handwashing in similar contexts. Moreover, the analysis applied in this study may also guide studies on other mediation pathways deemed important in different country contexts and generate valuable knowledge for a faster reduction of U5MR using other intervention models.

Methods

Aim

This study aims to investigate the effect of parental education on child mortality mediated through ANC uptake and the presence of handwashing stations in the household across three surveys: BDHS 2011, 2014 and 2017–18.

Study setting and design

The data used in this study is from Bangladesh, a South Asian country with a population of approximately 165 million, 46% of which live in urban areas [38]. Mediation analyses were conducted using secondary data from the BDHS 2011, 2014, and 2017–18. Using a two-stage stratified sampling method, these BDHSs selected households with ever-married women aged 15 – 49 years (12 – 49 years in 2011). The first stage involved selection of enumeration areas/clusters (600 in 2011 and 2014 and 675 in 2017–18) using probability-proportional-to-size. Then a complete household listing was performed in these clusters to create a sampling frame. The second stage involved systematic sampling of 30 households from each cluster. These surveys collected information on sociodemographic characteristics, health, healthcare utilisation and birth histories of eligible ever-married women from the selected households. This study used the relevant information on U5 children in the birth, household and community data files. The Demographic and Health Survey guidelines were used to merge the birth, household and community data files using the unique identifier information in these files. These merged data were analysed separately for each survey. Figure 1 illustrates the sample selection process and more details on the survey methodology can be found elsewhere [3, 4, 39].

Sample size

The sample sizes were 4,658 children from 4,658 households, 4,367 children from 4,193 households and 4,826 children from 4,611 households in the 2011, 2014 and 2017–18 surveys, respectively.

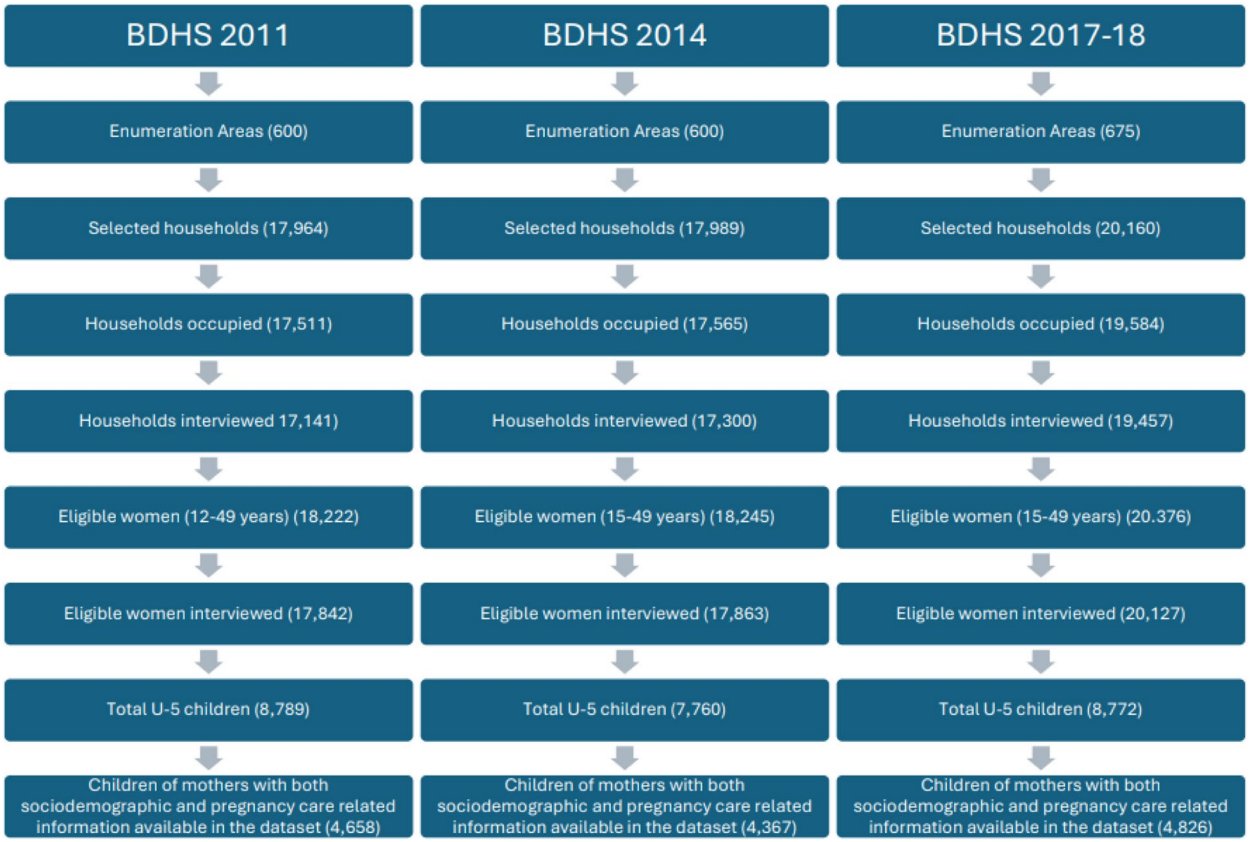


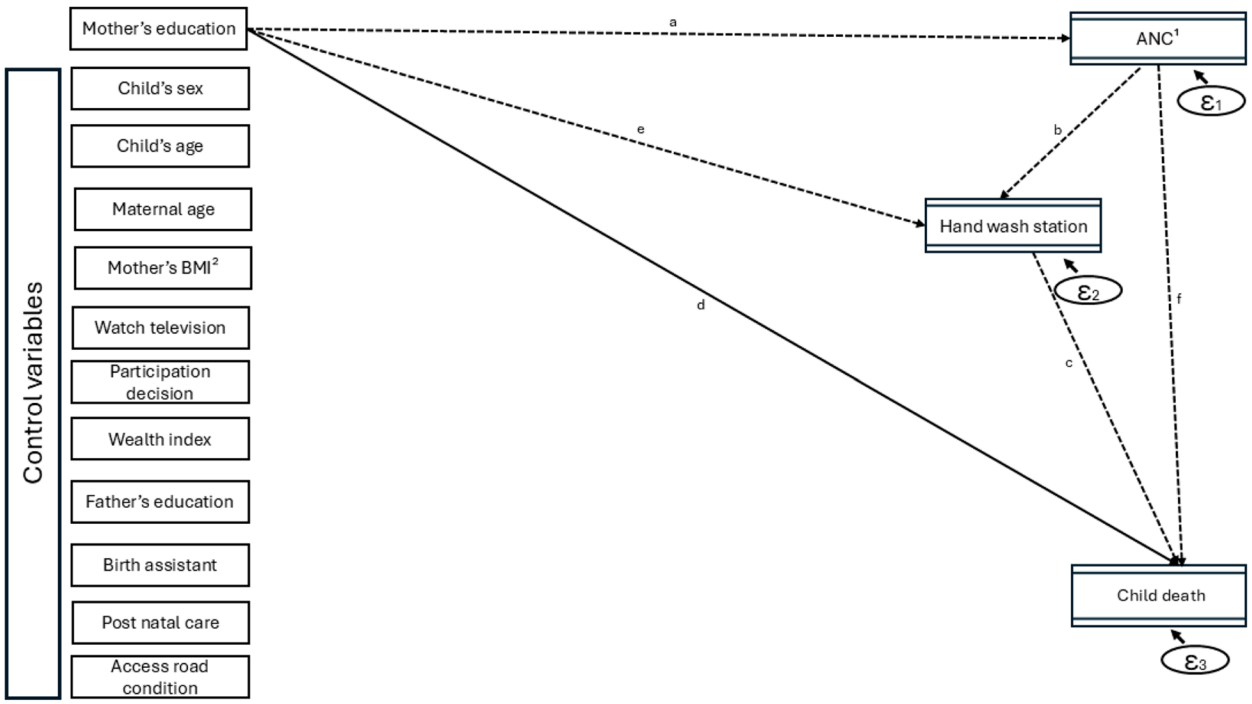
Fig. 1 Sample selection procedure

Hypothesised theoretical model for mediation

As highlighted in the background section, this study builds on two recent studies conducted by Mazumder et al. and other relevant studies to deepen the understanding of the stagnancy of U5MR reported in BDHS 2017–18 [3, 14, 15]. Based on existing evidence, this study hypothesised inter-relationships among the parents' education, ANC utilisation, availability of handwashing station and final outcome (child mortality) variables (Figs. 2, 3) [24, 25, 28, 30, 33, 40, 41]. Notably, in a mediation pathway model, the key predictor variable is considered as the exogenous variable (parents' education). The endogenous variable, on the other hand, is any variable which can be influenced by the exogenous variable (e.g., ANC, handwashing, child mortality).

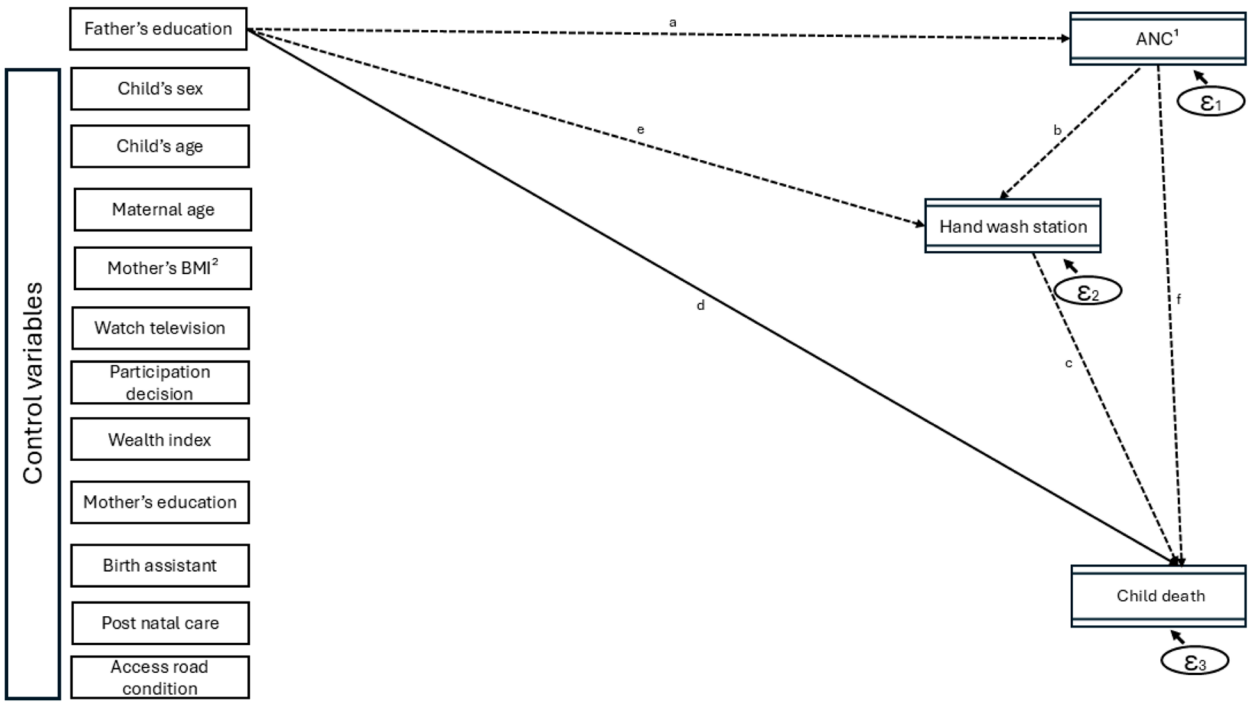
Any variable intervening in the pathway between the predictor and the outcome is a mediator (e.g., ANC utilisation, availability of handwashing station); a mediator is both endogenous, as it can be influenced by the exogenous, and exogenous, as it can also affect the outcome. In pathways, where the effect of the exogenous variable on the outcome can be sequentially mediated through multiple variables (mediators), there can be multiple endogenous variables. In the three-way sequential path this study investigates, education affects ANC uptake, ANC uptake affects availability of handwashing stations and availability of hand washing stations affects child health outcome, i.e., U5M. While estimating the total mediated effect in this three-way sequential path may appear complex, advanced statistical methods and statistical software can handle this well. Earlier studies that investigated sequential mediation pathways guided this study [42–46]. Notably, in sequential mediation, the mediator variables can act both as an outcome variable and a predictor (Figs. 2, 3; Pathway: a, b, c) [47].

As per the hypothesis, while either parent's education can directly affect child mortality, the effect of their education on child mortality can also be separately mediated through ANC utilisation or through the availability of handwashing stations in the households, leading to parallel mediation (Figs. 2, 3; Pathway: a, f; and Pathway: e, c). However, this study acknowledges that the cross-sectional nature of the BDHS data limits our scope to establish causal relationship among the exogenous and endogenous variables definitively while the cause-effect relationship is plausible.



¹ANC = Antenatal care; ²BMI = Body Mass Index

Fig. 2 Pathways of mother's education to U5M mediated through ANC utilisation and/or hand washing station's availability



¹ANC = Antenatal care; ²BMI = Body Mass Index

Fig. 3 Pathways of father's education to U5M mediated through ANC utilisation and/or hand washing station's availability

Variables

Studies on the impact of education, ANC, handwashing, U5M and the theoretical model for mediation (as illustrated above in Figs. 2, 3) guided the selection of a range of child and mother-specific, father and household-specific, community-specific, and health service-specific variables, as previously defined in Mazumder et al. [14, 15], and used elsewhere [14, 15, 21, 23–25, 28, 30–33, 40, 41, 48–55].

Endogenous and outcome variables

As indicated earlier, the exogenous and endogenous variables for this study were selected based on the theoretical plausibility of causal relationships (we acknowledge that temporal relationship can't be established using cross-sectional data) and existing evidence on the relationships. Then the bivariate relationship between the predictors and outcome variable in the data were examined for final selection of the exogenous and endogenous variables. A cut-off value of $p < 0.1$ was used to select the exogenous and endogenous variables for GSEM.

The death of a child before its fifth birthday was the final binary (0 = alive, 1 = dead) outcome variable in this study. Two mediator variables were the availability of a hand washing station in the household (0 = available, 1 = not available) and ANC utilisation status (0 = utilised at least one, 1 = utilised none).

Exogenous variables

Mother's education (0 = no or primary education, 1 = secondary or higher education) was used as the exogenous variable to examine its indirect effect on child mortality through the availability of a hand washing station and ANC utilisation. Similarly, father's education (0 = no or primary education, 1 = secondary or higher education) was used as the exogenous variable to see its indirect effect on child mortality through the same mediator variables.

Covariates

Twelve variables were considered as the control variables in this study, which was guided by the theoretical model [14, 15]. There were three child-specific control variables—child's sex (male, female), child's gestation type (singleton, twins or multiples), and child's age (12 months to 3 years and 11 months or younger).

Four variables were mother-specific control variables – mother's age at childbirth (18 years or younger, 19 to 24 years, 25 to 30 years and 31 years or above), mother's body mass index (normal weight, underweight and overweight or obese), mother's exposure to media (watched television, did not watch television) and participation in decision-making (some participation, no participation) [56]. Three variables—mother's participation in decisions on her own health care, large purchases for the household and visits to relatives were combined to create a composite variable for mother's overall participation in decision-making [17].

Wealth quintile (poorest, poorer, middle, richer and richest) was the only household-specific control variable in this study. Access roads in the community (good condition, poor condition) and division (Sylhet, Chittagong, Dhaka and Mymensingh, Khulna, Rajshahi, Rangpur and Barisal) were the two community-specific control variables. The two health-service-specific control variables were birth assistance (medically trained, not medically trained) and post-natal care (PNC) utilisation status (took PNC, did not take PNC).

Statistical analysis

Both univariate and bivariate analyses were performed to explore the dataset and estimate the frequencies. STATA's 'svyset' and 'svy' commands were used to account for the complex survey design in estimating the weighted frequencies. This study used a variance inflation factor (VIF) value of 10 based on the existing literature to determine the variables for the final analysis [57–59]. It did not include variables with VIF $\geq$ 10.

The structure of BDHS data is nested, i.e., there can be multiple children from the same mother, mothers can be nested within households, and households can be nested within the community. Therefore, we first investigated the level of clustering using null models, which showed that the clustering of U5M at none of these levels (mothers, household, community) was significant. Hence, this study conducted a weighted mediation analysis. Bernoulli family and logit function were applied to estimate the generalised structural equation model (GSEM). GSEM is an expansion of Structural Equation Modeling (SEM). SEM, a robust statistical method is used to investigate complex relationships among factors and can be used to test theoretical models by handling multiple equations simultaneously. While SEM is applicable only for continuous outcomes, GSEM can be applied on outcomes that are binary, ordered or count in nature. Further detail on GSEM method and formula can be found elsewhere [60–62].

Weighted mediation analyses using GSEM were conducted separately using 2011, 2014 and 2017–18 datasets to estimate the effects of mother's education on child mortality. The same approach was used to estimate the effects of father's education. These six models estimated the direct effects between exogeneous and endogenous variables, and these direct effects were used to calculate the indirect effects using "nlcom" post-estimation command of STATA. The estimated direct effects were: direct

effects of parents' education on ANC utilisation, availability of hand washing stations and child mortality; the direct effects of ANC utilisation on the availability of hand washing stations and child mortality and the direct effects of the availability of handwashing stations on child mortality (Figs. 2, 3).

After estimating the GSEM models, the "nlcom" post-estimation command of STATA was used to obtain the indirect effects for each indirect pathway (Figs. 2, 3). It is important to note that "nlcom" estimates standard errors using delta method. Delta method approximates standard error appropriately when sample size is large – a key feature of this study [63, 64]. The direct effects (coefficients) of each indirect pathway were multiplied to estimate the indirect or mediated effect (multiplicated coefficients) of these indirect pathways [16]. The sum of the multiplicated coefficients was used to estimate the total indirect effects of the exogenous variables. The total indirect effect and the direct effect of the exogenous variable were added to estimate the total effect of the exogenous variable. The effects are reported as log odds and their confidence intervals. The mediated proportion of the total effect was estimated by dividing the indirect effect by the total effect of the exogenous variable. The data analysis was performed using STATA 17.0 statistical software (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC.).

Results

Sample characteristics

Table 1 displays the unweighted and weighted frequency distributions of the sample characteristics. Overall, there was not much variation in the weighted and unweighted proportions.

The proportion of deceased children gradually decreased in the 2014 and 2017 surveys compared to 2011. The percentage of male and female children and children in different age groups were roughly similar across all surveys. Women who completed secondary or higher education increased over time; approximately 54%, 59% and 66% in the 2011, 2014 and 2017–18 surveys, respectively. Father's secondary or higher education showed a similar trend; proportions were roughly 44%, 47% and 52%, respectively, in these three surveys. Approximately 86%, 96% and 97% of households had hand washing stations in 2011, 2014 and 2017–18 surveys, respectively. The proportions of mothers who reported having utilised at least one ANC from any provider were roughly 69%, 79% and 92% in the 2011, 2014 and 2017–18 surveys, respectively.

The unweighted and weighted proportions of the division/region-specific samples in Sylhet, Chittagong, Dhaka and Mymensingh, and Barisal varied in each survey. Among these divisions, maximum variation was observed in Sylhet and Barisal. The unweighted proportions of their sample were approximately double the weighted proportions consistently across all three surveys. This addresses the purpose of weighting in BDHS: to adjust for the probability of selection, correct for oversampling or under sampling in regions, and ensure that the survey results are representative of the national population.

Weighted mediation analysis

Tables 2 present the weighted estimates (mothers and fathers) from GSEM. While only the direct effects are presented in Table 2, some of the direct effects, the mediated effect, total effect and proportion of the mediated effect are presented only in Table 3 (both parents).

Direct effects of education on antenatal care utilisation

Table 2 reveals that ANC utilisation was better when parents had secondary or higher education than no or primary education. However, the direct effect (Figs. 2, 3; Pathway: a) of mother's education decreased marginally over time (Table 2; Figs. 4, 5, 6; Pathway: a) whereas the effect of father's education increased marginally (Table 2; Figs. 7, 8, 9; Pathway: a). The log odds of not utilising ANC were 0.81 (coefficient: -0.81; 95% CI [-1.01, -0.6], $p<0.001$) units, 0.65 (coefficient: -0.65; 95% CI [-0.88, -0.42], $p<0.001$) units, and 0.57 (coefficient: -0.57; 95% CI [-0.87, -0.27], $p<0.001$) units lower in 2011, 2014 and 2017–18 surveys, respectively, among the mothers with secondary or higher education (Table 2; Figs. 4, 5,6; Pathway a). For comparison, refer to the log odds of not utilising ANC, for father's education, as presented in Table 2 and Figs. 7, 8, 9 (Pathway a).

Direct effects of education on the availability status of hand washing station

Tables 2 reveals that, compared to no or primary education, father's secondary or higher education reduced the risk (Figs. 2, 3; pathway: e) of not having a hand washing station in the household and roughly remained the same between 2011 and 2017–18. When the fathers had secondary or higher education, the log odds of not having a hand washing station in the household were 0.17 (coefficient: -0.17; 95% CI [-0.41, -0.08], $p>0.05$) units, and 0.16 (coefficient: -0.16; 95% CI [-0.56, -0.18], $p>0.05$) units lower in 2011and 2017–18 surveys, respectively (Table 2; Figs. 7, 8, 9; Pathway e). For comparison, refer to the log odds of not having a hand washing station for mother's education, as presented in Table 2 and Figs. 4, 5, 6 (Pathway e).

Table 1 Frequency distribution of the sample characteristics in three surveys

	2011 (*N* = 4658)		2014 (*N* = 4367)		2017 (*N* = 4826)	
	Unweighted Sample size	Weighted proportions	Unweighted Sample size	Weighted proportions	Unweighted Sample size	Weighted proportions
	n (%)	(%)	*n* (%)	(%)	*n* (%)	(%)
Living status of the child						
Alive	4473 (96.03)	96.34	4249 (97.3)	97.33	4717 (97.74)	97.74
Deceased	185 (3.97)	3.66	118 (2.7)	2.67	109 (2.26)	2.26
Sex						
Male	2376 (51.01)	50.97	2255 (51.64)	52.42	2531 (52.45)	52.31
Female	2282 (48.99)	49.03	2112 (48.36)	47.58	2295 (47.55)	47.69
Multiple or single						
Single	4613 (99.03)	99.11	4340 (99.38)	99.40	4777 (98.98)	99.01
Multiple	45 (0.97)	0.89	27 (0.62)	0.06	49 (1.02)	0.99
Age category of child						
12 months to 3 years	2895 (62.15)	62.07	2830 (64.8)	64.59	3007 (62.31)	62.72
11 months or younger	1763 (37.85)	37.93	1537 (35.2)	35.41	1819 (37.69)	37.28
Highest level of education attended by mother						
No education or primary education	2141 (45.96)	47.73	1772 (40.58)	41.63	1638 (62.31)	33.71
Secondary or attended higher	2517 (54.04)	52.27	2595 (59.42)	58.37	3188 (66.06)	66.29
Mother's age during childbirth (years)						
Mean (SE)	23.55 (0.08)	23.45 (0.1)	23.6 (0.09)	23.61 (0.11)	24 (0.08)	23.88 (0.09)
18 years or younger	721 (15.48)	15.60	734 (16.81)	16.55	637 (13.2)	13.83
19 to 24 years	2084 (44.74)	45.06	1807 (41.38)	41.59	2062 (42.73)	42.50
25 to 30 years	1219 (26.17)	26.52	1219 (27.91)	28.10	1417 (29.36)	29.28
31 years or above	634 (16.61)	12.81	607 (13.9)	13.76	710 (14.71)	14.39
Mother's Body Mass Index						
Normal weight	2749 (59.02)	60.01	2556 (58.53)	59.61	2970 (61.54)	62.16
Underweight	1373 (29.48)	29.45	1076 (24.64)	23.92	768 (15.91)	15.19
Overweight or obese	536 (11.51)	10.54	735 (16.83)	16.47	1088 (22.54)	22.64
Mother's exposure to media						
Watched television	2838 (60.93)	59.53	2571 (58.87)	58.55	2980 (61.75)	63.43
Did not watch television	1820 (39.07)	40.47	1796 (41.13)	41.45	1846 (38.25)	36.57
Participation in decision-making						
Some participation	3401 (73.01)	72.48	3177 (72.75)	73.83	4088 (84.71)	84.72
No participation	1257 (26.99)	27.52	1190 (27.25)	26.17	738 (15.29)	15.28
Highest level of education attended by father						
No or primary education	2586 (55.52)	57.66	2313 (52.97)	53.69	2294 (47.53)	47.57
Secondary or higher	2072 (44.48)	42.34	2054 (47.03)	46.31	2532 (52.47)	52.43
Wealth quintile						
Poorest	990 (21.25)	22.68	908 (20.79)	21.41	1053 (21.82)	20.89
Poorer	881 (18.91)	19.95	834 (19.1)	19.07	983 (20.37)	20.58
Middle	892 (19.15)	19.74	841 (19.26)	19.28	872 (18.07)	19.22
Richer	945 (20.29)	19.55	917 (21)	20.59	959 (19.87)	20.32
Richest	950 (20.4)	18.07	867 (19.85)	19.65	959 (19.87)	18.99
Hand wash place in the HH						
Observed	3980 (85.44)	85.56	4162 (95.31)	95.65	4656 (96.48)	96.82
Not observed or not in the dwelling	678 (14.56)	14.44	205 (4.69)	4.35	170 (3.52)	3.18
Access road to community						
Good condition	3285 (70.52)	67.77	3220 (73.73)	70.76	3985 (82.57)	81.60
Poor condition	1373 (29.48)	32.23	1147 (26.27)	29.24	841 (17.43)	18.40

Table 1 (continued)

	2011 (*N* = 4658)		2014 (*N* = 4367)		2017 (*N* = 4826)	
	Unweighted Sample size	Weighted proportions	Unweighted Sample size	Weighted proportions	Unweighted Sample size	Weighted proportions
	n (%)	(%)	*n* (%)	(%)	*n* (%)	(%)
Division						
Sylhet	718 (15.41)	7.42	657 (15.04)	9.29	673 (13.95)	7.73
Chittagong	924 (19.84)	22.78	835 (19.12)	21.84	792 (16.41)	21.03
Dhaka and Mymensingh	763 (16.38)	30.91	767 (17.56)	35.10	1280 (26.52)	33.64
Khulna	558 (11.98)	9.64	516 (11.82)	8.07	501 (10.38)	9.17
Rajshahi	589 (12.64)	13.21	532 (12.18)	10.06	513 (10.63)	11.84
Rangpur	591 (12.69)	10.58	540 (12.37)	9.83	551 (11.42)	10.86
Barisal	515 (11.06)	5.45	520 (11.91)	5.82	516 (10.69)	5.73
ANC						
One or more ANC	3227 (69.28)	67.38	3435 (78.66)	78.46	4437 (91.94)	92.05
No ANC	1431 (30.72)	32.62	932 (21.34)	21.54	389 (8.06)	7.95
Birth assistance						
Medically trained	1616 (34.69)	31.48	1944 (44.52)	43.26	2577 (53.4)	52.91
Not medically trained	3042 (65.31)	68.52	2423 (55.48)	56.74	2249 (46.6)	47.09
PNC within two months						
Took PNC	2489 (53.43)	51.33	2832 (64.85)	63.46	3178 (65.85)	64.34
Did not take PNC	2169 (46.57)	48.67	1535 (35.15)	36.54	1648 (34.15)	35.66

SE Standard Error, *CI* Confidence Interval, *Ref* Reference group, *HH* Household, *HW* Hand Washing, *St.* Station

*** $p < 0.001$, ** $p < 0.01$, * $p < .05$,

Direct effects of education on U5M

Tables 2 reveals that, compared to the parents' no or primary education, parents' secondary or higher education negatively affected (Figs. 2, 3; Pathway: d) child mortality, i.e., mortality declined. However, this effect decreased with time. Furthermore, the effect of mother's education was not statistically significant over the three time periods. Among the children of mothers with secondary or higher education, the log odds of U5M were 0.36 units (coefficient: -0.36; 95% CI [-0.82, 0.10], $p > 0.05$]) and 0.23 (coefficient: -0.23; 95% CI [-0.72, 0.27], $p > 0.05$) units lower in 2011 and 2017–18, respectively (Table 2; Figs. 4, 5, 6; Pathway d). For comparison, refer to similar log odds of U5M, for father's education, as presented in Table 2 and Fig. 7, 8, 9 (Pathway d).

Direct effects of antenatal care utilisation status on the availability status of hand washing stations and on U5M

No utilisation of ANC was shown to have a significant positive effect (increased the risk of having no hand washing station) on the unavailability of hand washing stations in the household (Table 2; Figs. 2–3; Pathway b). While the effect remained roughly same in the 2011 and 2014 surveys, it changed direction in the 2017–18 survey. However, the effect size was very small. GSEM results (Table 2; Figs. 4, 5, 6; Fig. 7, 8, 9; Pathway b) showed that the log odds of unavailability of hand washing station in the household were 0.28 (coefficient: 0.28; 95% CI [0.05, 0.52], $p < 0.05$) units, 0.29 (coefficient: 0.29; 95% CI [-0.18, 0.75], $p > 0.05$) units higher, in 2011, 2014 respectively, when the mother did not take ANC. Table 2 and Figs. 4, 5, 6 (Pathway f) also showed that the direct effect of ANC utilisation status on U5M was not significant, and the directions of the effects were inconsistent across the three surveys. No utilisation of ANC was associated with a higher risk of U5M in 2011 and 2014. Conversely, it was associated with a lower risk in 2017–18.

Direct effects of the availability status of hand washing stations on U5M

Table 2 reveals no specific pattern for the direct effects (Figs. 2–3; Pathway c) of the availability status of hand washing stations on U5M. Compared to the availability of handwashing stations, unavailability increased the risk of U5M. However, the effect decreased with time, and the direction of the effect in 2014 was opposite to the direction in 2011 and 2017–18 surveys.

Table 2 GSEM using mother's education, ANC uptake, hand washing station's availability and child's living status

Predictors	Endogenous variables in sequential mediation analysis								
	2011 (*N* = 4,647)			2014 (*N* = 4,367)			2017 (*N* = 4,826)		
	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child
	No ANC	Not observed	Dead	No ANC	Not observed	Dead	No ANC	Not observed	Dead
	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)
Hand washing station									
Observed	-	-	Ref	-	-	Ref	-	-	Ref
Not observed	-	-	0.8 (0.37, 1.23)***	-	-	-0.07 (-1.16, 1.02)	-	-	0.18 (-0.93, 1.29)
ANC									
One or more	-	Ref	Ref	-	Ref	Ref	-	Ref	Ref
None	-	0.28 (0.05, 0.52)*	0.39 (-0.03, 0.81)	-	0.29 (-0.18, 0.75)	0.24 (-0.31, 0.78)	-	-0.01 (-0.54, 0.52)	-0.68 (-1.52, 0.17)
Mother's highest level of education									
None or primary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary or higher	-0.81 (-1.01, -0.6)***	0.23 (-0.01, 0.47)	-0.36 (-0.82, 0.1)	-0.65(-0.88, -0.42)***	0.04 (-0.42, 0.49)	0.08 (-0.53, 0.69)	-0.57 (-0.87, -0.27)***	0.18 (-0.3, 0.66)	-0.23 (-0.72, 0.27)
Father's highest level of education									
None or primary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary or higher	-0.43(-0.62,-0.23)***	-0.17 (-0.41, 0.08)	-0.46 (-0.91, -0.002)*	-0.39 (-0.67, -0.11)**	-0.06 (-0.43, 0.55)	-0.31(-0.88, 0.27)	-0.69 (-1.01, -0.37)***	-0.16 (-0.56, 0.23)	-0.19 (-0.63, 0.25)
Sex									
Male	-	-	Ref	-	-	Ref	-	-	Ref
Female	-	-	-0.07 (-0.43, 0.29)	-	-	0.18 (-0.27, 0.63)	-	-	0.14 (-0.29, 0.58)
Multiple or single									
Single	-	-	Ref	-	-	Ref	-	-	Ref
Multiple	-	-	1.45 (0.46, 2.44)**	-	-	2.7 (1.72, 3.68)***	-	-	1.94 (0.9, 2.98)***
Age category of child									
12 months to 3 years	-	-	Ref	-	-	Ref	-	-	Ref
11 months or younger	-	-	2.68 (2.14, 3.23)***	-	-	3.19 (2.41, 3.96)***	-	-	3.34 (2.48, 4.21)***
Mother's age during childbirth									
18 years or younger	Ref	Ref	Ref	Ref	Ref	Ref	Ref	REf	Ref
19 to 24 years	0.28 (0.05, 0.51)*	-0.01 (-0.32, 0.29)	0.41 (-0.19, 1.01)	0.1 (-0.18, 0.39)	-0.08 (-0.68, 0.52)	-0.57 (-1.19, 0.05)	0.45 (0.003, 0.89)*	-0.24 (-0.76, 0.29)	-0.15 (-0.85, 0.55)
25 to 30 years	0.15 (-0.13, 0.43)	-0.09 (-0.4, 0.22)	-0.37 (-1.05, 0.3)	0.11 (-0.21, 0.44)	0.14 (-0.24, 0.53)	-0.84 (-1.56, -0.12)*	0.51 (0.02, 0.99)*	0.11 (-0.43, 0.67)	-0.26 (-1.03, 0.51)
31 years or above	0.35 (0.06, 0.64)*	0.0003 (-0.39, 0.39)	0.62 (-0.08, 1.32)	0.1 (-0.25, 0.44)	-0.34 (-1.14, 0.47)	-0.26 (-0.99, 0.46)	-0.63 (0.14, 1.13)*	-0.08 (-0.67, 0.51)	0.11 (-0.63, 0.85)
Mother's Body Mass Index									

Table 2 (continued)

Predictors	Endogenous variables in sequential mediation analysis								
	2011 (*N* = 4,647)			2014 (*N* = 4,367)			2017 (*N* = 4,826)		
	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child
	No ANC	Not observed	Dead	No ANC	Not observed	Dead	No ANC	Not observed	Dead
	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)
Normal weight	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Underweight	0.15 (-0.04, 0.33)	-0.07 (-0.3, 0.16)	-0.24 (-0.66, 0.18)	0.06 (-0.19, 0.3)	0.18 (-0.29, 0.66)	-0.63(-1.24, -0.02)*	0.3 (-0.01, 0.62)	0.25 (-0.22, 0.73)	0.28 (-0.34, 0.91)
Overweight or obese	-0.35 (-0.67, -0.02)*	0.08 (-0.31, 0.47)	0.95 (0.4, 1.5)**	-0.54 (-0.88, -0.2)**	0.1 (-0.58, 0.79)	0.19 (-0.41, 0.79)	-0.45 (-0.87, -0.04)*	0.02 (-0.54, 0.58)	0.8 (0.28, 1.31)**
Mother's exposure to media									
Watched television	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Did not watch television	0.31 (0.12, 0.49)**	-0.0006 (-0.24, 0.24)	-0.04 (-0.46, 0.37)	0.42 (0.18, 0.66)**	0.4 (-0.08, 0.88)	0.31 (-0.27, 0.9)	0.41 (0.11, 0.7)**	-0.09 (-0.56, 0.39)	-0.35 (-0.88, 0.17)
Decision making									
Some participation	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
No participation	0.05 (-0.13, 0.24)	0.18 (-0.05, 0.41)	-0.67 (-1.09, -0.24)**	0.14 (-0.06, 0.34)	-0.07 (-0.46, 0.32)	-0.28 (-0.89, 0.32)	-0.001(-0.37, 0.37)	-0.34 (-0.81, 0.12)	0.49 (-0.05, 1.02)
Wealth quintile									
Poorest	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Poorer	0.13 (-0.12, 0.39)	-0.22 (-0.47, 0.04)	0.19 (-0.38, 0.77)	-0.32 (-0.64, 0.002)	-0.34 (-0.81, 0.14)	0.14 (-0.47, 0.74)	-0.29 (-0.64, 0.05)	-0.55 (-1.1, 0.01)	-0.03 (-0.7, 0.64)
Middle	-0.19 (-0.44, 0.05)	-0.59(-0.92, -0.27)***	0.28 (-0.35, 0.91)	-0.58 (-0.88, -0.29)***	-0.51 (-1.17, 0.15)	-0.57 (-1.33, 0.19)	-0.53 (-0.94, -0.12)*	-1.21 (-1.96, -0.47)**	-0.41 (-1.17, 0.35)
Richer	-0.68(-0.96,-0.39)***	-1.15(-1.55, -0.74)***	0.44 (-0.19, 1.08)	-1.06 (-1.43, -0.7)***	-1.22(-2.12,-0.34)**	-0.18 (-0.96, 0.6)	-0.9 (-1.36, -0.43)***	-1.41 (-2.13, -0.69)**	-0.37 (-1.16, 0.43)
Richest	-1.61(-1.97,-1.28)***	-2.37 (-3, -1.74)***	0.44 (-0.39, 1.28)	-1.65(-2.24, 11.06)***	-3.22(-4.87,-1.55)***	-0.45 (-1.31, 0.41)	-1.9 (-2.66, -1.13)***	-4.36 (-6.44, -2.28)***	-0.37 (-1.28, 0.54)
Access road to community									
Good condition	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Poor condition	0.41 (0.18, 0.64)***	0.1 (-0.23, 0.43)	0.14 (-0.25, 0.53)	0.38 (0.04, 0.71)*	0.09 (-0.62, 0.8)	-0.39 (-0.98, 0.2)	0.12 (-0.23, 0.48)	0.01 (-0.55, 0.56)	0.53 (-0.03, 1.08)
Division									
Sylhet	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Chittagong	-0.16 (-0.48, (0.16)	-0.01 (-0.39, 0.38)	-0.57 (-1.27, 0.12)	0.11 (-0.43, 0.64)	0.11 (-0.93, 1.14)	-0.67 (-1.32, -0.01)*	0.04 (-0.43, 0.51)	-1.2 (-1.9, 0.49)**	-0.42 (-1.14, 0.3)
Dhaka and Mymensingh	-0.38 (-0.72, -0.03)*	-0.41 (-0.9, 0.07)	-0.13 (-0.73, 0.47)	-0.66 (-1.19,—0.13)*	-0.63 (-1.81, 0.55)	-0.51 (-1.18, 0.16)	-0.18 (-0.61, 0.25)	-2.21 (-3.07, -1.35)***	-0.37 (-1.04, 0.31)
Khulna	-0.67(-1.04,-0.03)***	-0.18 (-0.67, 0.31)	-0.73 (-1.48, 0.02)	-1.02 (-1.57, -0.47)***	-2 (-3.55, -0.45)*	-0.61 (-1.45, 0.22)	-1 (-1.76, -0.24)*	-1.96 (-2.9, -1.03)***	-0.02 (-0.79, 0.75)
Rajshahi	-1 (-1.38, -0.62)***	-0.47 (-0.99, 0.04)	-0.19 (-0.83, 0.46)	-0.37 (-0.87, 0.12)	-1.12 (-2.19, -0.05)*	-0.35 (-1.16, 0.46)	-0.71 (-1.31, 0.11)*	-1.66 (-2.54, -0.79)***	-0.33 (-1.25, 0.59)
Rangpur	-1.3(-1.68, -0.93)***	-1.92(-2.52, -1.32)***	-0.32 (-1.07, 0.43)	-0.67 (-1.22, -0.12)*	-1.2 (-2.2, -0.2)*	-1.5 (-2.36, -0.63)**	-1.07 (-1.82, -0.32)**	-4.65 (-6.68, -2.61)***	-0.63 (-1.47, 0.22)
Barisal	-0.64 (-0.98, -0.3)***	0.4 (-0.03, 0.84)	0.29 (-0.38, 0.96)	-0.27 (-0.8, 0.25)	0.59 (-0.4, 1.57)	-1.51 (-2.54, -0.48)**	0.18 (-0.32, 0.67)	-0.99 (-1.73, -0.25)**	-0.07 (-0.84, 0.69)

Table 2 (continued)

Predictors	Endogenous variables in sequential mediation analysis								
	2011 (*N* = 4,647)			2014 (*N* = 4,367)			2017 (*N* = 4,826)		
	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child	ANC	Hand wash place in the HH	Living status of the child
	No ANC	Not observed	Dead	No ANC	Not observed	Dead	No ANC	Not observed	Dead
	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)
Birth assistance									
Medically trained	-	-	Ref	-	-	Ref	-	-	Ref
Not medically trained	-	-	0.08 (-0.5, 0.67)	-	-	0.05 (-0.44, 0.54)	-	-	0.28 (-0.28, 0.84)
PNC within two months									
Took PNC	-	-	Ref	-	-	Ref	-	-	Ref
Did not take PNC	-	-	-0.31 (-0.79, 0.18)	-	-	0.52 (0.04, 1.01)*	-	-	0.79 (0.27, 1.31)**

CI Confidence Interval, *Ref* Reference group, *HH* Household, *HW* Hand Washing, *St.* Station

*** $p < 0.001$, ** $p < 0.01$, * $p < .05$

Parallel mediation of education's effect on U5M through antenatal care utilisation status and through the availability status of handwashing station

As Table 3 shows, compared to either parent's no or primary education, the effect of their secondary or higher education on U5M parallelly mediated through ANC utilisation status (Figs. 2–3; Pathways a, f) was negative (reduced U5M risk) but non-significant in 2011 and 2014. The effects in 2017–18 were opposite to the effects in 2011 and 2014. Education's (father) effect on U5M parallelly mediated through the availability status of handwashing stations was negative and reduced across the surveys. Mothers' education exhibited an inconsistent effect—was negative (reduced mortality risk) in 2014 but showed a positive effect (Table 3; Figs. 2–3; Pathways e, c) in the other two surveys.

Sequential mediation of education's effect on U5M through antenatal care utilisation status and the availability status of handwashing station

Table 3 also reveals that the effect of either parent's secondary or higher education sequentially mediated through ANC utilisation status and availability status of hand washing stations (Figs. 2–3; Pathways a, b, c) was inconsistent across the survey years; negative (reduced U5M risk) in 2011, and positive in the other two surveys.

Education's total mediated or indirect effect on U5M

Table 3 reveals that, in 2011 and 2014, compared to no or primary education, the total mediated or indirect effect of either parent's secondary or higher education on U5M, mediated through ANC utilisation status and availability status of hand washing stations, was negative, i.e., reduced the U5M risk. However, only the effect of father's education in 2014 was statistically significant. The effect of either parent's education in 2017–18 was opposite to the effects in 2011 and 2014. Hence, like the direct effects of either parent's education, the indirect effects on U5M decreased with time.

Total effect of parents' education on U5M

Overall, the total effect of father's education on U5M was slightly higher than the total effect of mother's education in 2011 and 2014 (Table 3). The effect of either parent's education was significant in 2011 only. Moreover, the effect was inconsistent and became positive (increased U5M risk) in 2017–18. The coefficients of the total effects of mother's education in 2011, 2014 and 2017–18 were -0.67 (95% CI [-1.32, -0.03], $p < 0.05$), -0.06 (95% CI [-0.82, 0.7], $p > 0.05$), and 0.19 (95% CI [-0.56, 0.94], $p > 0.05$), respectively. See Table 3 for the total effect of father's education.

Proportions of the mediated effect of parents' education

Table 3 presents the proportions of the mediated effects. The proportions of the effects of education on U5M mediated either parallelly or sequentially showed inconsistencies. These inconsistent proportions were insufficient to confer broadly which pathway mechanism influenced U5M more than the other. The proportions of the total mediated effect were inconsistent across the surveys. In 2011, 46% of the total effect of either parent's education was mediated through ANC utilisation and availability of hand washing stations in the household. In 2014 and 2017–18, due to the opposite direction of education's direct and total indirect effect, the proportions were greater than 100% except for the proportion of the mediated effect of father's education in 2014.

Discussion

This research used three nationally representative surveys to investigate the trend of the mediated effect of parents' education on child mortality in Bangladesh. At a high level, this study implies that for a more effective U5M reduction, initiatives need to acknowledge the dynamic nature of the inter-relationships of relevant factors rather than focusing on the performance of the factor/s of interest alone. This argument is congruent with the findings, which report both parallel and sequential mediation of education's effect through ANC utilisation and availability of hand washing stations in households, and a gradual reduction in the effect of parents' education over time. This gradual reduction needs to be interpreted by acknowledging relevant contextual factors. Firstly, per the 2017–18 survey, there was either a rise or stagnancy in the rate of child mortality from causes like prematurity, birth asphyxia, congenital malformation or birth injuries, i.e., causes that often require extensive hospital-based care [3, 65]. Secondly, roughly 20% of the Bangladeshi pregnant women received 4 + ANC with all the recommended components [3, 66]. Thirdly, practice related to standard handwashing can be low amid the presence of handwashing facility in a household [67]. Fourthly, the quality of school education in Bangladesh requires improvement [68, 69]. The following sections will delve into these contextual factors to provide a detailed analysis and discussion of the findings and their interplay with these factors.

Direct effect of parents' education on U5M

Our study found that the direct effect of parents' education on child mortality reduced and became non-significant over time. This means that, in the course of time, parents' education became less effective in reducing U5M. What our study reports is not anomalous. Instead, it is supported by literature and can be explained using

Table 3 Direct effects, indirect effects, total effects and proportion of indirect effects across three surveys

Effects	2011		2014		2017	
	Mothers	Fathers	Mothers	Fathers	Mothers	Fathers
	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)
Bivariate analyses						
Unadjusted direct effects						
Effect of education on mortality	-0.01 (- 0.03,—0.001)*	-0.01 (-0.02, 0.0002)	- 0.01 (-0.02,0.001)*	-0.02 (-0.03, -0.003)*	-0.01 (-0.02, 0.003)	-0.004 (-0.01, 0.003)
Effect of ANC on mortality	0.01 (0.001, 0.03)*		0.01 (-0.003, 0.03)		-0.01 (-0.02, 0.01)	
Effect of HW St. in the HH on mortality	0.03 (0.01, 0.06)**		-0.001 (-0.03, 0.03)		0.004 (-0.02, 0.3)	
GSEM						
Adjusted direct effects						
Effect of education on mortality	-0.36 (-0.82, 0.1)	-0.46 (-0.91, -0.002)*	0.08 (-0.53, 0.69)	-0.31 (-0.88, 0.27)	-0.23 (-0.72, 0.27)	-0.19 (-0.63, 0.25)
Effect of ANC on availability of HW St. in the HH	0.28 (0.05, 0.52)*		0.29 (-0.18, 0.75)		-0.008 (-0.54, 0.53)	
Effect of ANC on mortality	0.39 (-0.03, 0.81)		0.24 (-0.31, 0.78)		-0.68 (-1.52, 0.17)	
Effect of availability of HW St. in the HH on mortality	0.8 (0.37, 1.23)***		-0.07 (-1.16, 1.02)		0.18 (-0.93, 1.29)	
Adjusted indirect effect on the availability of HW St						
Effect of education on the availability of HW St. mediated through ANC uptake	-0.23 (-0.42, -0.03)*	-0.12 (-0.24, -0.002)	-0.19 (-0.48, 0.11)	-0.11 (-0.31, -0.08)	0.01 (-0.3, 0.31)	0.01 (-0.36, 0.38)
Adjusted indirect effects on mortality						
ANC uptakes' effect mediated through the availability of HW st. in the HH	0.23 (-0.01, 0.46)	0.23 (0.01, 0.46)	-0.02 (-0.33, 0.29)	-0.02 (-0.33, 0.29)	-0.001 (-0.1, 0.1)	-0.001 (-0.1, 0.1)
Education's effect mediated through ANC uptake	-0.31 (-0.67, 0.04)	-0.17 (-0.36, 0.03)	-0.15 (-0.52, 0.21)	-0.09 (-0.31, 0.12)	0.38 (- 0.12, 0.89)	0.47 (-0.16, 1.09)
Education's effect mediated through availability of HW station	0.18 (-0.03, 0.4)	-0.13 (-0.33, -0.07)	-0.002 (-0.05, 0.05)	- 0.01 (-0.09, 0.08)	0.03 (-0.18, 0.25)	-0.03 (-0.23, 0.17)
Education's effect mediated through ANC uptake and availability of HW station	-0.18 (-0.37,—0.01)	-0.1(-0.21, 0.2)	0.01 (-0.19, 0.21)	0.01 (-0.11, 0.13)	0.001 (-0.06, 0.06)	0.001 (-0.07, 0.07)

Table 3 (continued)

Effects	2011		2014		2017	
	Mothers	Fathers	Mothers	Fathers	Mothers	Fathers
	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)	Coefficients (95% CI)
Proportion of total effect mediated either parallelly or sequentially						
Proportion of education's total effect mediated parallelly through ANC uptake	0.47 (0.004, 0.93)*	0.2 (-0.002, 0.39)*	2.6 (-27.45, 32.64)	0.24(-0.37, 0.84)	2.03 (-4.66, 8.72)	1.88 (-2.27, 6.04)
Proportion of education's total effect mediated parallelly through availability of HW station	-0.27 (-0.73, 0.19)	0.16 (-0.08, 0.39)	0.04 (-1.01, 1.1)	0.01 (-0.2, 0.22)	0.17 (-0.89, 1.23)	-0.12 (-1.08, 0.84)
Proportion of education's total effect sequentially mediated through ANC uptake and availability of HW station	0.27 (-0.04, 0.59)	0.11 (0.02, 0.25)	-0.23 (-5, 4.55)	-0.02 (-0.33, 0.3)	0.004 (-0.29, 0.3)	0.004 (-0.27, 0.28)
Total indirect effect of education	-0.31 (-0.77, 0.14)	-0.4 (-0.71, -0.09)*	-0.14 (-0.54, 0.25)	-0.09 (-0.31, 0.13)	0.42 (-0.14, 0.98)	0.44 (-0.21, 1.09)
Total effect of education (direct effect + indirect effect)	-0.67 (-1.32, -0.03)*	-0.85 (-1.39,- 0.31)**	-0.06 (-0.82, 0.7)	-0.4 (-0.97, 0.17)	0.19 (-0.56, 0.94)	0.25 (-0.52, 1.01)
Proportion of education's mediated effect	0.46 (-0.02, 0.95)	0.47 (0.15, 0.79)**	2.42 (-25, 29.83)	0.23 (-0.37, 0.82)	2.21 (-4.63, 9.05)	1.77 (-1.85, 5.39)

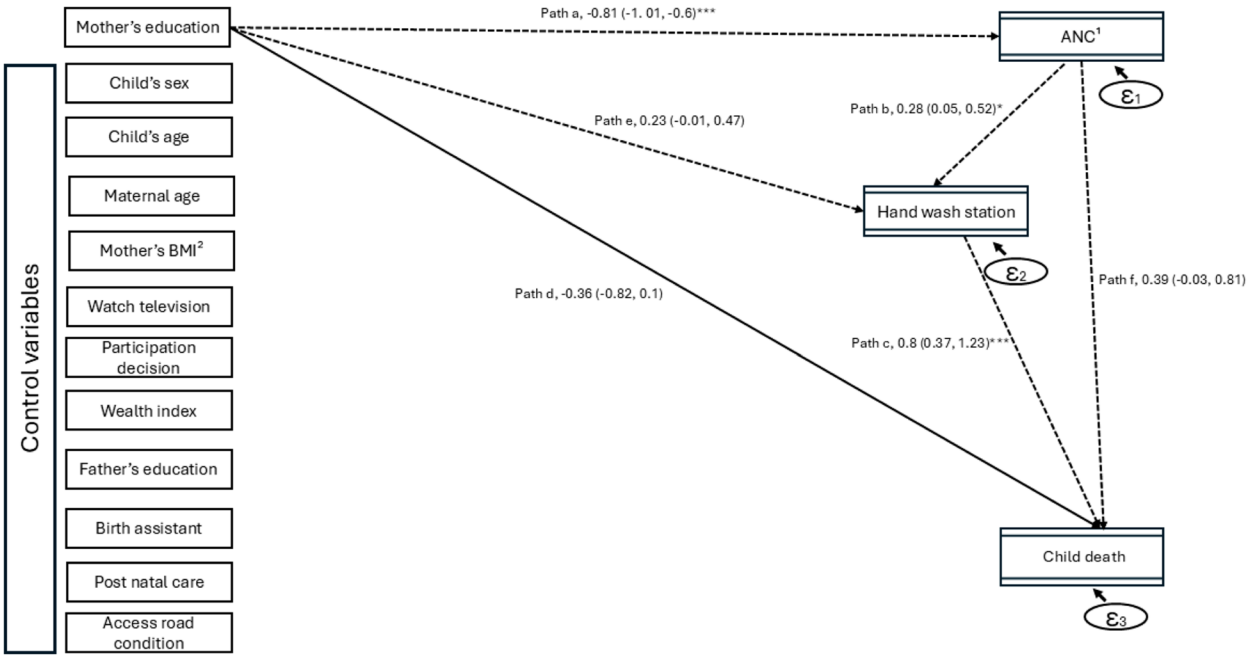
CI Confidence Interval, *Ref* Reference group, *HH* Household, *HW* Hand Washing, *St.* Station

*** $p < 0.001$, ** $p < 0.01$, * $p < .05$

contextual factors. A recent multi-country study reported a weakening association of parental education with child health outcomes [70]. Moreover, in our study context, a gradual reduction in education's effect is also possible partially due to the shift in the burden of cause-specific mortality. In other words, with time, a higher proportion of children died due to causes that largely required extensive hospital care. These are probably handled better when hospitals are well equipped, and carers like parents have better education, which is also highlighted in a recent study conducted in Bangladesh [14]. In contrast, if recognised early, mortalities from causes like diarrhoea or pneumonia, generally preventable or treatable using cost-effective interventions, have reduced remarkably during the same period [30, 71].

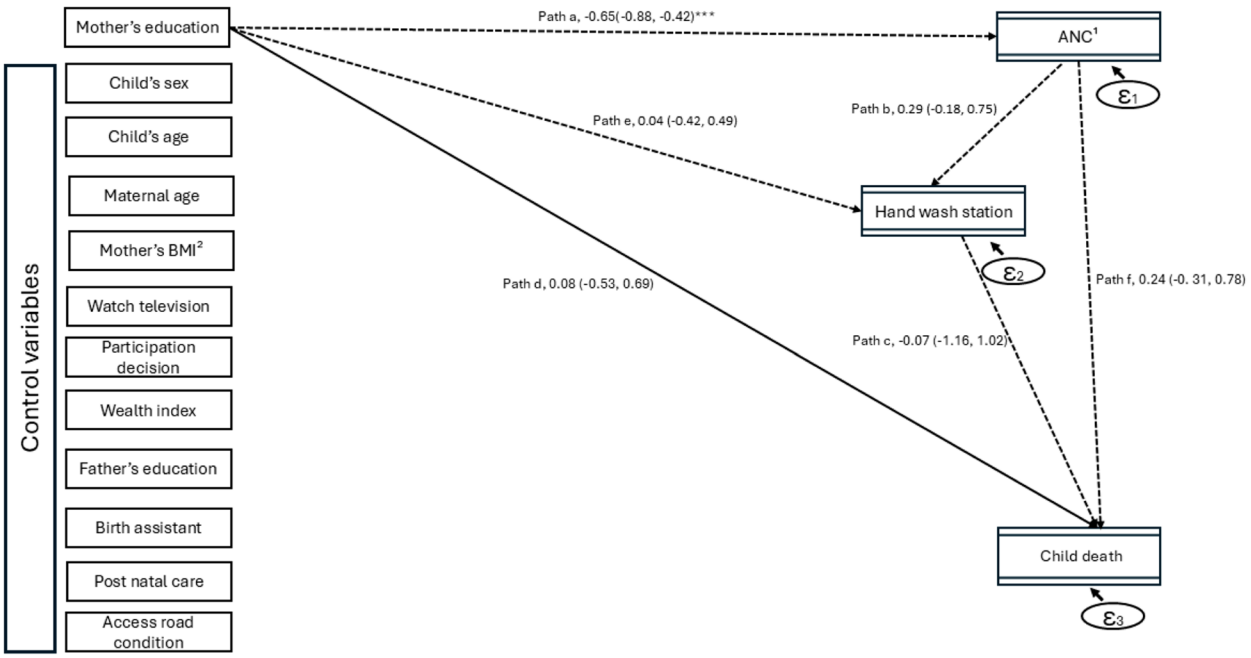
For example, between 2004 and 2011, U5MR from diarrhoea reduced from 7/1000 to 1/1000 live births, as opposed to either a rise or stagnation in mortalities from birth asphyxia, prematurity or congenital malformation [39]. Reduction of U5M from diarrhoea was possible mainly due to mass campaigns that raised awareness about diarrhoea and the coverage of cost-effective interventions, including hand washing [3, 30, 72]. The diarrhoea-focused mass campaigns equipped parents with school education with the required comprehension to recognise the signs of diarrhoea and take necessary actions to save the child from dying.

Like diarrhoea, pneumonia-specific mortality rates in Bangladesh also reduced remarkably. The rates per thousand live births were 18, 12 and 8 in 2004, 2011 and 2017–18 surveys, respectively [3, 39]. By early detection, it is possible to treat pneumonia with low-cost oral antibiotics, while hospitalisation would be required for severe pneumonia cases [73]. Moreover, pneumonia can be prevented through immunisation [30, 71]. Due to easily accessible antibiotics from drug shops and good



¹ANC = Antenatal care; ²BMI = Body Mass Index

Fig. 4 Pathways of mother's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2011)



¹ANC = Antenatal care; ²BMI = Body Mass Index

Fig. 5 Pathways of mother's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2014)

coverage of the national immunisation programme, it is a reasonable assumption that parents with limited years of education can still adopt prevention measures or seek the required treatment for their child's pneumonia [3, 74]. Consistent with our argument, Chopra et al. (2013) referred to increased access to primary education as

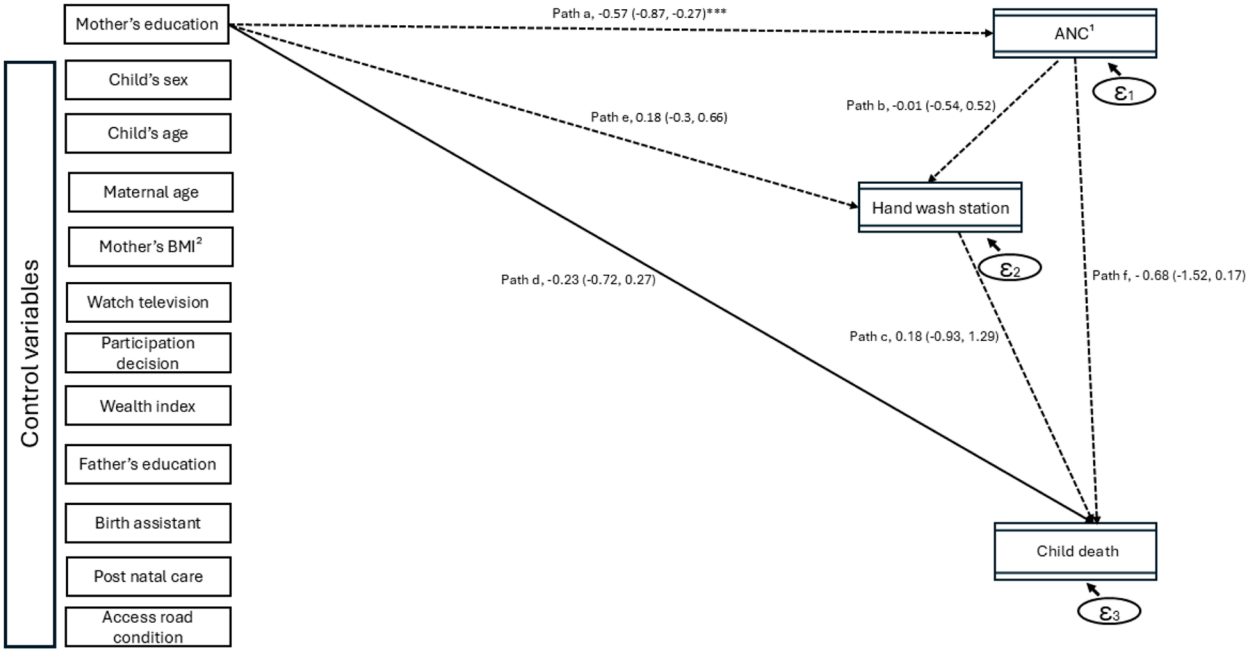


Fig. 6 Pathways of mother's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2017–18)

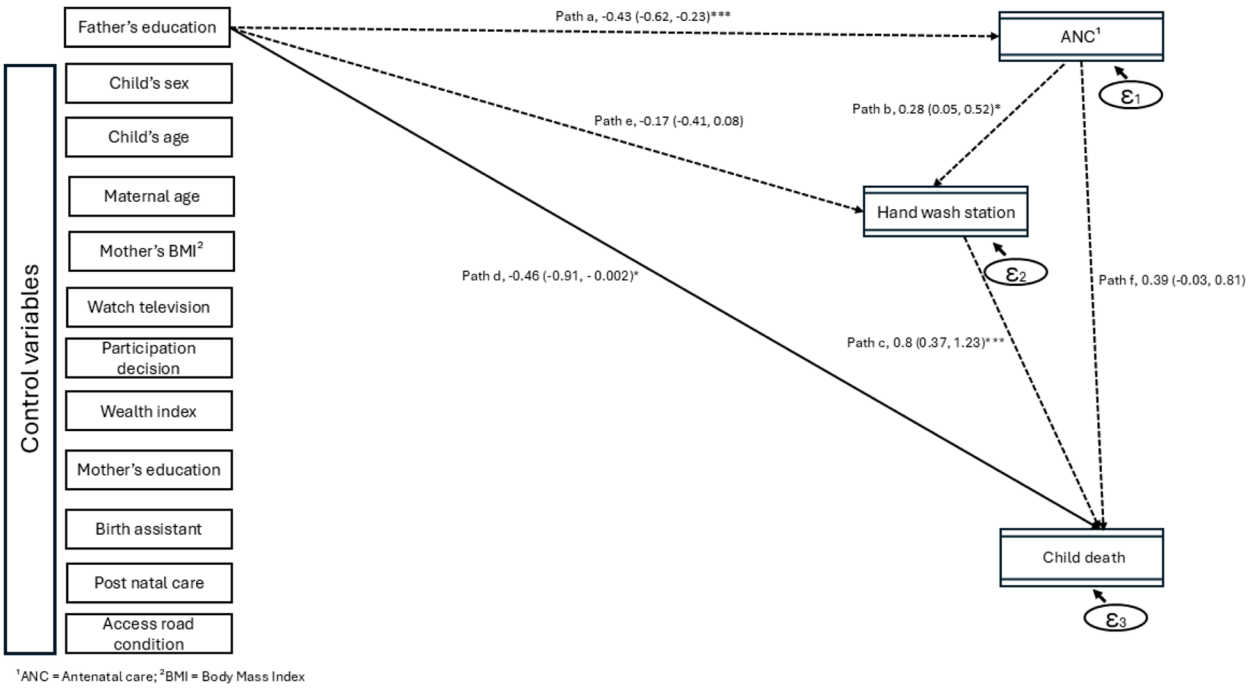


Fig. 7 Pathways of father's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2011)

one of the key drivers of global pneumonia mortality reduction between 2000 and 2011 [71, 72]. However, it would be hard for parents with similar education to seek appropriate, timely treatment for severe pneumonia that may require hospital-based care. A study conducted in India reported that children of mothers with

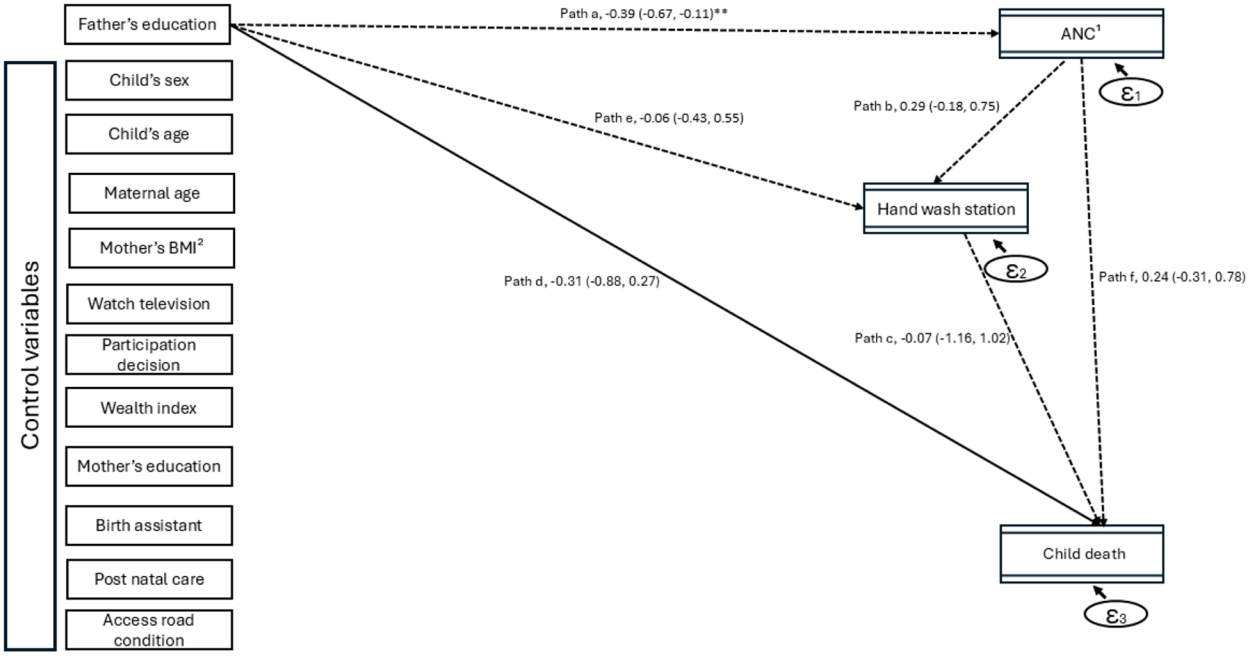


Fig. 8 Pathways of father's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2014)

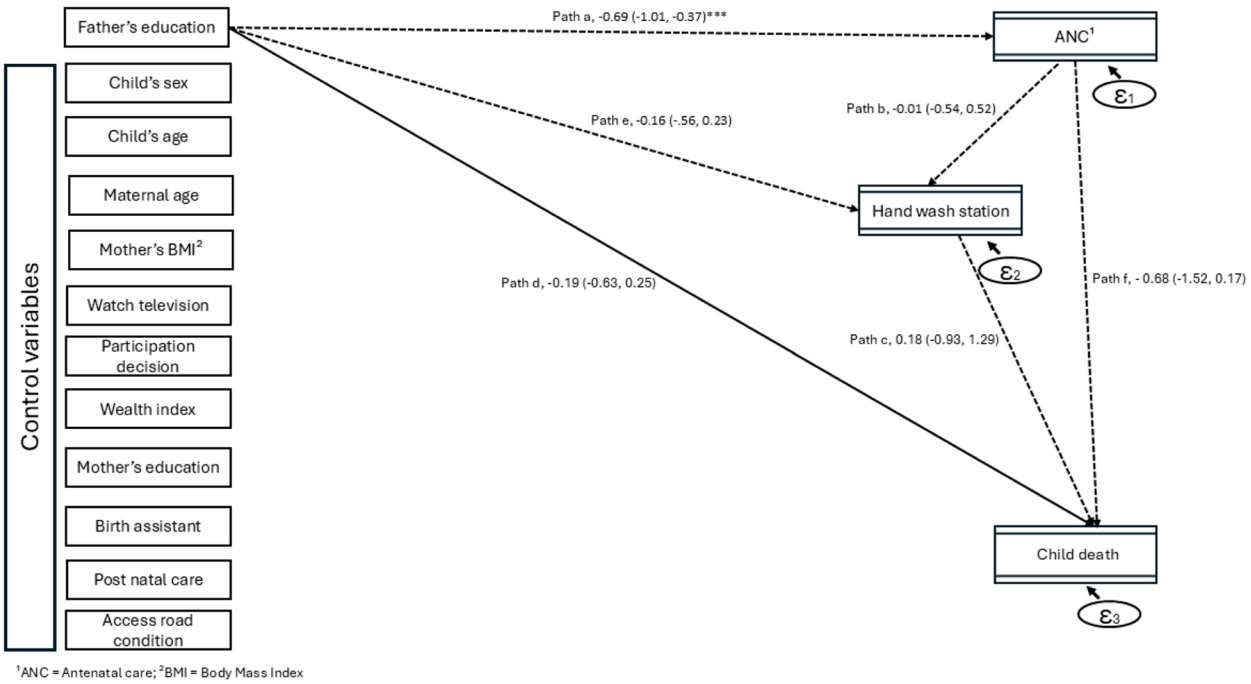


Fig. 9 Pathways of father's education to U5M mediated through ANC utilisation and/or hand washing station's availability (survey 2017–18)

less than undergraduate level had a 1.5 times higher risk of prolonged hospital stay for severe pneumonia compared to children from mothers with graduation or higher education [75].

Like severe pneumonia, causes of U5M that require extensive hospital care (such as birth asphyxia and prematurity) could likely be addressed more effectively with a higher level of parental education. A study conducted

in Bangladesh also reported that mothers with secondary and above education were at least 2.5 times more likely to seek care from trained providers for sick neonates [76]. In the Bangladeshi context, where the quality of school education is not up to the mark, it is presumable that primary education would fall short of preventing child deaths from more complicated causes that are harder to recognise and often require hospital care [69]. As expected, a recent study conducted in rural Bangladesh also reported that parents and other family members had poor knowledge, beliefs and practices regarding neonatal complications [77].

Direct effect of parents' education on antenatal care uptake

While the direct effects of neither parent's education on U5M were significant in 2014 or 2017–18, education's direct effect on ANC utilisation was consistently significant and high across three surveys. The association between a couple's education and ANC uptake is rational. Formal education enhances the couple's capacity to interpret health information from different sources and appreciate ANC's importance, leading them to ANC utilisation [78]. Moreover, education may also improve ANC uptake through empowerment and financial stability [79, 80]. Consequently, the literature supports our findings and reports a positive association between women's or husbands' education and ANC utilisation [81, 82].

Although the effect of a mother's secondary or higher education on ANC uptake was significantly high in our study, the effect steadily decreased over time. A study conducted in Ghana also reported a similar trend of education's effect on ANC utilisation [83]. In Bangladesh, the reduction in education's effect on ANC uptake (any ANC) could be due to the remarkable reduction in disparity related to ANC uptake between women with no education and women with secondary or higher education. For example, in the 2011 survey, women with secondary or higher education (93%) were more than twice as likely to report ANC utilisation than women with no education (40%) [39]. The proportions in the 2017–18 survey period were, 73% among the women with no education and 99% among the women with secondary or higher education [3]. This reduction in disparity probably was also facilitated by the country's effort to increase the coverage of ANC services. However, it is essential to be cautious in interpreting these statistics as this reduction in disparity does not apply to the uptake of quality ANC services, i.e., 4+ANC with all the recommended components of ANC. In 2017–18, only about 6% of women with no education received quality ANC services, as opposed to about 33% among women with secondary or higher education [3].

Direct effect of parents' education on the availability status of handwashing station

While the effect of father's education on the availability of hand-washing stations in households remained roughly steady, the effect of mother's education steadily increased (i.e., the risk of having no handwashing station while mother had secondary or higher education decreased) between 2011 and 2017–18. Just as education enhances awareness about the importance of utilising ANC, it similarly improves awareness regarding hand hygiene. Awareness related to hand hygiene promotes the availability of hand washing stations in the household. A study conducted in Ethiopia also reported findings congruent with our research; households headed by a person with secondary education had significantly higher odds of having basic hand-washing facilities compared to households headed by a person with no education [84]. This study reports the effect of household heads' education, whereas our study reports the effect of women's or husband's education. However, it can be argued that in the same household, the effect of any member's education on the availability of a handwashing station would be roughly similar.

Direct effect of antenatal care utilisation status on the availability status of hand washing station

Our study also reports a significant effect of ANC uptake on the availability of handwashing stations in 2011, which is also reasonable as counselling on handwashing is a component of standard ANC [35]. Although the effect size remained similar in 2014, it was not significant, and the effect in 2017–18 changed direction (having no ANC reduced the risk of having not had washing station). Again, the remarkably low coverage (18% per the 2017–18 survey) of quality ANC, i.e., ANC with all the recommended components, is one of the possible explanations [3]. To elaborate, it is likely that ANC contacts that did not cover all the recommended components (substandard ANC contacts: 82%) during service provision, did not provide counselling on handwashing [3]. The fact that a remarkably lower proportion (40%) of women received counselling on danger signs of pregnancy complications in 2017–18 than in 2014 (57%) supports our argument [3]. Furthermore, even if the ANC provider did provide counselling on handwashing, it was most likely not repeated in the subsequent (if received) ANC contacts, although repeated counselling in general, is a proven intervention for improving healthy practices [85]. Consequently, while the practice related to any ANC uptake increased remarkably, a notably small proportion of ANC maintained the standard and did not lead to expected changes in hand hygiene practices.

Direct effect of antenatal care on U5M

The quality of ANC also comes into play to explain the inconsistency of ANC's effect on U5M mortality. It is likely that U5M would be higher when mothers do not receive ANC compared to ANC uptake. Even though the effect was not significant, the direction of the effect of no ANC utilisation on U5M was in line with the expectation in the 2011 and 2014 surveys [4, 39]. Earlier studies conducted during same period reported similar direction of ANC on child mortality [86, 87]. In contrast to the direction in 2011 and 2014 survey, in the 2017–18 survey, the direction of the effect of ANC on U5M was the opposite – U5M was lower when the mother did not take ANC [3]. This unexpected finding possibly makes sense when the quality of ANC reported in the 2017–18 survey is considered. As around 82% of mothers did not receive quality ANC, it is possible that a larger proportion of the mothers of the deceased children received substandard ANC [3, 26]. Moreover, in the 2017–18 survey, only about 40% of women reported being informed about signs of pregnancy complications, as opposed to about 57% of women in 2014 [3, 4]. It is reasonable to assume that women who are unaware of neonatal danger signs may engage in poorer health-seeking practices, potentially leading to an increased U5M risk [16, 88]. However, it is also possible that among those who received ANC, a large proportion sought ANC due to having complications during pregnancy. Of course, children born to mothers with pregnancy complications would have a higher risk of death compared to children of mothers who did not seek ANC. To add further, a case–control study conducted in a subdistrict of Bangladesh also reported a higher risk of perinatal death when mothers sought ANC from a qualified provider. The data collection period of this study shares a similar timeline with BDHS 2017–18. This case–control study also referred to quality of care as one of the possible explanations for the increased mortality risk associated with ANC uptake [89].

Direct effect of handwashing station's availability status on U5M

Like ANC, the availability of handwashing stations in the household also appeared to have an inconsistent effect on U5M across three surveys. The association between standard handwashing practice and lower U5M risk is well established. However, BDHS does not contain information on hand-washing practices. Instead, it contains information on the availability of handwashing stations in the household, which we used as a predictor of U5M in this study. As the availability of handwashing stations is a precursor of handwashing, we can argue that the availability of handwashing stations in the household is a proxy of handwashing practice.

In line with our findings, a matched case–control study in Ethiopia reported that improper handwashing practice was associated with a higher U5M [27]. A randomised controlled trial conducted in Pakistan reported that handwashing with soap reduced pneumonia cases by 50% and diarrhoea cases by 53% among children [32]. As mentioned earlier, in recent decades, Bangladesh also has remarkably reduced mortalities from these two causes. Therefore, a higher risk of child death in households with no hand washing stations compared to households with handwashing stations is also not a real surprise. However, the effect of hand washing stations on U5M decreased between the 2011 and 2017–18 surveys. One of the possible explanations could be the shift in mortality causes, i.e., a rise in the proportion of causes (prematurity, birth asphyxia, congenital, etc.) that have less influence from hand washing [14, 90]. Moreover, the literature also suggests that having a handwashing station in the household may not always translate into proper handwashing practices [67].

Mediated effect of parents' education on U5M

Our study presents both parallel and sequential mediation of education's effect. The parallel or sequentially mediated effects were inconsistent across the surveys and thus insufficient to broadly determine which pathway mechanism influenced U5M more than the other. However, this study reports a reduction in the total mediated effect (i.e., the combined effect of the parallel and sequential pathway mechanisms); the total mediated effect reduced and the direction of the effect changed in 2017–18. This trend of education's mediated effect might seem unexpected; however, it is understandable when considering the direct effects discussed earlier and the contextual factors mentioned at the beginning of the discussion section. In summary, the gradual increase in deaths due to conditions requiring greater medical attention, the unmet need for improved quality of education, unusually low coverage of quality ANC services, and the potential failure in converting the availability of handwashing stations in households into appropriate handwashing practices resulted in a gradual reduction in the education's total mediated effect on U5M. Moreover, possibly due to the substandard quality of ANC, including a comparatively lower coverage (57% in 2014 vs 40% in 2017–18) of counselling on pregnancy complications, ANC uptake was associated with an increased U5M risk in 2017–18 [3]. Secondary or higher education's weakening effect, coupled with the negative effect of ANC uptake on U5M, changed the direction of the total mediated effect of education and was associated with a higher U5M risk. The aforementioned concepts also explain the inconsistencies in the parallel or sequentially mediated effect of education on U5M.

However, the limited number of studies investigating the trend of education's effect on U5M mediated through ANC utilisation status and availability status of handwashing stations in households restricts our ability to substantiate our findings with existing evidence. Still, studies that looked at these paths individually (parallel and sequential paths discussed in this study) broadly support the overall findings shared in our study. Previous studies on predictors of child mortality in Bangladesh reported a degrading effect of parental education on U5M. Although education was categorised differently compared to our study, overall, most of the education categories exhibited a reducing effect [91, 92]. The survey-year-specific findings on the direction of education's effect reported in our study are also in agreement with existing findings. Based on an analysis of pooled survey data, Khan et al. reported a lower risk of child mortality when parents had better education. However, our study did not find any significant association between parents' education (except for 2011 with father's education) and child mortality; this could be due to the differences in the methods. For example, Khan et al. used a different approach for sample selection compared to our study [93]. Survey-specific studies conducted by Paul et al. on BDHS 2017–18 data, and Jamee et al. on multiple indicator cluster survey (MICS) (2019) data reported an effect of mother's education on child mortality, broadly coherent with our study [8, 94].

Overall, existing evidence also supports a degrading effect of education on ANC utilisation between 2011 and 2014, as reported in this study [95]. However, based on analysis of MICS (2019), Jamee et al. reported that ANC reduced the risk of child mortality, while our analysis of BDHS 2017 data found the opposite. This contrast could be due to the difference in how ANC services are defined in the study; while our study considered ANC from any provider, Jamee et al. considered ANC from skilled providers only [94]. Nevertheless, the inconsistent effect of ANC on U5M over time, as our study found, has also been interpreted in reference to other comparable studies mentioned earlier in this discussion Sect. [86, 87, 89]. Similarly, the possible mechanism of the reducing effect of ANC on the availability of hand washing stations, as well as the reducing effect of hand washing stations on U5M, as mentioned earlier, are in line with the existing evidence [3, 35, 67, 90]. The integration of evidence from multiple studies examining different paths of the mediation pathway that we investigated helps us to relate the broader picture presented by this study – the reduction of education's overall (direct and indirect) effect on U5M and the change of its direction due to the inconsistent effect of ANC and handwashing.

Policy implications

While this study reports a weakening overall effect of both parents' education on U5M, it also highlights the scope of strengthening the programmes and policies for U5M reduction by unmasking the underperforming areas in the pathway between education and U5M. The rising proportion of mortalities from causes that require greater medical attention has undoubtedly made the task of mortality prevention harder than before. However, had the quality of education and ANC improved proportionately with the rise in the proportion of U5M from the more complicated causes, the U5M outcomes would probably have been better. Meticulous studies aimed at understanding how to improve the quality of education and ANC could guide the development of effective initiatives to effectively reduce U5M, regardless of the causes.

Strengths and limitations of the study

This study is unique as it conducted a weighted mediation analysis on three nationally representative surveys to unmask the stagnancy of U5M, while studies on stagnation are scant. More importantly, applying existing evidence, our study explains why education and ANC fell short over time to have the expected impact on U5M reduction. The most significant strength is that it provides evidence to justify that improving the quality of education and ANC could reduce U5M more effectively and achieve SDG 3.2.1.

One of the key limitations of this study rests with the cross-sectional nature of data, which cannot be used to establish a temporal relationship between endogenous, exogenous and other predictors. However, the key predictors, such as parents' education and ANC uptake, have a temporal relationship with U5M, while the availability of hand washing stations may not. Another limitation of this study also lies with the nature of the dataset; information on ANC utilisation was available only for children born within three years of the surveys. This limited our scope of investigation on how the mediated effect was on children older than three years. However, according to the combined data of 2011, 2014, and 2017–18 surveys, about 98% of the U5 children died within three years of birth. Therefore, our analysis still considered the characteristics of almost all the deceased children to report its findings. Another limitation related to the dataset—information on the components of ANC was not available for all surveys, therefore, binary ANC variable used in this study merely represents the number of visits. Furthermore, there may be other unobserved factors/latent variables affecting the relationships of exogenous and endogenous variables implying the presence of other pathways. Not including them in the model could have over or under-estimated the effects. Lastly, the scope of

our study is limited to the variables available in BDHS dataset, while there could be other relevant factors.

Conclusions

This study aimed to investigate parental education's effect on U5M mediated through ANC uptake status and the availability status of hand washing stations. The analysis revealed a decreasing and inconsistent effect, partially responsible for the stagnant U5MR reported in the 2017–18 survey. The declining direct effect of parents' education on U5M highlights the inadequacy of education in reducing U5M. It stresses the need to improve the quality of education, which has been highlighted in other studies, too [68, 69]. Updating the school curriculum to achieve better public health outcomes has been recommended in the existing literature [96, 97]. In the context of Bangladesh, an updated school curriculum, guided by research, with a greater emphasis on maternal and child health education could improve the quality of education, leading to an effective U5M reduction. Although the impact of improved quality of education on U5M may not be reflected soon enough to help achieve SDG 3.2.1, it will certainly help to achieve relevant post-SDG goals.

As reflected in this study, the quality of ANC services in Bangladesh also requires significant improvement. Mandatory use of ANC cards during ANC services can help to improve the quality of ANC services by enhancing the accountability of service providers. The national guideline in Bangladesh also recommends using ANC cards during service delivery [35, 98]. However, the government needs to ensure the availability of these cards and strictly monitor the use of these cards during ANC services [98]. ANC service providers' mandatory reporting to the managers (sub-district, district and division-level managers) about the quality of provided ANC services can be an integral part of monitoring. To improve the accountability of the service providers, scanned copies of ANC cards with the service recipient's signature should be made a compulsory part of ANC service reports.

Future studies should investigate other potential pathways between predictors and U5M to support development of more effective programmes and policies. The pathway models should be adjusted for unobserved confounders as appropriate according to the literature.

Abbreviations

ANC	Antenatal Care
BDHS	Bangladesh Demographic and Health Survey
GSEM	Generalised Structural Equation Modeling
PNC	Postnatal Care
SDG	Sustainable Development Goal
SEM	Structural Equation Modeling
U5	Under 5
U5M	Under-5 Mortality
U5MR	Under-5 Mortality Rate
VIF	Variance Inflation Factor

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Authors' contributions

T.M., I.M., D.A. and T.N. conceptualised this research, developed the methodology and arranged the required resources. With guidance from the co-authors, T.M. conducted data curation and data analysis and developed the first draft of the manuscript. I.M., D.A. and T.N. reviewed the manuscript and provided feedback. T.M. addressed those to finalise the manuscript for submission. The revised manuscript was approved by all the authors before submission.

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Data availability

The dataset(s) supporting the conclusions of this article are available in the Demographic and Health Surveys repository, https://dhsprogram.com/Data/.

Declarations

Ethics approval and consent to participate.

The de-identified data from BDHS 2011, 2014 and 2017–18 was accessed upon approval from the ICF. As these secondary data were nonsensitive in nature, the Research Ethics Committee of the University of Canberra exempted this study from the ethical review process (reference:11579).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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