DOI: 10.1111/1471-0528.12634
www.bjog.org

Original article

Education and severe maternal outcomes in developing countries: a multicountry cross-sectional survey

Ö Tunçalp,[a] JP Souza,[a] MJ Hindin,[b] CA Santos,[c] TH Oliveira,[c] JP Vogel,[a,d] G Togoobaatar,[e] DQ Ha,[f] L Say,[a] AM Gülmezoglu,[a] on behalf of the WHO Multicountry Survey on Maternal and Newborn Health Research Network

[a] UNDP/UNFPA/UNICEF/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP), Department of Reproductive Health and Research, World Health Organization, Geneva, Switzerland [b] Department of Population, Family and Reproductive Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA [c] Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, São Paulo, Brazil [d] School of Population Health, Faculty of Medicine, Dentistry and Health Sciences, University of Western Australia, Perth, WA, Australia [e] Department of Health Policy, National Center for Child Health and Development, Tokyo, Japan [f] National Hospital of Obstetrics and Gynecology of Vietnam, Hanoi, Vietnam
Correspondence: Dr Ö Tunçalp, Department of Reproductive Health and Research, World Health Organization, Avenue Appia 20, Geneva CH–1211, Switzerland. Email tuncalpo@who.int

Accepted 4 November 2013.

Objective To assess the relationship between education and severe maternal outcomes among women delivering in healthcare facilities.

Design Cross-sectional study.

Setting Twenty-nine countries in Africa, Asia, Latin America, and the Middle East.

Population Pregnant women admitted to 359 facilities during a period of 2–4 months of data collection between 2010 and 2011.

Methods Data were obtained from hospital records. Stratification was based on the Human Development Index (HDI) values of the participating countries. Multivariable logistic regression analyses were conducted to assess the association between maternal morbidity and education, categorised in quartiles based on the years of formal education by country. Coverage of key interventions was assessed.

Main outcome measures Severe maternal outcomes (near misses and death).

Results A significant association between low education and severe maternal outcomes (adjusted odds ratio, aOR, 2.07; 95% confidence interval, 95% CI, 1.46–2.95), maternal near miss (aOR 1.80; 95% CI 1.25–2.57), and maternal death (aOR 5.62; 95% CI 3.45–9.16) was observed. This relationship persisted in countries with medium HDIs (aOR 2.36; 95% CI 1.33–4.17) and low HDIs (aOR 2.65; 95% CI 1.54–2.57). Less educated women also had increased odds of presenting to the hospital in a severe condition (i.e. with organ dysfunction on arrival or within 24 hours: aOR 2.06; 95% CI 1.36–3.10). The probability that a woman received magnesium sulphate for eclampsia or had a caesarean section significantly increased as education level increased ($P < 0.05$).

Conclusions Women with lower levels of education are at greater risk for severe maternal outcomes, even after adjustment for key confounding factors. This is particularly true for women in countries that have poorer markers of social and economic development.

Keywords Education, health systems, human development index, inequity, near miss, severe maternal morbidity.

Please cite this paper as: Tunçalp Ö, Souza JP, Hindin MJ, Santos CA, Oliveira TH, Vogel JP, Togoobaatar G, Ha DQ, Say L, Gülmezoglu AM, on behalf of the WHO Multicountry Survey on Maternal and Newborn Health Research Network. Education and severe maternal outcomes in developing countries: a multicountry cross-sectional survey. BJOG 2014; 121 (Suppl. 1): 57–65.

Introduction

Launched in 2000, the Millennium Development Goal 5 (MDG 5) aimed for a three-quarter reduction in the maternal mortality ratio between 1990 and 2015. As 2015 approaches, increasing efforts have been made to improve maternal health. Despite a 47% decline in maternal mortality since 1990, it is unlikely that the MDG5 global target will be met.[1] An estimated 287 000 maternal deaths occurred in 2010, with nearly all (99%) occurring in

low- and middle-income countries (LMICs).[2] The majority of these deaths are avoidable, and maternal mortality has been justly described as the starkest example of the disparities between the developed and developing world.[3,4] It is well recognised that one of the most powerful social determinants of health is education,[5–7] which is associated with a range of improvements in people's wellbeing, including infant and maternal health.[8–10]

Education has been shown to have a profound effect on a mother's use of maternal health services,[10] and a global analysis of predictors of maternal mortality showed that levels of female literacy and schooling were significantly associated with maternal death.[11] A recent WHO-led analysis of maternal outcomes following delivery in 23 LMICs showed that, compared against women with more than 12 years of education, women with no education had 2.7 times the risk of maternal mortality.[12]

Despite strong evidence that education is a powerful and modifiable determinant of maternal mortality and service use, there is no research examining the effect of education on other key maternal indicators, such as coverage of interventions and severe maternal outcomes, especially in terms of access to care. We conducted a secondary analysis of the WHO Multicountry Survey (WHOMCS) in order to assess the association of levels of education on access to health care and severe maternal outcomes among women delivering in health care facilities in 29 countries.[13]

Methods

The study protocol and methodology of the WHOMCS have been published previously.[13,14] In summary, it is a cross-sectional survey implemented in 359 health facilities from 29 countries, conducted between May 2010 and December 2011, including 314 623 women. A stratified, multistage cluster sampling approach was used to obtain a sample of facilities from two randomly selected provinces and the capital city of each country. The institutions sampled had to have over 1000 deliveries per year and the capacity to perform caesarean sections. Data were collected for 2–3 months depending on the annual number of deliveries per facility.

All women giving birth and with a severe maternal outcome, regardless of gestational age, during the data collection period were included. Women with severe maternal outcomes (SMOs) were defined by either maternal deaths or maternal near miss. Trained data collectors reviewed medical records during the study period and used this data to complete the paper data form at hospital discharge, transfer, or death. Information on the demographic and health characteristics, pregnancy, delivery, and maternal and perinatal outcomes of individual women were obtained from medical records. Data were then entered onto a web-based data management system.

Study population and variables

The key independent variable was education level, by quartiles created using the educational attainment variable in the survey, which collected years of formal education as a continuous variable. Initially, the database was examined and inconsistencies were addressed. The number and percentage of women by availability of the education variable was examined by country (Table S1). There was wide variation in the ranges of missing values, from <5% to more than 10%, and therefore we excluded countries if they had more than 10% of missing data for this variable. Education quartiles were developed for each country based on the years of formal education collected in the survey in each country (Table S2). The first quartile (Q1 or bottom 25%) was defined as the quartile with the lowest education, and the fourth quartile (Q4 or top 25%) was defined as the highest-educated quartile, using the XTILE function in STATA/SE 12.0 (Stata Corp LP, College Station, TX, USA). The highest quartile (top 25%) served as the reference group in all analyses performed.

According to the Human Development Index (HDI), countries were classified by the World Bank into four groups (very high, high, medium, and low), based on quartiles, thereby reducing the level of variation within each group, as shown in Table S3.[15] This index, first introduced in 1990, measures social and economic development by combining indicators of life expectancy, educational attainment, and income into a composite index.[15] As a result of missing data (>10% on education), Argentina and Japan were excluded, leaving Qatar by itself in the very high HDI category. We merged the very high and high groups to avoid a category containing just a single country. The background characteristics of the women included in the analyses were age, marital status, and number of pregnancies. The facility capacity index score was defined as the total score of essential and additional services provided by the selected health facilities, as explained elsewhere.[12,16]

Severe maternal outcomes were defined as maternal deaths and maternal near misses, identified by clinical, laboratory, and management markers. The variables related to access to healthcare facilities were defined as the presence of any organ dysfunction upon arrival or within 24 hours and dead upon arrival or within 24 hours.

Complications included in our analysis were haemorrhage, infections, hypertensive disorders, and complications related to abortion, ectopic pregnancy, and anaemia. Coverage of interventions (prophylactic oxytocin, therapeutic oxytocin, magnesium sulphate for eclampsia, prophylactic antibiotics for caesarean section, and parenteral antibiotics

for sepsis and systemic infections) was assessed among women who needed these specific interventions. Furthermore, caesarean sections, including caesarean section before labour, were assessed among delivering women.

Statistical analysis

We conducted multivariable regression analyses to assess the association between education level and severe maternal outcomes, including those related to access to healthcare facilities. The models were adjusted for non-independence at the facility level, and at the individual level adverse maternal outcomes were adjusted for maternal age, marital status, number of pregnancies, institutional capacity score, and HDI score of the country. Furthermore, this model was stratified by HDI groups. $P < 0.05$ was considered to be significant. Statistical analyses were conducted using STATA/SE 12.0 (Stata Corp LP).

Pearson's chi-square trend tests were conducted, taking into account the clustering effect of the survey design, to compare the coverage of interventions, access to caesarean section, and burden of complications by education quartiles.

Results

The WHOMCS collected data on 314 623 pregnant women in 359 facilities, who were admitted regardless of gestational age. Overall, 8.3% of responses were missing on the education variable, and we excluded these data ($n = 25\ 872$). Using 10% as a threshold for missing data on education, the case-wise deletion of countries led us to omit Afghanistan, Angola, Argentina, Brazil, Cambodia, Japan, Sri Lanka, and Uganda ($n = 69\ 626$). Analyses were conducted on 219 124 women from 261 facilities in 21 countries, all of which had ≤5% missing data on the education variable.

Table 1 summarises the background characteristics of the study population, classified by HDI groups. The majority of our study population was between the ages of 20 and 34 years (79%), with a partner (91%), and having had three or fewer pregnancies (81.6%). In our study population, 13.6% of the women had no education, with 26.4% of the women with no education being in the low HDI group. In terms of adverse maternal outcomes, women in low HDI group countries experienced the highest percentage of maternal near miss and maternal deaths: 1.1 and 0.28%, respectively.

When we analysed the adverse maternal outcomes by the education levels of the women (Table 2), women in the lowest quartile (Q1) had consistently higher odds of experiencing severe maternal outcomes overall, as well as maternal near miss and maternal death. In the adjusted multivariable model, these associations remained significant for severe maternal outcomes (adjusted odds ratio, aOR, 2.07; 95% confidence interval, 95% CI, 1.46–2.95; $P < 0.001$), maternal near miss (aOR 1.80; 95% CI 1.25–2.57; $P < 0.001$), and maternal death (aOR 5.62; 95% CI 3.45–9.16; $P < 0.001$). In the adjusted model, the variables related to access to healthcare facilities showed that the odds of the presence of any organ dysfunction upon arrival or within 24 hours was twice as likely among women in the lowest quartile (Q1) versus women in the highest quartile (Q4) (aOR 2.06; 95% CI 1.36–3.10; $P < 0.001$). Furthermore, the women in the lowest education quartile (Q1) were more than five times as likely to die upon arrival, or within the first 24 hours of arrival, at a hospital than the women in the highest quartile (aOR 5.43; 95% CI 2.59–11.39; $P < 0.001$).

Table 3 shows the association between adverse maternal outcomes and educational level stratified by HDI groups. When stratified by HDI groups, education level was not significantly associated with experiencing severe maternal outcomes in the higher HDI countries. In contrast, for women in the lowest education quartile (Q1) living in countries classified under medium and low HDI groups, the odds of experiencing a severe maternal outcome were more than twice those of the women in the highest education quartile (Q4): aOR 2.36 (95% CI 1.33–4.17) and aOR 2.65 (95% CI 1.54–2.57), respectively. As shown in Table 3, these associations remain significant after adjustment for the other adverse maternal outcomes as well as for the indicators associated with access to healthcare facilities.

The burden of complications was highest among the women in the lowest education quartile (Q1). The women in this group accounted for 42% of haemorrhage cases, 44% of hypertensive disorders, 41% of infections, 48% of complications related to abortion or ectopic pregnancy, 41% of anaemia, and 42% of the other complications reported (Figure 1).

Table 4 summarises the coverage of interventions among women who needed them by education level. There were no statistically significant differences among women in different education levels for prophylactic antibiotics for caesarean section; however, therapeutic oxytocin for the treatment of postpartum haemorrhage and parenteral antibiotics for systemic infections had a downwards trend towards the highest education quartile ($P = 0.007$ and 0.02, respectively). The probability that a woman received magnesium sulphate for eclampsia significantly increased as education level increased ($P = 0.001$). When adjusted for other factors included in our multivariable modelling, only the association between magnesium sulphate coverage for eclampsia and higher levels of education remained significant (Q1 aOR 0.65; 95% CI 0.53–0.80; $P < 0.001$), whereas the association for the other groups attenuated. As shown in Table 5, among women in the study population who delivered by caesarean section, 27.2% of the women in the

Table 1. Background characteristics of the study population and adverse maternal outcomes, classified by HDI groups (n = 219 124)

	HDI groups 1 and 2 (very high/high) *n* (%)	HDI group 3 (medium) *n* (%)	HDI group 4 (low) *n* (%)	Total *n* (%)
Age				
<20 years	7224 (15.7)	7522 (7.7)	7848 (10.3)	22 594 (10.3)
20–34 years	32 365 (70.5)	81 089 (83.4)	59 657 (78.5)	173 111 (79.0)
≥35 years	6288 (13.7)	8506 (8.8)	8327 (11.0)	23 211 (10.6)
Missing	58 (0.1)	60 (0.1)	180 (0.2)	298 (0.1)
Marital status				
Without a partner	5831 (12.7)	8382 (8.6)	5164 (6.8)	19 377 (8.8)
With a partner	40 034 (87.2)	88 683 (91.3)	70 620 (92.9)	199 337 (91.0)
Missing	70 (0.1)	112 (0.1)	228 (0.3)	410 (0.2)
Number of pregnancies				
1 pregnancy	15 455 (33.7)	39 759 (40.9)	26 516 (34.9)	81 730 (37.3)
2–3 pregnancies	21 150 (46.0)	45 277 (46.6)	30 654 (40.3)	97 081 (44.3)
>3 pregnancies	9326 (20.3)	12 128 (12.5)	18 830 (24.8)	40 284 (18.4)
Missing	4 (0.01)	13 (0.01)	12 (0.02)	29 (0.01)
Years of formal education				
No education	695 (1.5)	8933 (9.2)	20 055 (26.4)	29 683 (13.6)
Primary (1–6 years)	6768 (14.7)	13 842 (14.2)	9810 (12.9)	30 420 (13.9)
Lower secondary (7–9 years)	45 521 (20.8)	20 573 (21.2)	14 025 (18.4)	45 521 (20.8)
Upper secondary (10–12 years)	72 811 (33.2)	34 277 (35.3)	22 100 (29.1)	72 811 (33.2)
Tertiary (>12 years)	40 689 (18.6)	19 552 (20.1)	10 022 (13.2)	40 689 (13.6)
Missing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Years of schooling by ranges				
Quartile 1 (Lowest)	18 386 (40.0)	25 857 (26.6)	20 055 (26.4)	60 103 (27.4)
Quartile 2	9822 (21.4)	33 132 (34.1)	21 770 (28.6)	71 144 (32.5)
Quartile 3	6612 (14.4)	18 636 (19.2)	24 165 (31.8)	47 188 (21.5)
Quartile 4 (Highest)	11 115 (24.2)	19 552 (20.1)	10 022 (13.2)	40 689 (18.6)
Facility capacity index: mean (SD)	67.3 (20.5)	58.5 (14.6)	49.5 (15.0)	57.2 (17.4)
Severe maternal outcomes				
No	45 550 (99.2)	96 554 (99.4)	74 993 (98.7)	217 097 (99.1)
Yes	385 (0.8)	623 (0.6)	1019 (1.3)	2027 (0.9)
Maternal near miss				
No	45 568 (99.2)	96 683 (99.5)	75 206 (98.9)	217 457 (99.2)
Yes	367 (0.8)	494 (0.5)	806 (1.1)	1667 (0.8)
Maternal death				
No	45 917 (99.96)	97 048 (99.87)	75 799 (99.72)	218 764 (99.84)
Yes	18 (0.04)	129 (0.13)	213 (0.28)	360 (0.16)

lowest education quartile (Q1) had a caesarean section, compared with 40.9% of the women in the highest education quartile (Q4) ($P < 0.001$). The same trend was observed for caesarean sections conducted before labour began: 9.8 versus 17.9% ($P < 0.001$). When adjusted for other factors included in our multivariable modelling, both of these associations remained significant (results not shown).

Discussion

Main findings

Our study showed that lower levels of maternal education are associated with women experiencing severe maternal outcomes, including maternal near miss and death. This relationship was stronger in lower HDI countries. Moreover, these women were more likely to present at healthcare facilities with worse health status compared with women with higher education levels. Additionally, we demonstrated that a number of interventions, such as coverage of magnesium sulphate for eclampsia and caesarean section, were more likely to be provided to women with higher education levels.

Strengths and limitations of the study

The WHOMCS is currently the largest study that has been conducted to explore the prevalence of severe maternal outcomes (including near-miss cases), using standardised

Table 2. Unadjusted and adjusted odds of adverse maternal outcomes, by education quartiles

	Number of women	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Adverse maternal outcomes			
Severe maternal outcomes (*n* = 191 804)			
Education Q4 (highest)	34 403	1.00	1.00
Education Q3	38 625	1.34 (0.95–1.89)	1.48 (1.05–2.07)*
Education Q2	41 219	1.21 (0.83–1.77)	1.20 (0.81–1.74)
Education Q1 (lowest)	77 557	2.10 (1.48–2.97)***	2.07 (1.46–2.95)***
Maternal near miss (*n* = 191 804)			
Education Q4 (highest)	34 403	1.00	1.00
Education Q3	38 625	1.27 (0.88–1.85)	1.40 (0.98–2.00)
Education Q2	41 219	1.11 (0.74–1.66)	1.09 (0.74–1.60)
Education Q1 (lowest)	77 557	1.82 (1.26–2.63)***	1.80 (1.25–2.57)
Maternal death (*n* = 191 804)			
Education Q4 (highest)	34 403	1.00	1.00
Education Q3	38 625	1.96 (1.12–3.41)*	2.43 (1.42–4.18)***
Education Q2	41 219	2.17 (1.20–3.92)*	2.51 (1.33–4.74)**
Education Q1 (lowest)	77 557	4.67 (2.83–7.68)***	5.62 (3.45–9.16)***
Adverse maternal outcomes related to access to a healthcare facility			
Presence of any organ dysfunction upon arrival or within 24 hours (*n* = 14 929)			
Education Q4 (highest)	2503	1.00	1.00
Education Q3	3057	1.11 (0.73–1.69)	1.21 (0.79–1.85)
Education Q2	3127	1.45 (0.98–2.14)	1.48 (1.01–2.20)*
Education Q1 (lowest)	6242	2.07 (1.38–3.09)***	2.06 (1.36–3.10)***
Dead at arrival or within 24 hours (*n* = 14 931)			
Education Q4 (highest)	2502	1.00	1.00
Education Q3	3058	1.72 (0.77–3.83)	1.99 (0.89–4.48)
Education Q2	3130	2.50 (1.12–4.50)*	2.45 (1.16–5.19)*
Education Q1 (lowest)	6241	5.34 (2.58–11.05)***	5.43 (2.59–11.39)***

The unadjusted odds ratios were adjusted for any clustering effect at the facility level. The adjusted odds ratios were adjusted for: maternal age; marital status; number of pregnancies, including current pregnancy; institutional capacity score; human development index of the country; and clustering at the facility level.
Levels of significance: *$P < 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

methodology of collection and analysis of data across 29 countries, which provided a large enough sample size, including a number of key variables, to conduct these analyses. Therefore, we were able to explore associations never studied before, such as severe maternal morbidity (near miss) and adverse maternal outcomes upon arrival at a healthcare facility, stratified by countries in different levels of economic and social development. Furthermore, instead of categorising education in terms of primary, secondary, etc., our analysis took into account the country-level differences by developing education quartiles for each country based on the years of formal education in each country.

There are several limitations. WHOMCS includes data that are limited to healthcare facilities; therefore, our results cannot be generalisable to the total populations in our study countries, where substantial proportions of women deliver at home. Even though we adjusted our models for a number of demographic and reproductive health-related variables, we did not have any information on some important factors such as economic status, place of residence (urban/rural), and history of antenatal care, contributing to residual confounding. We were therefore unable to sort out all of the potential factors leading to both poor educational attainment and higher adverse maternal health outcomes. Future analyses might also consider exploring the interactions between young age, nulliparity, and lower levels of education.

Interpretation

Health inequity is closely related to social determinants of health, where the burden of ill health is greatest in lower socio-economic groups.[17] A policy analysis highlighted that in six countries with marked progress in reducing maternal mortality, effective policies included investing in women's education.[1] In our study, the women in the lowest education

Table 3. Adjusted odds of adverse maternal outcomes, by education quartiles and Human Development Index (HDI)

	Very high/high HDI *n* = 32 692 Adjusted odds ratio (95% CI)	Medium HDI *n* = 86 606 Adjusted odds ratio (95% CI)	Low HDI *n* = 71 984 Adjusted odds ratio (95% CI)
Adverse maternal outcomes			
Severe maternal outcomes			
Education Q4 (highest)	1.00	1.00	1.00
Education Q3	0.76 (0.32–1.81)	1.91 (1.24–2.96)**	1.67 (1.01–2.75)*
Education Q2	0.76 (0.44–1.30)	1.90 (1.10–3.28)*	1.08 (0.57–2.05)
Education Q1 (lowest)	0.98 (0.50–1.93)	2.36 (1.33–4.17)**	2.65 (1.54–2.57)***
Maternal near miss			
Education Q4 (highest)	1.00	1.00	1.00
Education Q3	0.77 (0.33–1.79)	1.86 (1.16–2.99)**	1.47 (0.85–2.56)
Education Q2	0.79 (0.46–1.33)	1.63 (0.94–2.82)	0.93 (0.46–1.86)
Education Q1 (lowest)	0.98 (0.52–1.85)	1.82 (1.02–3.25)*	2.22 (1.22–4.04)**
Maternal death			
Education Q4 (highest)	1.00	1.00	1.00
Education Q3	0.73 (0.04–13.5)	2.09 (0.82–5.35)	3.19 (1.52–6.67)**
Education Q2	Omitted	3.54 (1.26–9.93)*	2.39 (1.07–5.35)*
Education Q1 (lowest)	1.77 (0.17–18.7)	6.09 (2.50–14.88)***	6.31 (3.45–11.51)***
	High HDI *n* = 2762	**Medium HDI *n* = 6749**	**Low HDI *n* = 5388**
Adverse maternal outcomes related to access to a healthcare facility			
Presence of any organ dysfunction upon arrival or within 24 hours			
Education Q4 (highest)	1.00	1.00	1.00
Education Q3	0.53 (0.18–1.58)	1.66 (0.91–3.06)	1.59 (0.94–2.69)
Education Q2	0.87 (0.44–1.71)	2.20 (1.14–4.24)*	1.48 (0.83–2.65)
Education Q1 (lowest)	0.71 (0.27–1.88)	3.80 (2.05–7.04)***	2.22 (1.36–3.62)**
Dead upon arrival or within 24 hours			
Education Q4 (highest)	1.00	1.00	1.00
Education Q3	0.47 (0.02–10.71)	1.81 (0.31–10.57)	3.07 (1.10–8.57)*
Education Q2	Omitted	5.77 (1.19–28.00)*	2.17 (0.92–5.15)
Education Q1 (lowest)	0.70 (0.06–8.32)	11.7 (2.57–53.50)***	5.06 (2.00–12.77)***

The models were adjusted for non-independence at the facility level, and at the individual level the adverse maternal outcomes were adjusted for: maternal age; marital status; number of pregnancies, including current pregnancy; and institutional capacity score.
Levels of significance: *$P < 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

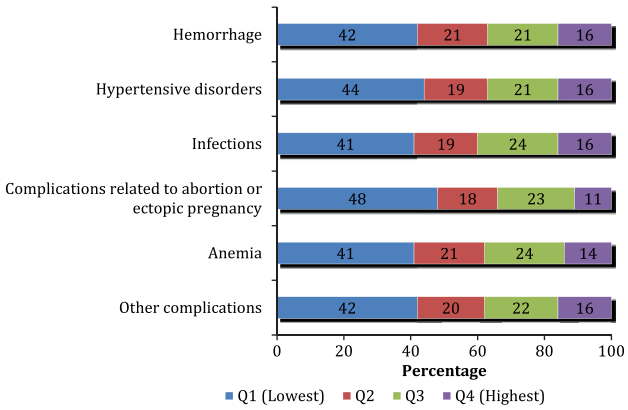

Figure 1. Burden of complications among women, based on their education levels (Q1, lowest; Q4, highest).

quartiles were significantly more likely to experience severe maternal outcomes, including maternal death. These findings were supported by a recent study from Bangladesh, where female education was a strong predictor of maternal mortality.[18] Our findings were also consistent with the results from the WHO Global Survey,[12] and showed a stronger relationship between educational levels and severe maternal outcomes, especially when comparing the lowest and highest educational quartiles within middle and low HDI country groups.

One of the possible underlying reasons for this strong relationship between education level and severe maternal outcomes is that less educated women might experience longer primary and secondary delays in deciding to seek and reach care, respectively.[19,20] Our current analysis

Table 4. Coverage of interventions among women who needed them, by education quartiles

Coverage of interventions	Q1 (lowest)% (95% CI)	Q2% (95% CI)	Q3% (95% CI)	Q4 (highest)% (95% CI)	Total	*P*
Prophylactic oxytocin (*n* = 218 012)	94.2 (92.2–95.8)	93.2 (90.2–95.3)	91.0 (86.5–94.1)	94.2 (91.4–96.2)	93.3 (90.9–95.1)	0.03
Therapeutic oxytocin (*n* = 3056)	89.3 (86.0–91.8)	89.6 (85.4–87.1)	82.5 (76.8–87.1)	81.5 (71.8–88.3)	86.7 (83.0–89.7)	0.007
$MgSO_4$ for eclampsia (*n* = 779)	88.8 (84.8–91.8)	82.9 (74.0–89.2)	70.8 (57.3–81.4)	93.4 (80.5–98.0)	85.0 (79.2–89.4)	0.001
Prophylactic antibiotics for caesarean section (*n* = 67 732)	86.5 (81.4–90.4)	88.3 (84.0–91.5)	85.0 (77.1–90.5)	90.5 (87.1–93.1)	87.4 (83.4–90.6)	0.12
Parenteral antibiotics for systematic infections (*n* = 628)	83.8 (74.6–90.2)	87.7 (74.1–94.7)	68.2 (40.9–86.9)	65.4 (40.2–84.1)	76.6 (55.8–89.4)	0.02

Coverage indicators were calculated as the proportion of the target population who received the intervention.

Table 5. Caesarean section rates among women delivering at study facilities, by education quartiles (*n* = 218 580)

Interventions	Education quartiles					
	Q1 (lowest)% (95% CI)	Q2% (95% CI)	Q3% (95% CI)	Q4 (highest)% (95% CI)	Total	*P*
Caesarean section	27.2 (25.0–29.6)	30.2 (27.7–32.9)	30.9 (27.7–34.1)	40.9 (37.5–44.4)	31.0 (28.7–33.4)	<0.001
Caesarean section before labour	9.8 (8.4–11.3)	11.7 (10.1–13.6)	12.5 (10.8–14.4)	17.9 (15.3–20.9)	12.2 (10.8–13.7)	<0.001

demonstrates that less educated women are indeed more likely to arrive at hospital presenting with organ dysfunction or death; however, a recent systematic review reports that focusing on the first two delays may mask the fact that many health facilities in developing countries are still chronically under-resourced and unable to effectively manage severe obstetric complications.[21] In our study, which included several types of healthcare facility in each country, the results further suggest that there is disparity between lower and higher education quartiles in terms of the coverage of evidence-based interventions, such as magnesium sulphate for the treatment of eclampsia, or a caesarean section, which in many cases is a life-saving surgery, indicating delays in receiving timely quality of care while at the healthcare facility. Therefore, assessing and improving the quality of care and management for these cases using tools such as the WHO Maternal Near-Miss Approach, or the Maternal Death Surveillance and Response, will be crucial.[13,22,23]

We stratified the analyses by HDI groups to further explore education level as an inequity factor in different settings. The level of education ceased to be a significant factor in relation to adverse maternal outcomes in the higher HDI countries. In contrast, the associations got stronger among middle and lower HDI level countries. This suggests that in countries with higher economic and social development, functioning healthcare systems can compensate for the inequality associated with educational attainment, whereas in less developed countries it still causes a discrepancy in terms of outcomes, access to services, and coverage of interventions such as caesarean section. It should be noted here that we did not have information on the indications for caesarean sections or emergency caesarean section status defined by decision or operation time.[24] Education is a marker of social development and inclusion, and although it is difficult to disentangle the intrinsic contribution of education to improved maternal outcomes in our analysis, it strongly indicates that less advantageous populations face additional barriers in reaching high-quality care.

Conclusion

Our study demonstrates that in countries that have poorer markers of social and economic development, education is a significant factor contributing to the disparities experienced by women delivering in healthcare facilities. It underlines that the countries with strong healthcare systems, which are ready to provide integrated, continuous, high-quality care, both as routine and in an emergency, are more likely to compensate for adverse outcomes faced by women with lower levels of education. In addition to ensuring universal education as a key policy, low-cost, effective interventions implemented within strengthened healthcare systems are needed to prevent maternal morbidity and mortality.

Disclosure of interests
We declare that we have no conflicts of interest.

Contribution to authorship
OT, JPS, MJH, CAS, and THO conceptualised the article and the analysis plan. OT conducted the analyses in collaboration with MJH and JPS, and OT wrote the first draft of the article. JPS, MJH, CAS, THO, JPV, GT, DQH, AMG, and LS contributed to the interpretation of the results and editing of the article. All authors read and approved the final version of the article.

Details of ethics approval
The UNDP/UNFPA/UNICEF/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP) Specialist Panel on Epidemiological Research reviewed and approved the study protocol for technical content. This study was approved by the WHO Ethical Review Committee and the relevant ethical clearance mechanisms in all countries (protocol ID, A65661; date of approval, 27 October 2009).

Funding
This study was financially supported by: the UNDP/UNFPA/UNICEF/WHO/World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP); World Health Organization (WHO); United States Agency for International Development (USAID); Ministry of Health, Labour and Welfare of Japan; and Gynuity Health Projects. The sponsors had no role in data collection, analysis, or interpretation of the data, the writing of the report, or the decision to submit for publication. All authors had access to the analysis plan, the outputs of that analysis, and could see the data if they wished to do so. All authors participated in the final discussion and approved the submission.

Acknowledgements
The authors wish to thank all members of the WHO Multicountry Survey on Maternal and Newborn Health Research Network, including regional and country coordinators, data collection coordinators, facility coordinators, data collectors, and all of the staff at participating facilities who made the survey possible.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Number and percentage of women by availability of the education variable by country.

Table S2. Sample sizes and ranges of years of education calculated by country and HDI groups.

Table S3. Country grouping by HDI. ■

References

1 Mbizvo MT, Say L. Global progress and potentially effective policy responses to reduce maternal mortality. *Int J Gynaecol Obstet* 2012;119 (Suppl 1):S9–12.
2 World Health Organization, UNICEF, UNFPA, The World Bank. *Trends in Maternal Mortality: 1990 to 2010*. Geneva, Switzerland: WHO, UNICEF, UNFPA, and The World Bank Estimates, 2012.
3 Filippi V, Ronsmans C, Campbell OM, Graham WJ, Mills A, Borghi J, et al. Maternal health in poor countries: the broader context and a call for action. *Lancet* 2006;368:1535–41.
4 Ronsmans C, Graham WJ. Maternal mortality: who, when, where, and why. *Lancet* 2006;368:1189–200.
5 Albert C, Davia M. Education is a key determinant of health in Europe: a comparative analysis of 11 countries. *Health Promot Int* 2011;26:163–70.
6 Luo ZC, Wilkins R, Kramer MS. Effect of neighbourhood income and maternal education on birth outcomes: a population-based study. *CMAJ* 2006;174:1415–20.
7 Basu AM, Stephenson R. Low levels of maternal education and the proximate determinants of childhood mortality: a little learning is not a dangerous thing. *Soc Sci Med* 2005;60:2011–23.
8 Caldwell J. Education as a factor in mortality decline: an examination of Nigerian data. *Popul Stud* 1979;33:395–413.
9 Caldwell JC. The cultural, social and behavioral determinants of health in the Third World. *Soc Sci Med* 1993;36:125–35.
10 Govindasamy P, Ramesh BM. *Maternal Education and the Utilization of Maternal and Child Health Services in India*. National Family Health Survey Subject Reports. Number 5. International Institute for Population Sciences, Mumbai, India, Macro International Inc, Maryland, USA.
11 McAlister C, Baskett T. Female education and maternal mortality: a worldwide survey. *J Obstet Gynaecol Can* 2006;28:983–90.
12 Karlsen S, Say L, Souza JP, Hogue CJ, Calles DL, Gulmezoglu AM, et al. The relationship between maternal education and mortality among women giving birth in health care institutions: analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health. *BMC Public Health* 2011;11:606.
13 Souza JP, Gulmezoglu AM, Vogel J, Carroli G, Lumbiganon P, Qureshi Z, et al. Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study. *Lancet* 2013;381:1747–55.
14 Souza JP, Gulmezoglu AM, Carroli G, Lumbiganon P, Qureshi Z, WHOMCS Research Group. The world health organization multicountry survey on maternal and newborn health: study protocol. *BMC Health Serv Res* 2011;11:286.
15 United Nations Development Programme. Human Development Index (HDI). Available from: [http://hdr.undp.org/en/statistics/hdi/]. Accessed 9 July 2013.
16 Vogel JP, Souza JP, Gulmezoglu AM, Mori R, Morisaki N, Lumbiganon P, et al., on behalf of the WHO Multicountry Survey on Maternal and Newborn Health Research Network. Maternal complications and perinatal mortality: findings of the World Health Organization Multicountry Survey on Maternal and Newborn Health. *BJOG* 2014;121(Suppl.1):76–88.
17 Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. *Am J Public Health* 1992;82:816–20.

18 Chowdhury ME, Ahmed A, Kalim N, Koblinsky M. Causes of maternal mortality decline in Matlab, Bangladesh. *J Health Popul Nutr* 2009;27:108–23.
19 Thaddeus S, Maine D. Too far to walk: maternal mortality in context. *Soc Sci Med* 1994;38:1091–110.
20 Gabrysch S, Campbell OM. Still too far to walk: literature review of the determinants of delivery service use. *BMC Pregnancy Childbirth* 2009;9:34.
21 Knight HE, Self A, Kennedy SH. Why are women dying when they reach hospital on time? A systematic review of the 'third delay'. *PLoS ONE* 2013;8:e63846.
22 World Health Organization. *Evaluating the Quality of Care for Severe Pregnancy Complications: The WHO Near-Miss Approach for Maternal Health*. Geneva: WHO; 2011.
23 Hounton S, De Bernis L, Hussein J, Graham WJ, Danel I, Byass P, et al. Towards elimination of maternal deaths: maternal deaths surveillance and response. *Reprod Health* 2013;10:1.
24 Tuncalp O, Stanton C, Castro A, Adanu R, Heymann M, Adu-Bonsaffoh K, et al. Measuring coverage in MNCH: validating women's self-report of emergency cesarean sections in Ghana and the Dominican Republic. *PLoS ONE* 2013;8:e60761.