

Commentary

An Ecologic Analysis of Maternal Mortality Ratios

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Ecologic associations have provided the basis for numerous programs to reduce maternal mortality. Shiffman (2000:274) recently suggested that room for optimism exists regarding reducing maternal mortality because “only a portion of the variance in national maternal mortality” is associated with indices of national wealth, and because interventions such as improving “women’s education levels and the proportion of deliveries attended by trained health personnel” may reduce maternal mortality. Ecologic associations, however, do not constitute causal evidence because they do not account for multiple contextual factors without which there might be no association.

Some have suggested that the causes of maternal mortality are many and may require more comprehensive solutions than those Shiffman proposes (Liljestrand 1999; Ravindran and Berer 1999). The failure of single solutions, including the training of traditional birth attendants and promotion of antenatal care, to show clear reductions in maternal mortality has not reduced optimism concerning the selection and large-scale implementation of approaches that ecologic data are used to justify. We argue that the indices ecologically associated with maternal mortality ratios are highly intercorrelated and do not necessarily indicate that improving one aspect of the health system, such as the skills of delivery attendants, will, in fact, reduce maternal mortality.

Methods

In 1993, the authors conducted an ecologic analysis of the correlates of maternal mortality that are commonly

cited in the literature (Loudon 1992; Maine 1992; Tinker et al. 1993) from data available from UNICEF and WHO (UNICEF 1993; WHO 1993) to evaluate the potential of promising interventions. Indices such as antenatal care, contraceptive prevalence, and other correlates were included in the analysis because they were perceived potentially to affect pregnancy and pregnancy outcome (Loudon 1992; Maine 1992; Tinker et al. 1993). The potential effectiveness of some of these correlates was questioned (Rooney 1992; Koblinsky et al. 1999).

Our 1993 analysis included data from the 11 countries for which complete data were available for a national estimate of maternal mortality ratios (MMR), receipt of antenatal care, tetanus toxoid immunization, contraceptive prevalence, adult literacy, gross national product (GNP), skilled attendant at delivery (“skilled attendants” is defined as “physicians, nurses, midwives, or primary health-care workers trained in midwifery skills”), and institutional delivery.

Recently, we have updated this analysis with data published by UNICEF in 1999, prior to its use of statistically derived MMRs. Data for 84 countries for the same variables were available for analysis. We used the same indices in these new analyses with the exclusion of GNP. The analysis was updated using UNICEF data because using other sources (such as the Demographic and Health Surveys) would have reduced the sample by 20 percent or more.

The relationship of each variable was fit to the MMR without weighting the data for country populations. We determined that linear fit best described the relationship of maternal mortality with literacy, tetanus toxoid coverage, antenatal care, and the proportion of deliveries with skilled attendants, whereas a log transformation best described the relationship between contraceptive prevalence and MMR. An exponential transformation best described that of institutional deliveries and MMR. We conducted backward stepwise linear and fitted regression analyses for contraceptive prevalence and in-

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stitutional deliveries using these variables to predict the maternal mortality ratio, allowing each variable not significantly associated with MMR (at the $p>0.05$ level) to be deleted, first deleting the least important, then the next least important, and so on.

Results

The descriptive statistics for these variables, and for the countries' total populations, are presented in Table 1. The table shows the range of values for data from the countries included in the analysis, demonstrating that the results have a wide range of representation. The maternal mortality ratio was inversely associated with all of the variables included in the analyses, and the remaining variables were all positively associated with one another except for tetanus toxoid immunization (see Table 2).

Five models were calculated in the unweighted linear regression analyses, with the most complete model accounting for 80 percent of the total variance (data not shown) and the model excluding the most variables accounting for 79 percent of the total variance (R^2). The final regression model contained two variables, contraceptive prevalence ($b = -6.54 - \text{s.e. } 1.60; p<0.001$) and skilled attendant during delivery ($b = -11.64 - 1.35; p<0.001$). Similarly, five unweighted regression models with fitted terms for contraceptive prevalence and institutional delivery were calculated, the full model accounting for 84 percent of the variance and the final model, including only the linear term for skilled attendant at delivery ($b = -10.08 - 1.19; p<0.001$) and the log term for contraceptive prevalence ($b = -199.27 - 30.45; p<0.001$), accounting for 83 percent of the variance.

The analyses clearly indicate that a greater proportion of deliveries with a skilled attendant and higher contraceptive prevalence rates are both associated with lower national maternal mortality ratios.

Discussion

These associations are the basis for UNICEF's more recent derivation of maternal mortality ratios, in which the proportion of deliveries with skilled attendants and the TFR were used for countries without a national estimate of MMR (WHO 1996). The models consistently favored inclusion of skilled attendants at delivery and, therefore, excluded the highly correlated variable, institutional delivery. Institutional delivery without skilled attendants is probably exceptional. The exclusion of antenatal care from the final stepwise regression models indicates the

Table 1 Average levels and variation of indices, 84 countries

Indicator	Standard			
	Mean	deviation	Minimum	Maximum
MMR (per 100,000 live births)	584	518	29	1,800
Adult literacy (percent)	65	23	14	98
Tetanus-toxoid immunization (percent)	53	25	10	100
Received antenatal care (percent)	69	25	8	100
Contraceptive prevalence (percent)	35	24	1	84
Skilled attendant at delivery (percent)	57	29	2	100
Deliveries in health facilities (percent)	51	30	2	99
Total population (in thousands)	49,028	168,990	174	1,232,083

Source: UNICEF (1999).

bivariate association between antenatal care and maternal mortality and is mediated by the association of MMR with skilled attendant at delivery and contraceptive prevalence. This result is believable because the usual components of antenatal care may not reduce maternal mortality effectively. For example, in a national study of 78 birthing centers in the United States, Rooks et al. (1989) demonstrated that prenatal risk assessment was not effective at preventing maternal deaths or at ensuring the rational use of health services. In that study, 15 percent of women were identified as being at high risk during the prenatal period and were, therefore, ineligible to deliver in birthing centers. Of these women, 85 percent had normal labor and deliveries. Conversely, 15 percent of the 85 percent of women identified as being at low risk and who were, therefore, eligible to deliver in birthing centers experienced last-minute obstetric complications that required referral and transport to a hospital for care.

The ecologic results, however, do not necessarily mean that placing skilled attendants in a community would reduce its maternal mortality. Experience has shown, for instance, that midwives with community-based posts in Indonesia and clinic-based posts in Vietnam who received intensive training in life-saving skills were still not capable of managing obstetric emergencies in practice, possibly because of a low volume of deliveries and even lower numbers of complicated deliveries (Sloan et al. 1998; Starrs 1998). For example, if a skilled community-based attendant assists at five deliveries a month, she would assist at 60 deliveries per year. If, as is commonly hypothesized (Starrs 1998), 15 percent of women experience peripartum emergency conditions, and the causes of maternal death were similar to the WHO estimates for developing countries, the assistant would attend nine emergency deliveries a year, including two to three cases of postpartum hemorrhages, one case each of sepsis, toxemia, and postabortion complication, possibly one case of obstructed labor, and two to three other emergency conditions. Devoid of supportive clinical interaction with colleagues and frequent su-

Table 2 Pearson product moment bivariate correlations of indices of maternal mortality ratios, 84 countries

Variable	Literacy (%)	TT (%)	ANC (%)	CP (%)	Skilled attendant at delivery (%)	Institutional delivery (%)	GNP
MMR (deaths per 100,000 live births)	-0.79 (0.00)	-0.29 (0.00)	-0.59 (0.00)	-0.77 (0.00)	-0.86 (0.00)	-0.78 (0.00)	-0.46 (0.00)
Literate (percent)	1.00	0.25 (0.02)	0.70 (0.00)	0.77 (0.00)	0.82 (0.00)	0.77 (0.00)	0.45 (0.00)
Tetanus toxoid immunization (TT) (percent)		1.00	0.20 (0.07)	0.27 (0.01)	0.26 (0.02)	0.22 (0.04)	0.05 (0.64)
Received antenatal care (ANC) (percent)			1.00	0.46 (0.00)	0.73 (0.00)	0.76 (0.00)	0.41 (0.00)
Contraceptive prevalence (CP) (percent)				1.00	0.73 (0.00)	0.67 (0.00)	0.35 (0.00)
Skilled attendant at delivery (percent)					1.00	0.92 (0.00)	0.56 (0.00)
Institutional deliveries (percent)							0.59 (0.00)

GNP = Gross national product.

Source: UNICEF (1999).

pervision, even this relatively high volume of community-based deliveries is unlikely to maintain the skilled attendants' emergency obstetric skills.

Similarly, increasing contraceptive prevalence could reduce maternal deaths while increasing the maternal mortality ratio. If new contraceptive acceptors were relatively affluent women, who would be most likely to deliver in hospitals and receive timely emergency care when needed, the number of maternal deaths in the numerator would remain virtually unchanged, whereas the number of live births in the denominator could be substantially reduced, thus raising the ratio.

Although literacy was dropped out of all analyses in progressive models, the correlation between literacy and both skilled attendant at delivery ($r = 0.82$; $p = 0.000$) and delivery in a health-care facility ($r = 0.77$; $p = 0.000$) indicates that literacy mediates the use of appropriate health care. When included as the only predictive variable in the first of a four-step hierarchical regression analysis, literacy was significantly associated with the use of health services and skilled delivery attendants.

The analyses here and that presented by Shiffman (2000) are ecologic and not causal. In conjunction with evidence from Indonesia (Starrs 1998) and Vietnam (Sloan et al. 1998) and with historical evidence (Loudon 1992), they indicate, however, that in certain circumstances, such as in Vietnam, where adequate institutional support is available to women and they make use of it, the presence of skilled attendants at delivery is critical to reducing maternal mortality. Access to skilled attendants is not only a function of the availability of emergency obstetric care, but also of education and other factors such as access to transportation for which data were not available

from these sources. Likewise, the impact of improving emergency obstetric services alone may also be limited in countries such as Bangladesh, where only 5 percent of women deliver in health-care facilities (Mitra et al. 1997).

Conclusions

Aggregate data analysis is subject to ecologic fallacy, and the observed associations may not be causally related at the individual level. In the past decade, theoretical arguments have suggested the promotion of safe motherhood by means of training traditional birth attendants, by providing antenatal care, by improving women's education, and by enhancing emergency obstetric services. We found other, possibly key factors: consistent relationships between lower MMRs and national levels of contraceptive prevalence and the proportion of deliveries attended by skilled personnel. These analyses indicate that increasing the proportion of women delivering with skilled attendants merits testing for its true effectiveness in reducing maternal mortality under different conditions, including in settings where institutional delivery is rare and where delivery in primary-care clinics is common but delivery in hospitals is rare.

References

- Koblinsky, Marjorie A., Oona M.R. Campbell, J. Heichelheim. 1999. "Organizing delivery care: What works for safe motherhood?" *Bulletin of the World Health Organization* 77(5): 399-406.
- Liljestrand, Jerker. 1999. "Reducing perinatal and maternal mortality in the world: The major challenges." *British Journal of Obstetrics and Gynaecology* 106(9): 877-880.

- Loudon, Irvine. 1992. *Death in Childbirth: An International Study of Maternal Care and Maternal Mortality, 1800–1950*. Oxford: Oxford University Press.
- Maine, Deborah. 1992. *Safe Motherhood Programs: Options and Issues*. New York: Center for Population and Family Health, Columbia University School of Public Health.
- Mitra, S.N., Ahmed Al-Sabir, Anne R. Cross, and Kanta Jamil. 1997. *Bangladesh Demographic and Health Survey 1996–1997*. Calverton, MD: Macro International.
- Ravindran, T.K. Sundari and Marge Berer. 1999. "Preventing maternal mortality: Evidence, leadership, resources, action." In *Safe Motherhood Initiatives: Critical Issues*. Eds. Marge Berer and T.K. Sundari Ravindran. *Reproductive Health Matters*. Pp. 3–12.
- Rooks, Judith Pence, Norman L. Weatherby, E. Ernst, M. Kitty, S. Stapleton, David Rosen, and Allan Rosenfield. 1989. "Outcomes of care in birth centers: The national birth center study." *New England Journal of Medicine* 321(26): 1,804–1,811.
- Rooney, Cleone. 1992. *Antenatal Care and Maternal Health: How Effective Is It? A Review of the Evidence*. Geneva: World Health Organization, Division of Family Health, Maternal Health and Safe Motherhood Programme 92.4.
- Shiffman, Jeremy. 2000. "Can poor countries surmount high maternal mortality?" *Studies in Family Planning* 31(4): 274–289.
- Sloan, Nancy L., Beverly Winikoff, Paul Arthur, Andrés Calle, Goli Fassihian, Do Trong Hieu, Ana Langer, Nguyen Thi Nhu Ngoc, Ernesto Pinto, and Charlotte Quimby. 1998. *Executive Summary: The Safe Motherhood Demonstration Projects*. New York: Population Council. Pp. 12–23.
- Starrs, Anne. 1998. *The Safe Motherhood Action Agenda: Priorities for the Next Decade*. New York: Safe Motherhood Interagency Group. P. 32.
- Tinker, Anne, Marjorie A. Koblinsky, Patricia Daly, Cleone Rooney, Charlotte Leighton, Marcia Griffiths, A.A. Zahidul Huque, and Barbara Kwast. 1993. "Making Motherhood Safe." *World Bank Discussion Paper* No. 202. Washington, DC: The World Bank. Pp. 14–15.
- United Nations Children's Fund (UNICEF). 1993. *The State of the World's Children*. New York: UNICEF.
- . 1999. *The State of the World's Children 1998*. New York: UNICEF.
- World Health Organization (WHO). 1993. *Coverage of Maternity Care: A Tabulation of Available Information, Third Edition*. Geneva: World Health Organization, Family and Reproductive Health Programme 93.7.
- World Health Organization and United Nations Children's Fund. 1996. *Revised 1990 Estimates of Maternal Mortality: A New Approach by WHO and UNICEF*. Geneva: World Health Organization.