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Source: *Population and Development Review*, Vol. 10, Supplement: Child Survival: Strategies for Research (1984), pp. 25-45
Published by: Population Council
Stable URL: http://www.jstor.org/stable/2807954
Accessed: 04/10/2013 01:42

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An Analytical Framework for the Study of Child Survival in Developing Countries

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This essay proposes a new analytical framework for the study of the determinants of child survival in developing countries. The approach incorporates both social and biological variables and integrates research methods employed by social and medical scientists. It also provides for the measurement of morbidity and mortality in a single variable. The framework is based on the premise that all social and economic determinants of child mortality necessarily operate through a common set of biological mechanisms, or proximate determinants, to exert an impact on mortality.[1] The framework is intended to advance research on social policy and medical interventions to improve child survival.

Traditionally, social science research on child mortality has focused on the association between socioeconomic status and levels and patterns of mortality in populations (Figure 1A). Correlations between mortality and socioeconomic characteristics are used to generate causal inferences about the mortality determinants. Income and maternal education, for example, are two commonly measured correlates (and inferred causal determinants) of child mortality in developing country populations. Specific medical causes of death are generally not addressed by social scientists, and the mechanisms by which socioeconomic determinants operate to produce the observed mortality differentials remain largely an unexplained "black box."

Medical research focuses primarily on the biological processes of diseases, less frequently on mortality per se. The differing assumptions and methods are classified in Figure 1B. Studies of cause of death attribute mortality to specific disease processes (such as infections or malnutrition), using information obtained from death reports or clinical case records. Clinical trials assess the therapeutic effect of a particular medical technology. Field intervention studies measure the effectiveness of personal preventive measures on

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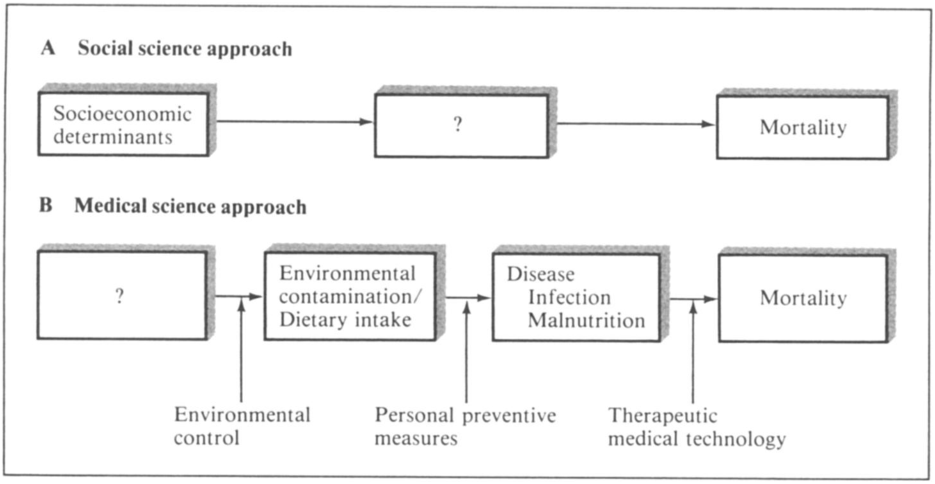
FIGURE 1 Conceptual models of social science and medical science approaches to research on child survival



levels of morbidity and mortality in a population. Epidemiological studies may define mechanisms of disease transmission in the environment—for example, the connection between environmental contamination (polluted drinking water) and disease (cholera). Intervention studies alter the environment to reduce disease transmission (as with malaria vector control). Nutrition research focuses on breastfeeding, dietary practices, and food availability as they relate to nutritional status.

The dependent variable most commonly measured in medical research is morbidity, that is, the manifestations of disease processes among survivors—usually calculated as the incidence and prevalence of disease states in a population. The ultimate consequences of disease for mortality in populations at large tend to be neglected, and socioeconomic determinants are generally ignored or dealt with only superficially.

While both the social and medical sciences have made major contributions to our understanding of child mortality in developing countries, the differing concerns and methodologies have compartmentalized such knowledge and constrained the development of potentially more useful approaches to understanding child survival. An even more critical problem is that the selection of a particular research approach usually results in policy and program recommendations biased along disciplinary lines. A new analytical approach incorporating both social and medical science methodologies into a coherent analytical framework of child survival therefore is clearly needed.

The proximate determinants framework

The development of a proximate determinants approach to the study of child survival presented here[2] is based on several premises:

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1 In an optimal setting, over 97 percent of newborn infants can be expected to survive through the first five years of life.
2 Reduction in this survival probability in any society is due to the operation of social, economic, biological, and environmental forces.
3 Socioeconomic determinants (independent variables) must operate through more basic proximate determinants that in turn influence the risk of disease and the outcome of disease processes.
4 Specific diseases and nutrient deficiencies observed in a surviving population may be viewed as biological indicators of the operations of the proximate determinants.
5 Growth faltering and ultimately mortality in children (the dependent variable) are the cumulative consequences of multiple disease processes (including their biosocial interactions). Only infrequently is a child's death the result of a single isolated disease episode.

The key to the model is the identification of a set of proximate determinants, or intermediate variables, that directly influence the risk of morbidity and mortality. All social and economic determinants must operate through these variables to affect child survival.[3] The proximate determinants are grouped into five categories:

— Maternal factors: age; parity; birth interval.
— Environmental contamination: air; food/water/fingers; skin/soil/inanimate objects; insect vectors.
— Nutrient deficiency: calories; protein; micronutrients (vitamins and minerals).
— Injury: accidental; intentional.
— Personal illness control: personal preventive measures; medical treatment.

Each of the *maternal factors* has been shown to exert an independent influence on pregnancy outcome and infant survival through its effects on maternal health. Synergism may also exist between maternal variables—for example, short birth spacing combined with young maternal age.

Environmental contamination refers to the transmission of infectious agents to children (and mothers). The four categories representing the main routes whereby infectious agents are transmitted to the human host are air—the route of spread for the respiratory and many "contact"-transmitted diseases; food, water, and fingers—the principal routes of spread for diarrheas and other intestinal diseases; skin, soil, and inanimate objects—the routes for skin infections; and insect vectors, which transmit parasitic and viral diseases.

Nutrient deficiency relates to the intake of the three major classes of nutrients—calories, protein, and the micronutrients. A critical point here is

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that the survival of children is influenced by nutrients available not only to the child but also to the mother. Maternal diet and nutrition during pregnancy affect birth weight and, during lactation, influence the quantity and nutrient quality of breastmilk.

Injury includes physical injury, burns, and poisoning. Although accidental injuries are often considered random events, their frequency and pattern in a population in fact reflect environmental risks that differ according to socioeconomic and environmental contexts. Injuries may also be intentionally inflicted, the most extreme example being infanticide.

As one component in *personal illness control,* healthy individuals take preventive measures to avoid disease. These include traditional behaviors like observing taboos, as well as modern practices such as immunizations or malaria prophylaxis. An important inclusion is the practices and the quality of care during pregnancy and childbirth. The second component in this category, medical treatment, relates to measures taken to cure diseases after they become manifest.

Figure 2 depicts a framework showing how these five groups of proximate determinants operate on the health dynamics of a population. All proximate determinates in the first four groups influence the rate of shift of healthy individuals toward sickness. The personal illness control factors influence both the rate of illness (through prevention) and the rate of recovery (through treatment). Specific states of sickness (infection or nutrient deficiency) are basically transitory: ultimately there is either complete recovery or irreversible consequences manifested by increasing degrees of permanent growth faltering (or other disability among the survivors) and/or death.[4]

A novel aspect of this conceptual model is its definition of a specific disease state in an individual as an indicator of the operation of the proximate determinants rather than as a ''cause'' of illness and death. This is not to undervalue the usefulness of etiology-specific classification of disease and death for the development of rational therapeutic and preventive interventions. Rather, the aim is to emphasize the social as well as medical roots of the problem. This in fact is the standard approach of epidemiology, which begins with a biological problem in the host and then searches for its social determinants in order to develop rational control measures. The strategic approach to child survival research implied by this framework parallels methods used in the epidemiology of the chronic diseases rather than of the acute diseases. Chronic diseases such as heart disease are typically multifactorial in causality, have long latency periods between disease exposure and manifestation, and are powerfully influenced by lifestyle and socioeconomic circumstances. There is ample evidence in the medical literature that child mortality, especially in developing countries, also possesses these attributes (Puffer and Serrano, 1975; Mata, 1978).

The proximate determinants (or the intermediate variable) approach to child survival parallels the approach used by Davis and Blake (1956) in developing an analytical framework for the study of fertility. The problems posed

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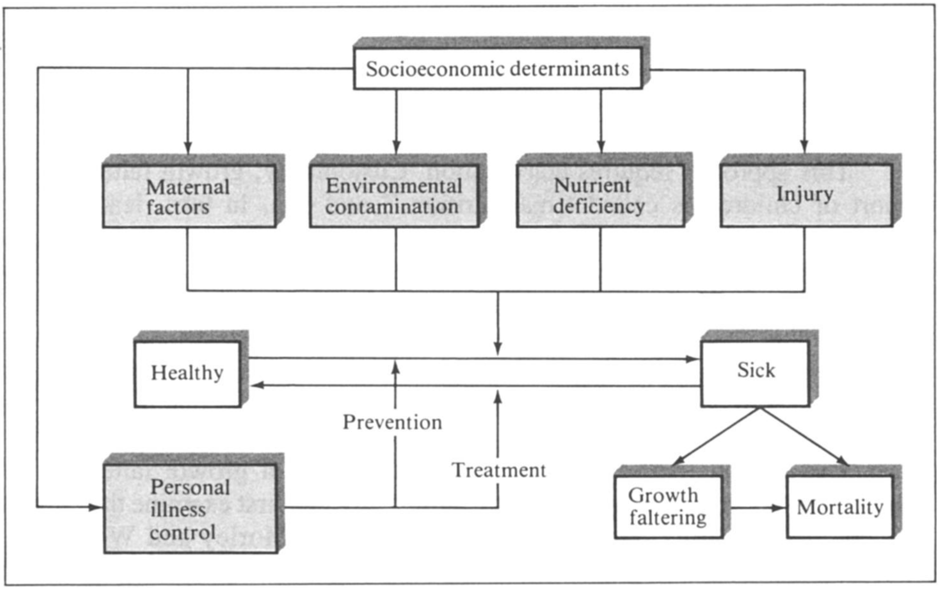
FIGURE 2 Operation of the five groups of proximate determinants on the health dynamics of a population



by mortality analysis, however, are far more complex because a child's death is the ultimate consequence of a cumulative series of biological insults rather than the outcome of a single biological event. This is quite different from the fertility model, in which all determinants operate to influence a single biological event (conception to generate a birth). Thus, it appears unlikely that a proximate determinants framework for mortality is easily amenable to a quantification of component contributions to mortality change, like the elegant system Bongaarts (1978) has developed for the fertility model.

Development of a conceptual framework for the study of child survival requires both a definition of the proximate determinants of mortality and a redefinition of the independent and dependent variables. These definitions are implied in the premises presented earlier, but greater precision and elaboration of their measurement and mode of action are indicated.

The dependent variable

Typically, social scientists examine mortality as the dependent variable. This has strength because deaths are definitive events that may be easily measured and aggregated. An exclusive focus on mortality, however, handicaps research because death is a rare event, the measurement of which necessitates the study of large populations or the cumulation of the morality experience of smaller populations over long periods. With few exceptions, social scientists pay scant attention to the health status of survivors. In contrast, medical scientists typ-

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ically focus on the diseases or nutritional status of survivors. This approach permits intensive study of smaller populations; it has the shortcoming, however, that past deaths among the birth cohorts being studied are often not taken into account. A logical question, then, is how to combine counts of the dead with observations on the living into a unified scale or index of the health status of a population. The model proposed here combines the level of growth faltering among survivors with the level of mortality of the respective birth cohort to create such an index.

This approach requires clarification. Customarily, growth faltering in a cohort of children is called "malnutrition," and this, in turn, leads to the inference that it is simply the consequence of dietary deficiency. There is now abundant evidence that growth faltering is due to many factors and that it may be more appropriately considered a nonspecific indicator of health status.[5] Thus, combining a measure of growth faltering with mortality can generate a single dependent variable that can be scaled over all members of the population of interest (both survivors and deceased). Doing so reduces one bias common to medical research and strengthens the explanatory power of social research.

To assess the validity of integrating the level of growth faltering and mortality into a common indicator of health status, we first examine the current procedure for scaling "malnutrition" in children (Morley and Woodland, 1979). Children are weighed and their actual weight-for-age is compared with the expected (median) weight-for-age based on standard growth charts (Jelliffe, 1967; American Public Health Association, 1981). Typically, each child's weight is expressed as a percentage of the expected weight-for-age. The degree of growth faltering is a function of the negative deviation from the median.[6] The classification system proposed by Gómez includes three grades of malnutrition: Grade I: 75–89 percent of standard weight-for-age; Grade II: 60–74 percent; Grade III: below 60 percent (Gómez et al., 1955). Since one standard deviation of the normal weight distribution is usually about 10–11 percent of the median weight-for-age, Gómez Grade I malnutrition overlaps somewhat with the normal range.[7]

The significance of weight-for-age as an indicator of general health status derives from prospective studies in Bangladesh, India, and New Guinea. Measurements of cohorts of children under age 3 years were taken at one point in time, the cohorts were followed prospectively for periods of one to two years, and mortality rates were calculated by weight-for-age groups. The results, summarized in Figure 3, show a consistent increase of death risk with lower weight-for-age. Use of a logarithmic scale illustrates what has long been recognized in newborns, namely, the near exponential increase of mortality risk with greater negative deviations from an expected normal weight (Federici and Terrenato, 1980).[8] The figure also shows a plot of early neonatal deaths by birth weight, which follows much the same pattern.

Based on this pattern of mortality risks among survivors by weight-for-age, our suggested method of incorporating child deaths into a common "health status index" is to assign the child deaths a "score" of Grade IV. A variable

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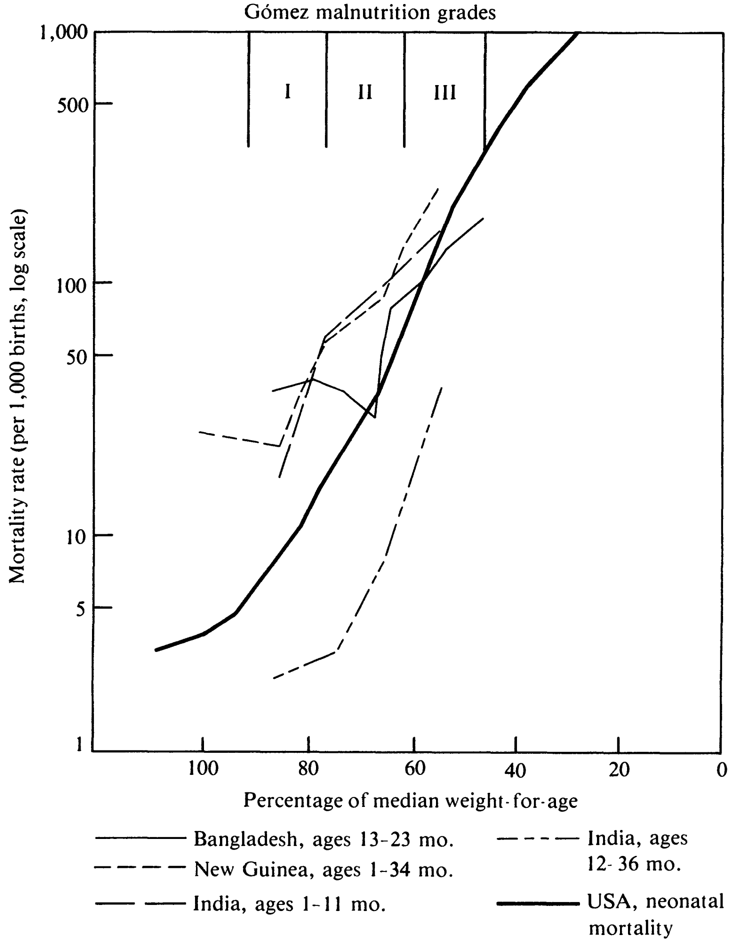
FIGURE 3 Child mortality rates by percentage of expected (median) weight-for-age, based on prospective studies of children in Bangladesh, India, and New Guinea



SOURCES: For Bangladesh, 13-23 mo. (Chen et al., 1980); New Guinea, 1-34 mo. (Heywood, 1982); India, 1-11 mo. and 12-36 mo. (Kielman and McCord, 1978); USA (NCHS, 1972).

so constructed can be useful as a relative measure of the current health status of a population cohort, and since this measure reflects cumulative past morbidity experience, it may be suitable for single-round retrospective surveys searching for determinants of child survival.

One caveat needs to be stated regarding the use and interpretation of this combined growth faltering plus mortality variable. Since growth faltering indicates the current health status of a population, it can serve as a measure of the *relative* risk of various subgroups of that population to mortality in the future. However, it will not serve as a valid index to relate specific absolute levels of mortality across populations. This is because the probability of dying

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at a given level of growth faltering varies greatly between populations according to the prevalence of certain diseases and the availability of medical services. As an example, some Latin American countries as well as New Guinea have documented mortality declines without a significant change in the "nutritional status" of survivors (Solimano and Vine, 1980; Teller et al., 1979; Malcolm, 1974).

Proximate determinants

In order to achieve maximum analytical value, the proximate determinants should not only serve as indicators of the various mechanisms producing growth faltering and death; they also should be measurable in population-based research. In some cases the proximate determinants are measurable directly, in other cases indirectly, as detailed below.

Maternal factors

The maternal factors of age, parity, and birth interval (since last birth and to the next birth where appropriate) are ordinarily measured directly by interview.

Environmental contamination

In field studies, the levels of environmental contamination reflecting the various routes of spread of disease may be measured directly by carrying out microbiological examination of samples of air, water, food, skin washing, or vectors. Usually when this is done for public health surveillance, only a single "indicator organism" is selected for measurement: for example, *E. coli* bacteria from human feces is measured in food or water. A more practical means of assessing the relative intensity of environmental contamination is to measure the number of recent episodes (incidence) of a group of acute infectious diseases in the cohort of children under study. These diseases can be selected to evaluate each of the major routes of environmental contamination (Mosley, 1980a). For example, respiratory diseases (colds, influenza, pneumonia) can be used for airborne infections, diarrheal diseases for food- and water-borne infections, and skin infections/infestations and neonatal tetanus for diseases spread by skin and soil. For chronic diseases, indicators of prevalence in the population are often more useful. Examples are skin tests for tuberculosis, stool examinations for intestinal parasites related to fecal contamination of the environment, physical examinations for scabies and trachoma, and blood smears for malaria.

All of the above are direct means of assessing levels of environmental contamination, either by searching for infective agents in the environment or by measuring those agents' effects in a population. Levels of potential exposure to disease can also be approximated and scaled by using a series of simple physical indexes that are known to be strongly correlated with the levels of biological contamination of the environment. For example, air contamination and risk of contact-acquired respiratory infections can be inferred from the

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intensity of household crowding (persons per room); water contamination can be scaled by source of supply (ditch, pond, open well, protected well, hand-pump, piped supply); household food contamination, by cleaning, cooking, and storage practices; and potential fecal contamination, by the presence of latrines or toilets, or the use of soap and water.

Where appropriate, more than one measure may be used to obtain a composite index (e.g., incidence of diarrheal disease, prevalence of round-worm parasites, absence of toilet facilities). But when this is done, care should be taken to avoid a common error of treating each measure as an isolated factor, particularly in multivariate models, since the interpretation of the results will be confounded by multicollinearity.

Nutrient deficiency

As with environmental exposure, nutrient availability to the infant (or to the mother during pregnancy and lactation) can be measured directly by weighing of all foods before consumption, accompanied by biochemical analysis of food samples. Less precise measures may be obtained by observing what is eaten, or by a recall history of the diet. These cruder measures may be particularly useful in assessing relative levels of nutrient intake.

Deficiency of specific nutrients in the diet can also be assessed by physical or biochemical measures. Examples are low serum albumin levels for protein deficiency, signs of xerophthalmia for vitamin A deficiency, and anemia for iron deficiency. These physical and biochemical measures of nutritional status, however, should be interpreted with caution, since, as noted earlier, physiological manifestations of nutrient deficiency may also be due to such other factors as recurrent infections.

Injury

The operation of this intermediate variable is measured by the incidence of recent injuries, or the cumulative prevalence of injury-related disabilities (e.g., scarring from burns).

Personal illness control

For preventive measures this variable is commonly assessed by the reported use of such preventive services as immunizations, malaria prophylaxis, or antenatal care. For curative measures, generally the providers of care and types of therapy taken for specific conditions are assessed. Because traditional practices as well as modern scientific medicine should be included in this group, the kinds of therapies or providers must be scaled independently according to probable efficacy.

As these illustrations demonstrate, a variety of procedures can be used to measure and scale the proximate determinants of child survival, ranging from sophisticated biological analysis of environmental and food specimens, to medical examination of individuals, to visual observations of the environment, to simply asking questions. Some methods are more precise than others,

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but not necessarily better for population-based research. For example, direct microbiological examination of water can give the precise bacterial count of the sample, but since the sample is taken from only one site on one occasion, it is unlikely to be a valid indicator of the risk of infection over an entire year. The observation that the water source is a canal used for bathing, cooking, and fecal waste disposal will be far more appropriate in this case.

Socioeconomic determinants

We next examine a range of socioeconomic determinants (independent variables) and illustrate how they operate through the proximate determinants to influence the level of growth faltering and mortality. The socioeconomic determinants are grouped into three broad categories of variables that are commonly followed in the social science literature.[9]

— Individual-level variables: individual productivity (fathers, mothers); traditions/norms/attitudes.

— Household-level variables: income/wealth.

— Community-level variables: ecological setting; political economy; health system.

Individual-level variables

Individual productivity Three elements that determine the ''productivity'' of household members are skills (typically measured by educational level), health, and time. If the ''product'' of interest is a healthy surviving child, the childbearing and childrearing adult (usually the mother) should be considered separately from other adults (usually the father).

For fathers, particularly in the urban sector, educational levels usually correlate strongly with occupation, and therefore with household income. Fathers' education is a strong determinant of the household's assets and the marketable commodities the household consumes. Thus, in many cases correlations between health effects and educational level of fathers (or other nonchildbearing, economically productive adult members in a household) largely occur because of operations on the proximate determinants through the income effects. Father's education may also influence attitudes and thus preferences in choice of consumption goods, including child care services. This effect is likely to be most significant for child survival when more educated fathers are married to less educated mothers.

For mothers, the situation is entirely different. Their skills, time, and health operate directly on the proximate determinants. Because of biological links between the mother and infant during pregnancy and lactation, the mother's health and nutritional status as well as her reproductive pattern influences the health and survival of the child. Because of her responsibility for her own care during pregnancy and the care of her child through the most vulnerable

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stages of its life, her educational level can affect child survival by influencing her choices and increasing her skills in health care practices related to contraception, nutrition, hygiene, preventive care, and disease treatment. In fact, so many proximate determinants may be directly influenced by a mother's education to radically alter chances for child survival, that one of the authors was prompted to label the process ''social synergy'' (Mosley, 1983).

Finally, the ''production'' of a healthy child also requires a mother's time for prenatal visits, attendance at the well-baby clinic, breastfeeding, food preparation, washing clothes, bathing the child, house cleaning, and sickness care. A mother's time may also be required for (or diverted to) other economically productive activities that may or may not be related to child health. In traditional societies, a sharp division of labor by sex tends to maximize the mother's time for child care. On the other hand, in transitional societies characteristic of many developing countries, child care time often competes with time needed for income-generating work (Birdsall and Greevey, 1978; Engle, 1981). The consequences for infant health and mortality depend largely upon the general economic circumstances of the household. For poor families, a mother's outside work may result in child neglect or care by a less skilled sibling, while a wealthy family may hire a skilled and attentive nursemaid (Popkin, 1975; Kumar, 1977). Poor and rich mothers may experience equivalent time-saving and maternal and child health benefits from contraceptive use. By contrast, if both poor and rich mothers find it necessary to use bottlefeeding as a time-saving technology, the consequences to child survival for the two families may be radically different.

Traditions/norms/attitudes Grouped under this category are factors that shape and modify the economic choices and health-related practices of individuals according to the cultural traditions and norms of the society. The following are among the important cultural determinants of child health and survival.

Power relationships within the household—While in most traditional societies the mother has full responsibility for child care, she may have little control over allocation of resources (food) to herself or her child or over critical child care practices (diet, sickness care) (Safilios-Rothschild, 1980). Often decisions in these areas are reserved for the elders, particularly the mother-in-law or the husband, and the latter may rigidly adhere to useless or harmful traditional practices. Caldwell (1979) postulates that one key change in traditional societies produced by mother's education is a shift of intrahousehold power relationships toward the mother to the benefit of her offspring.

Value of children—There is growing evidence that this variable, commonly associated with fertility research, is also important to child survival (Scrimshaw, 1978; Simmons et al., 1982). In economic terms, a family's investments in child care may be conditional on expected returns. Marriage expectations can be a major economic factor in child survival: for example, in Kenya, where girls are valued for the brideprice they bring, child survival

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rates are slightly higher for females than for males, while in South Asia, where female dowry is the main concern, the reverse is true (Mott, 1979; Poffenberger, 1981). In terms of proximate mechanisms through which this determinant operates, recent studies in rural Bangladesh and Amman, Jordan, have attributed higher female than male child mortality to differential feeding and medical care practices, while Scrimshaw observes that some societies may resort to intentional injury (infanticide) to achieve family size/composition goals (Chen, Huq, and D'Souza, 1981; Urban Development Department, 1982; Scrimshaw, 1978).

Beliefs about disease causation—Anthropological literature is replete with examples of how a society's beliefs about disease causation shape behavior that has an impact on the proximate determinants of child survival. These range from ritualistic disease prevention practices, to choice of therapies and practitioners for sickness care, to sexual taboos and abstinence to prevent illness in the suckling child (Fabrega, 1972; Kleinman et al., 1975). One manifestation of this phenomenon is the commonly reported "underutilization" of modern (Western) health facilities when they are introduced into traditional societies. Probably one of the most powerful influences of formal education is the transmission of concepts of modern scientific medicine. When the mother is exposed to such information, it can transform her preferences for health care practices so as to significantly improve child survival, often without investment of additional economic resources.

Food preferences—Patterns of dietary intake and food choice are probably among the strongest "culturally conditioned" tastes across all societies, as confirmed by the dietary heterogeneity even in developed countries. Because maternal diet during pregnancy and lactation (and even in the mother's own childhood) and patterns of breastfeeding and supplementation are potent determinants of child survival, food preferences can assume importance in many developing countries, particularly where food taboos and restrictions are commonly practiced during pregnancy, lactation, weaning, and illness. A deleterious dietary practice of international concern is the withholding of food and fluids during diarrheal illness, a situation now being addressed through the worldwide promotion of oral rehydration therapy (Grant, 1982).

Household-level variables

Income/wealth/effects A variety of goods, services, and assets at the household level operate on child health and mortality through the proximate determinants. Below are some major ways in which income effects influence child health.

Food—Critical is the stable availability of a basic minimum food supply of sufficient variety to ensure adequate amounts of all nutrients. The sanitary quality of food (clean, fresh, free from spoilage) is also important in preventing disease transmission.

Water—Both quantity and quality of water supply are important determinants of exposure to disease. Adequate quantity is essential to permit bath-

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ing, washing, and cleaning, and quality (not only at the source but also in the household) for drinking and food preparation.

Clothing/bedding—Sufficient clothing for protection under local climatic conditions and to allow a change for washing reduces the incidence of skin infections and parasitic infestations.

Housing—Both size and quality are factors. Poor ventilation and crowded sleeping conditions predispose household members to respiratory and skin infections. Adequate sanitation requires vermin-proof screens, construction materials that can be cleaned, and separate rooms for cooking, bathing, toilets, sleeping, storage of food and water, and for livestock. Plumbing and sewer connections greatly simplify hygienic care.

Fuel/energy—An adequate supply of fuel is essential for proper cooking of food, boiling water, and sterilizing stored food and utensils (especially for infant bottles). Energy is needed for refrigeration to prevent diarrheal diseases due to bacterial overgrowth in stored food, as well as for warmth to reduce the likelihood of respiratory infections in cold climates.

Transportation—Access to preventive/curative medical facilities, to markets for consumption goods and food, and to places of income-generating employment is essential.

Hygienic/preventive care—This requires the means to purchase soap, cleansing materials, insecticides, and the like for household use, as well as vitamins, iron supplements, contraceptives, and the means to pay for such preventive services as antenatal care, well-child care, and immunizations.

Sickness care—Included here are costs of services and commodities, such as physicians, hospitalization, and drugs, including maternity care during childbirth.

Information—Through radio, television, newspapers, magazines, books, and informal channels, households can obtain information about proper nutrition, hygiene, contraception, and immunizations.

This brief list of goods and services illustrates why "income" is generally a powerful determinant of child mortality. In poor societies in particular, families may spend 80 percent or more of their disposable income on food; thus variations in income or food prices may be directly translated into rising rates of mortality and malnutrition. This was well documented in the mid-1970s in rural Bangladesh, the tea estates of Sri Lanka, and São Paulo, Brazil (Chowdhury and Chen, 1977; Meegama, 1981; Wood, 1982). In rural subsistence economies, even seasonal variability in income and/or food availability can lead to seasonal swings in mortality (Chambers, 1980; Chen et al., 1979).

Community-level variables

Ecological setting The ecological setting includes climate, soil, rainfall, temperature, altitude, and seasonality. In rural subsistence societies, these variables can have a strong influence on child survival by affecting the quantity and variety of food crops produced, the availability and quality of water,

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vector-borne disease transmission, the rate of proliferation of bacteria in stored foods, the survival of parasite larvae and eggs in soil, and the drainage of sewage. Ecological variables can also influence the availability of income-generating work, the access to and use of medical facilities, and the time mothers can spend at home in child care.

Political economy The classic study of India's population by Davis (1951) attributed much of the rise in life expectancy (from about 25 years to 50 years) in the first half of this century to the prevention of recurrent famines that had characterized the subcontinent's history; this was achieved by stabilizing food supplies with railroads, road networks, irrigation, markets, and political security. Among the politico-economic factors that can operate to influence child survival are the following.

Organization of production—Whether the mode of production and distribution of benefits is communal or based on individual entrepreneurship can determine the distribution of resources and the availability and stability of food supplies.

Physical infrastructure—Railroad, roads, electricity, water, sewage, and telephone systems can influence health, particularly through their impact on the relative price of staples as well as of health-related goods, services, and information. Many studies have shown, for example, that the poor pay more in money, time, and effort for poor-quality water than do the rich, who have access to an equivalent supply of pure piped water (Briscoe, 1983).

Political institutions—These include organizations at the local level and their ties with centralized authority for policy guidance and/or program implementation, law enforcement and security systems, and popular associations such as labor unions, cooperatives, and political parties. The importance of such political and administrative structures has been emphasized in international comparisons of child mortality, as well as in regional comparisons such as the contrast of Kerala with West Bengal (UN Population Division, 1983; Nag, 1983). Furthermore, the literature on the success or failure of various health action projects, whether national or small-scale, cites the vital roles of local leadership, obstruction by elites, inertia of supporting agencies, and lack of "political will" (Mosley, 1983).

Health system variables How does the formal (Western) health system fit into this conceptual scheme? Interestingly, although there is a general presumption that "modern medicine" must improve the health of populations, there has been little effort to spell out the likely connections or their mechanisms of operation.

Within the proximate determinants model, the formal health system is viewed as operating in the following ways.

Institutionalized (imposed) actions—These are disease-control measures mandated by law (rather than left to individual discretion) to affect the health of populations at large. They potentially can have a powerful impact on mortality. These measures may be financed and directly implemented either

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by the health system (epidemic control measures such as vector control programs, quarantine, immunizations) or by private enterprise with the health system assuming a supervising/inspection role. Examples of the latter are regulations governing the sanitary quality of commercial foods, milk, water, sewage, air, housing, restaurants, hospitals, and factories.

Implementation of such institutionalized measures is subject to strong economic constraints: the allocation of financial resources to the government health system for preventive activities, its allocation within that system, and the economic resources of private enterprises in the community. Typically in poor countries, in the calculus of many individuals in the community (and of the health system) transfer payments (bribes) to the health system will yield a greater "benefit" than the making of investments in the required environmental improvements. While such a stance would seem to have obvious detrimental consequences for the health of populations, there is little research to determine at what economic level mandated health measures might be expected to be effective. Thus, developing countries characteristically are overburdened by "enforced" but ineffective health laws.

Cost subsidies—The second major area of health system action consists of cost subsidies to change the relative prices of health-related goods and services. In contrast to institutionalized measures, which are generally designed to reduce disease exposure, these inputs operate primarily through the "personal illness control" proximate determinants. They are likely to have a much smaller impact on health status, primarily because most national health budgets are allocated to inputs that operate only after sickness has occurred. This limitation is coupled with the fact that utilization of these services, even if freely available, is voluntary and thus critically dependent upon health beliefs and preferences. In some developing countries, this cultural barrier alone can reduce the health impact of the formal health care system almost to zero (Assaad and Katsha, 1981).

Like institutionalized measures, cost subsidies are subject to economic constraints both within the system and at the individual level. The consequence of cost constraints within the system is rationing of services. This should be carried out equitably; however, few health ministries have planned rationing. The frequent result is concentration of health resources in the urban areas, thereby selectively subsidizing the most advantaged segments of the population. At the individual level, the cost constraint is manifested by such features as the exponential decline of rural health center utilization by residential distance from the facility (Jolly and King, 1966).

Public information/education/motivation—Education/motivation programs can operate at several levels. Politically, they can influence governments to allocate more funds or more effectively use limited resources for health services, or to modify general development strategies to better protect people's health; institutionally, they can upgrade the skills of traditional practitioners or of health workers; individually, they can enhance the skills and change the attitudes and preferences of parents, especially mothers, thereby promoting child survival.

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The role of technology—Medical technology improves the effectiveness and efficiency with which the proximate determinants may be manipulated by the health system. Most modern scientific technologies like vaccines and antibiotics are pinpointed to specific disease agents. Often, powerful modern technologies like insecticides have significant adverse side effects as well. Within the health system, technologies can be applied by institutional mandate (DDT, smallpox vaccination, water and sewer systems, proper sanitation and refrigeration in commercial food processing); they can be made available with a cost subsidy (vaccines, drugs, vitamins, oral rehydration salts, contraceptives); or people can be encouraged by education to use them at their own cost (soap, boiling water, toilets).

Since all such technologies are intrinsically "powerful," their health and mortality impact on populations revolves around three issues: (1) what is the potential contribution of the intervention toward improving child survival when analyzed in the proximate determinants model, taking into account biological synergy? (2) to what portion of the population will the technology be available? and (3) will it be used and used effectively? These are analogous to issues in demographic impact analyses to relate contraceptive use to fertility changes in a population. The problem with respect to morbidity and mortality is more complex, as attested by the controversy over the demographic impact of malaria eradication in Sri Lanka (Gray, 1974) and by recent studies of measles mortality after vaccination in Zaire (Kasongo Project Team, 1981; Aaby et al., 1981). The complexity of the problem should not deter research on this issue, however, in view of current proposals to invest vast resources in technology-oriented health strategies with little consideration given to the social and economic constraints that may limit their impact.

As the preceding discussion suggests, the task of delineating and scaling the impact of the socioeconomic variables on the proximate determinants of child health and mortality falls to a wide range of social science disciplines, both those that observe populations and institutions at large and those that quantify economic transactions and the effects of income factors on family goals and outcomes. The need for a multidisciplinary approach to understanding and alleviating child mortality is clear.

Discussion

The purpose of an analytical framework in the study of child survival is to clarify our understanding of the many factors involved in the family's production of healthy children in order to provide a foundation for formulating health policies and strategies. The significance of the proximate determinants model does not lie in simply a listing of the multiplicity of variables of interest or in concerns with scaling and measurement of these factors: many field surveys already address these topics. Rather, the key advantage of the model lies in the organization of seemingly disparate measures of environmental conditions; of dietary, reproductive, and health care practices; and of disease

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states into a coherent framework in which they are linked to one another and to child survival on the one hand and to socioeconomic factors on the other. The value of the framework is its parsimony. By limiting the proximate determinants to 14 specific factors grouped into five broad categories, we are able to arrive at a scheme that makes feasible the integrated analysis of the biological and social determinants of mortality.

The analytical model implies a major reorientation in research approaches by both health and social scientists looking at child mortality. Specifically, it suggests that child mortality should be studied more as a chronic disease process with multifactorial origins than as an acute, single-cause phenomenon. Use of the model should facilitate specification of the different orders of causality and possible interactions among the socioeconomic determinants. Regarding the dependent variable, the degree of physical deterioration (growth faltering) among surviving children in a population is combined with the mortality experience into a nonspecific measure of the level of adverse conditions facing the population.

There are numerous situations in which a multidisciplinary approach to the study of child survival could provide guidance for health policymakers in the developing world. For example, in many developing countries large differences in infant and child mortality have been observed between various regions, or between mothers with different educational or social characteristics within a given area. In-depth investigation to connect these ecological or socioeconomic factors to specific proximate determinants can give policymakers insights into health-related development strategies that could reduce these differentials.

A rewarding opportunity for multidisciplinary research using this model is provided by "natural experiments," that is, situations in which health or social interventions are being introduced into large populations. For example, rural or urban development projects may change the ecological setting and/or provide additional income-earning opportunities for men and women. Typically these are presumed to lead to improved health in the family, though, in fact, the consequences for child welfare may be mixed. Research in conjunction with such interventions can not only assess the overall health impact of alternative development strategies, but also more sharply define which among a number of specific factors amenable to change by health policymakers are of greatest consequence for child survival.

Notes

1 The terms proximate determinants, intermediate variables, and mechanisms may be used interchangeably.

2 The framework presented here is slightly modified from its original form as developed in Mosley (1983). Specifically, "nutrient availability" factors have been renamed "nutrient deficiency" factors, and the factors of "vitamins" and "minerals" have been combined to "micronutrients."

3 There are two alternative approaches to solving this problem. One requires a detailed

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classification of all known causes of disease and death in every individual in order to make inferences about the social factors contributing to mortality. This approach was used by Puffer and Serrano (1975) in studying mortality among 36,000 children in the Americas. A second approach, proposed here, is to search for and identify several basic mechanisms common to all diseases of interest and through which all socioeconomic determinants must operate.

4 Noteworthy in this framework are biological interactions among the proximate determinants. The effects of the proximate determinant "nutrient deficiency" is modulated by the physiological factors of appetite, absorption, and metabolism. Similarly, the effects generated by "environmental contamination" are influenced by the host's ability to resist infection. In this latter case, host resistance may be compromised by injury, low birth weight, or immaturity at birth. Host defenses may be strengthened by improved nutrition and by vaccines. Also implicit in the framework are the biological mechanisms of synergism between malnutrition and infection. Infections reduce appetite and cause unnecessary metabolic wastage of nutrients, thereby precipitating or aggravating malnutrition; malnutrition, in turn, reduces host resistance, thereby increasing the risk of more severe disease outcomes due to infection.

5 Typically, body wasting and growth retardation are called "malnutrition." While this is the biological situation at the cellular or somatic level, the term "malnutrition" also implies the existence of a specific "cause" of the condition (lack of sufficient food). This assumption commonly leads to a particular public health intervention (feeding programs). There is a growing body of evidence that the level of "malnutrition" among children is as much dependent on maternal health factors and infections as it is on the nutrient deficiency. It is thus more appropriate to consider the levels of physical stunting and wasting in cohorts of children as nonspecific indicators of health status (as is the case with the level of mortality) rather than as a specific indicator of dietary deficiency (Mata, 1978; Cole and Parkin, 1977).

6 For simplicity, the discussion will deal only with weight-for-age measurements, although similar findings have been shown for measures of height-for-age and arm circumference (Chen et al., 1980; Sommer and Loewenstein, 1975; Heywood, 1982).

7 More recent recommendations have proposed that the difference between the observed and expected weight-for-age be expressed in standard deviation units (*z* score). As noted above, one standard deviation equals roughly 10–11 percent of the expected weight-for-age (Waterlow et al., 1977).

8 The absolute levels and differences between studies shown in Figure 3 are not comparable because of different study designs, treatments available, and so on.

9 Schultz (1979) and Palloni (1981) provide a basis for the organization of socioeconomic determinants in our discussion.

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