Prevalence of nutritional wasting in populations: building explanatory models using secondary data

Isabel D. Fernandez,[1] John H. Himes,[2] & Mercedes de Onis[3]

Objective To understand how social context affects the nutritional status of populations, as reflected by the prevalence of wasting in children under 5 years of age from Africa, Latin America, and Asia; to present a systematic way of building models for wasting prevalence, using a conceptual framework for the determinants of malnutrition; and to examine the feasibility of using readily available data collected over time to build models of wasting prevalence in populations.

Methods Associations between prevalence of wasting and environmental variables were examined in the three regions. General linear mixed models were fitted using anthropometric survey data for countries within each region.

Findings Low birth weight (LBW), measles incidence, and access to a safe water supply explained 64% of wasting variability in Asia. In Latin America, LBW and survey year explained 38%; in Africa, LBW, survey year, and adult literacy explained 7%.

Conclusion LBW emerged as a predictor of wasting prevalence in all three regions. Actions regarding women's rights may have an effect on the nutritional status of children since LBW seems to reflect several aspects of the conditions of women in society. Databases have to be made compatible with each other to facilitate integrated analysis for nutritional research and policy decision-making. In addition, the validity of the variables representing the conceptual framework should be improved.

Keywords Nutritional status; Body height; Weight loss; Infant, Low birth weight; Child; Risk factors; Nutrition surveys; Models, Statistical; Developing countries; Asia; Africa; Latin America (*source: MeSH, NLM*).

Mots clés Etat nutritionnel; Taille corporelle; Perte poids; Nourrisson faible poids naissance; Enfant; Facteur risque; Enquête nutritionnelle; Modèle statistique; Pays en développement; Asie; Afrique; Amérique latine (*source: MeSH, INSERM*).

Palabras clave Estado nutricional; Estatura; Pérdida de peso; Recién nacido de bajo peso; Niño; Factores de riesgo; Encuestas nutricionales; Modelos estadísticos; Países en desarrollo; Asia; África; América Latina (*fuente: DeCS, BIREME*).

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Voir page 290 le résumé en français. En la página 290 figura un resumen en español.

Introduction

Malnutrition is a serious global issue. Each year, some 24 million babies are born too small to lead healthy lives because their mothers were either ill or malnourished (*1, 2*). Among children under five years of age in the developing world, 206 million are stunted (low height for age), 50 million are wasted (low weight for height), and 167 million are underweight (low weight for age) due to lack of food and the presence of disease (*3*). In 1995, 6.3 million of the 11.6 million deaths among children aged under five years were associated with malnutrition, mainly because of the potentiating effect of mild-to-moderate malnutrition (*3, 4*). Ultimately, malnutrition results from inadequate intake of nutrients and/or from disease factors that affect digestion, absorption, transport, and utilization of nutrients. However, there are also economic, social, political, and cultural causes of malnutrition (*5*), which underscore the close link between malnutrition, the general standard of living, and whether a population is able to meet its basic needs, such as food, housing, and health care (*5, 6*). Because of the link between malnutrition and social factors, the nutritional status of a population is a sensitive indicator of the quality of life in the community (*7, 8*).

Determining the nutritional status of populations

The prevalences of wasting and stunting have been widely used to characterize the nutritional status of populations (*6, 9*). Wasting reflects a deficit in weight relative to height due to a deficit in tissue and fat mass, whereas stunting reflects a deficit in height relative to age due to linear growth retardation. Epidemiological evidence suggests that the first response to a nutritional and/or infectious insult is weight loss (wasting), followed by retardation in linear growth (stunting) (*10*). If the insult persists, children will cease to grow in height and will lose weight, thus augmenting the process of wasting (*11*). Finally, if children survive, they will become chronically wasted. As a consequence, the prevalence of wasting in populations will be high. According to Ties-Boerma et al. (*12*), the prevalence of wasting reflects survival factors because only those who survive until the survey date are measured. Wasting in early childhood also has well-established effects on later morbidity and mortality (*13–16*).

Use of secondary datasets

Although secondary datasets provide important and cost-effective approaches to understanding health determinants,

[1] Assistant Professor, Department of Community and Preventive Medicine, University of Rochester School of Medicine and Dentistry, 601 Elmwood Avenue, Box 644, Rochester, NY 14642, USA (email: diana_fernandez@urmc.rochester.edu). Correspondence should be addressed to this author.

[2] Professor, Department of Epidemiology, School of Public Health, University of Minnesota, Minneapolis, MN, USA.

[3] Medical Officer, Department of Nutrition for Health and Human Development, World Health Organization, Geneva, Switzerland.

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the relationship between aggregate variables and population health and well-being is often not fully investigated before health and social policies are prepared (*17*). Information routinely collected by national governments, international agencies, and nongovernmental organizations needs to be integrated, so that the social determinants of malnutrition can be better understood and used to develop nutritional policy at regional and national levels.

Goals of the study

In the present study, we examined the effects of social national variables on wasting, using a comprehensive conceptual framework that explains malnutrition in specific contexts (*5*). Although the framework has been used previously for predicting wasting at the population level (*18, 19*), to our knowledge this is the first time that an attempt has been made to use variables to represent each of the three levels of the conceptual framework. Moreover, by examining the predictive ability of the framework, we tested how adequately the variables included represented each level of the conceptual framework. The goals were to understand how the social context affects the nutritional status of populations, as reflected by the prevalence of wasting in children under 5 years of age from Africa, Latin America, and Asia; to present a systematic way of building models for wasting prevalence, using a framework for the determinants of malnutrition; and to examine the feasibility of using readily available data collected over time to build models of wasting prevalence in populations.

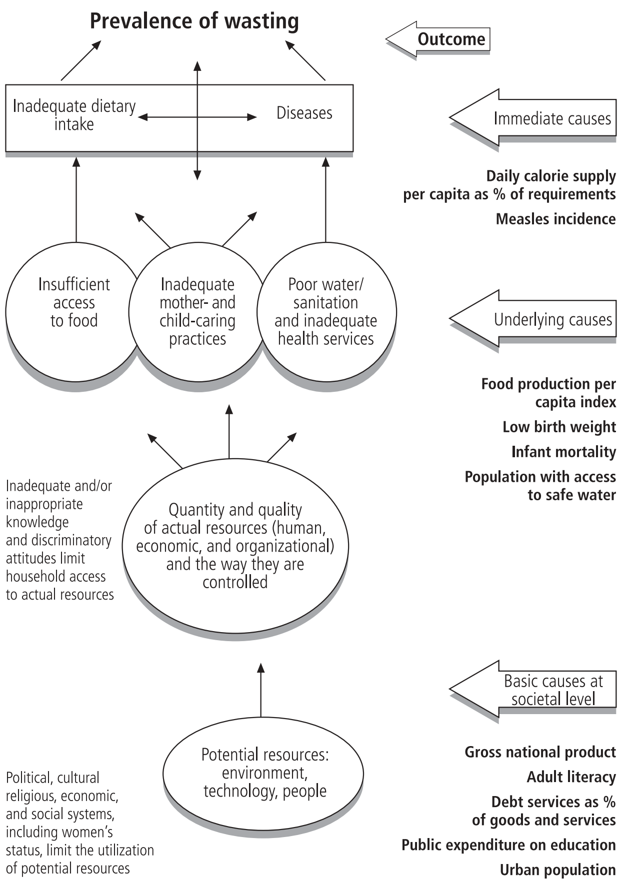
Methods

Identifying determinants of wasting

The population determinants of wasting prevalence were analysed within a framework adapted from the United Nations Children's Fund (UNICEF) (*5*). According to this framework, the prevalence of wasting in a population is determined by immediate, underlying, and basic causes (Fig. 1). Immediate causes are inadequate dietary intake and disease, while underlying causes lead to inadequate dietary intake and disease. Underlying causes are usually interrelated and mainly concern the unmet basic needs of children and women. There are three main groups of underlying causes: inadequate health services and an unhealthy environment; inadequate household food security; and inadequate mother- and child-caring practices. Most underlying causes are themselves the result of basic (or structural) causes related to the unequal distribution of resources in a society, the historical background, and external factors. Basic causes include political, legal, and cultural factors that could counteract the best efforts of households to attain good nutrition for all members.

Ecological associations among wasting prevalence (weight-for-height –2 Z-score[a]) (*9*), morbidity, mortality, and socioeconomic variables were examined by United Nations (UN) region (Table 1). Initial models controlled for the effect of the survey year and all relevant variables were centred around the mean to avoid multicollinearity in Africa, as the quadratic term for the year of the survey was statistically significant only in Africa. Wasting prevalence was initially regressed on prevalence of stunting, since an association had previously been found in some regions of the world, though not in others (*18*, *20*). Including the prevalence of stunting in the analysis did not change the final results and will not be further discussed. Variables representing each level of the framework were added to models resulting from these initial analyses (Fig. 1; Table 1).

Fig. 1. **Conceptual framework for determining the prevalence of wasting in a population**



Source: ref. *5*. WHO 01.361

Data on wasting

The prevalence of wasting was defined as the percentage of children under 5 years of age who fell under –2 Z-scores for the United States National Center for Health Statistics/Center for Disease Control international reference median for weight-for-height (*9*, *17*). Technical aspects, uses, and interpretation of the weight-for-height index and indicator have been extensively discussed in the literature (*6, 9, 21*). Data on wasting prevalence were obtained from the WHO Global Database on Child Growth and Malnutrition (*3*, *9*).

In the present study, countries were grouped according to UN regional distribution, since it follows a more logical geographical grouping than that of WHO. For example, according to the WHO regional distribution, Ethiopia and

[a] A Z-score (a standard deviation score) expresses the anthropometric value as a number of standard deviations (or Z-scores) above or below the reference median or mean value. It is calculated using the following equation: Z-score = (observed values – median value of the reference population)/standard deviation value of the reference population.

Table 1. Definitions of ecological variables and their sources

Variable	Definition (source)
Immediate causes	
Insufficient dietary intake	
Daily calorie supply per capita as % of requirements	Average number of calories needed to sustain a person at normal levels of activity and health by age, sex, body weight and environmental temperature (FAO[a, b])
Disease burden of the population	
Measles incidence	Number of cases for all ages/mid-year population[c]
Underlying causes	
Food security	
Food production per capita index (in 1980 = 100)	Annual average quantity of food produced per capita in relation to that produced in the index year (FAO[b])
Deficits in mother- and child-caring practices	
Low birth weight	Percentage of babies with birth weight less than 2500 g (WHO[b])
Infant mortality	Annual number of deaths of children under one year of age per 1000 live births (UNPD[b, d])
Healthy environment	
Population with access to safe water	Percentage of population with access to a safe water supply (UNICEF,[e] WHO[b])
Basic causes	
Income at the national level	
Gross national product per capita	Total domestic and foreign value added claimed by residents divided by the population number, in current US$ (World Bank[b])
End result of the development process	
Adult literacy	The number of people aged over 15 years who reportedly can read and write, divided by the number of the population in the same age group, expressed as a % (UNESCO[f, g])
External economic dependency	
Debt services as % of goods and services	Sum of the repayments of money lent and payments of interest made in foreign currencies, goods, or services on external, public, publicly guaranteed, and private nonguaranteed debts as a proportion of the exports of goods and services (OECD,[b, h] World Bank[b])
Fulfillment of basic educational needs	
Public expenditure on education as % of gross national product	Public expenditure on the provision, management, inspection, and support of preprimary and secondary schools; universities and colleges; vocational, technical, and other training institutions (UNESCO, World Bank[b])
Ecological conditions	
Urban population as % of the total population	Percentage of the population living in urban areas as defined according to the national definition used in the most recent population census (UNPD[b])

[a] FAO = Food and Agriculture Organization of the United Nations.
[b] Source: *Human development report*, United Nations Population Division, 1990, 1991, 1992, 1993, 1994, 1997.
[c] Number of cases: Expanded Programme on Immunization and World Health Statistics. Population estimates: *Demographic yearbook*, United States Census Bureau, 1995, 1997.
[d] UNPD = United Nations Population Division.
[e] UNICEF = United Nations Children's Fund (*2*).
[f] UNESCO = United Nations Educational, Scientific and Cultural Organization.
[g] Source: *Statistical yearbook*, UNESCO, 1964, 1973, 1975, 1981, 1982, 1985–86, 1987, 1988–89; and source in footnote b.
[h] OECD = Organisation for Economic Co-operation and Development.

Sudan are part of the WHO Eastern Mediterranean Region, instead of being part of the WHO African Region. The three UN regions (Africa, Latin America, and Asia) were chosen because a considerable number of surveys had been carried out in them within the timespan of the dataset. Other regions of the world were excluded due to the scarcity of surveys. The criteria for including surveys from these countries are outlined in Box 1. To model the prevalence of wasting in populations, variables representing the immediate, underlying, and basic causes of the framework were selected. The inclusion criteria are listed in Box 2.

Study design

An ecological, cross-sectional analysis was designed using all the surveys within each country and survey year as analytical units. In other words, each observation analysed comprised one survey performed in a country in a particular year. Since some countries contributed more than one survey over the period we studied (1960–95), general linear mixed models were used to account for the lack of independence of the observations, by modelling the covariance structure of the outcome variable (prevalence of wasting). A mixed linear model permits the data to exhibit correlation and nonconstant variability (*22, 23*). The random-effects component (the variable for survey performed in one particular year within a country) modelled a compound symmetry covariance structure. By modelling a compound symmetry structure, it was assumed that one observation (prevalence of wasting) of a country (one survey) has a constant correlation with the other surveys of the same country and is not correlated with surveys of other countries (*22, 23*). The fixed-effects components were the independent predictors of the prevalence of wasting at the population level. All the variables were continuously distributed. The analyses were stratified by UN region. Explanatory models were compared according to the changes in the between- and within-country variability of wasting

Box 1. Country surveys: inclusion criteria

The country surveys were included in the study if:

- they were carried out in developing countries of the three selected United Nations regions. Deficits in nutritional status indicators are more prevalent in developing than in industrialized countries. When such deficits are high, the causes are mainly environmental (*11*) and the range of prevalences is wider than in industrialized countries.
- they had pooled data for both genders;
- they had a sample size >50 children;
- the prevalence estimates in the surveys were weighted by sample size for each age in the 0–4.99-year range. When surveys covered broader age-ranges (e.g. 0–6.99 years), a weighted average of wasting prevalence for the 0–4.99-year range was estimated.

Box 2. Ecological variables: inclusion criteria

Variables representing the immediate, underlying, and basic levels of the conceptual framework were selected if:

- they were conceptually appropriate;
- they had a reliable data source;
- they had a comprehensive time series;
- simple correlations between variables for each level of the conceptual framework did not exceed 75% (r <0.75). Ecological variables were matched to the anthropometric surveys by country and year ($\pm$5 years), and their definitions and sources arranged according to the framework levels (Table 1).

prevalence (random-effects component), the goodness-of-fit of the models to the data (fixed-effects component), and the magnitude of the effect and the statistical significance of each predictor (β coefficients and t tests). The mixed model was fitted using the Mixed Procedure in SAS Software version 6.12 (SAS Institute, Inc., Cary, NC, USA).

Model building

Variables representing each level of the conceptual framework were added consecutively as sets to models resulting from the initial regression equations. If the conceptual framework were adequately specified, immediate-level causes would capture most, if not all, of the variability in wasting prevalence at the ecological level. Once immediate-level causes were already in the model, adding the underlying- and basic-level causes to the model should not improve the fit of the model to the data. This was tested by treating the variables as sets. Subsequently, simpler models within each level of the conceptual framework were examined to select the most parsimonious model for estimating wasting prevalence. The best regression model derived from one level was the initial model to which variables of subsequent levels were added.

Results

Anthropometric deficits for Africa, Latin America, and Asia and are shown in Table 2 and Table 3. Measures of variability (Table 2) represent variation both among countries within regions and within countries among years and should be interpreted cautiously. Latin America had survey data for approximately 30 years (1966–95), while Africa and Asia had data for 26 and 22 years, respectively (1969–95 and 1973–95). The countries and number of surveys included from each country are listed in Annex A (available on our web site: http://www.who.int/bulletin).

Wasting among children under five years of age was most prevalent in Asia (Table 2), where approximately 24% of the surveys recorded critical wasting (i.e. wasting prevalence >15%) (Table 3). Wasting was least prevalent in Latin America (3.03%, Table 2), with a mean prevalence close to that expected for a normal distribution (2.5%). In contrast, with respect to morbidity, mortality, and socioeconomic indicators, values for measles incidence, calorie supply per capita, food production per capita, infant mortality, access to safe water, public expenditure for education, gross national product per capita, and adult literacy were generally worse in Africa.

Comparison of models

In Africa, the final model included a quadratic term for year of the survey, low birth weight (LBW) (underlying level), and adult literacy (basic level) and explained approximately 7% of the between-country variability of wasting prevalence (P <0.05, Table 4). In Latin America, the final model included the main effects of the survey year (initial model) and LBW (underlying level) and explained 37.5% of the variability (P = 0.01, Table 4). In Asia, the final model included measles incidence (immediate level), LBW (underlying level), and access to safe water (underlying level) and accounted for a 64% reduction in the between-country variability (P <0.005, Table 4).

Fixed effects — final models

In Africa, LBW (underlying level) and adult literacy (basic level) emerged as independent predictors of wasting prevalence (β = 0.27, P = 0.08; β = –0.10, P = 0.02, respectively), while the quadratic term for survey year retained its statistical significance at all levels (Table 5). In Latin America, LBW (underlying-level) was associated with prevalence of wasting (β = 0.17, P <0.01), once the data were controlled for the survey year. In Asia, measles incidence (immediate level), LBW (underlying level), and access to safe water (underlying level) were independent predictors of wasting prevalence (β = 0.85, P = 0.07; β = 0.26, P <0.01; β = –0.08, P<0.01, respectively).

Discussion

The effects of social context on the nutritional status of populations

We attempted to build explanatory models of wasting prevalence in children under 5 years of age for Africa, Latin America, and Asia using secondary datasets. The results suggested that explanatory models of wasting prevalence must differ across regions.

In Asia, measures of the population disease burden (incidence of measles as an immediate factor, measures of environmental health (percentage of the population with access to safe water as an underlying factor), and measures of the presence of basic health services and mother- and child-caring practices (LBW as an underlying factor), explained 64% of the variability in wasting prevalence. More distal determinants of malnutrition, representing the distribution of resources in a society, were not predictive of wasting prevalence in Asia.

In Africa and Latin America, there seemed to be a time trend in wasting prevalence. In Africa, wasting prevalence approximately followed a U-shape over the timespan of the study (1969–95), initially decreasing in earlier years before

Table 2. Measures of central tendency for anthropometric variables

Variable	Africa	Latin America	Asia
Prevalence of wasting[a]			
No. of surveys	157	99	112
Mean	7.18 (5.68)[b]	3.03 (2.15)	10.39 (6.58)
Range	0.90–40.40	0.30–10.00	1.10–32.70
Immediate causes			
Measles incidence[c]			
No. of surveys	166	98	112
Median	0.9 [0.2/2.3][d]	0.3 [0.08/0.71]	0.25 [0.08/0.58]
Range	0.0–26.8	0.0–5.3	0.0–9.6
Calorie supply per capita[e]			
No. of surveys	177	102	111
Mean	97.0 (15.0)	104.7 (12.7)	102.4 (14.9)
Range	11.8–131.0	80.0–102.0	62.0–135.0
Underlying causes			
Food production per capita[f]			
No. of surveys	154	67	91
Mean	91.4 (12.7)	97.9 (15.2)	102.0 (18.5)
Range	51.0–134	63.0–132.0	68.0–147.0
Low birth weight[g]			
No. of surveys	166	84	100
Mean	13.5 (4.2)	11.1 (3.6)	19.4 (11.1)
Range	5.0–32.0	5.0–20.0	5.0–50.0
Infant mortality[h]			
No. of surveys	199	100	107
Mean	107.7 (37.5)	59.1 (33.4)	78.4 (40.9)
Range	17.0–231.0	11.0–151.0	7.0–205.0
Access to safe water[i]			
No. of surveys	177	90	114
Mean	46.6 (20.7)	71.4 (19.2)	59.8 (25.4)
Range	6.0–100.0	12.0–100.0	5.0–100.0
Basic causes			
Public expenditure on education[j]			
No. of surveys	168	102	110
Mean	4.1 (1.8)	3.9 (1.6)	3.9 (1.6)
Range	0.4–9.1	0.6–8.8	0.6–8.5
GNP per capita[k]			
No. of surveys	179	102	110
Median	370.0 [230/680]	1210 [620/2010]	400 [220/880]
Range	80.0–3830.0	200.0–8110.0	110.0–18060.0
Adult literacy rate[l]			
No. of surveys	152	80	94
Mean	47.1 (19.0)	78.5 (13.7)	64.7 (23.4)
Range	8.0–88.0	45.0–99.0	13.0–95.0
Debt services[m]			
No. of surveys	160	86	94
Median	19.0 [10/27]	23.6 [12.5/31.3]	18.0 [12/23]
Range	2.0–83.0	1.0–294.0	0.6–59.6
Urban population[n]			
No. of surveys	197	97	107
Mean	28.1 (14.2)	58.8 (18.1)	33.9 (23.0)
Range	2.0–83.0	21.0–92.0	4.3–100

[a] Percentage of children under 5 years of age with weight-for-height below –2 Z-scores.
[b] Figures in parentheses are standard deviations.
[c] Measles incidence per 1000 people, all ages.
[d] Figures in brackets are 25th/75th percentiles.
[e] Daily calorie supply per capita as percentage of requirements.
[f] Food production per capita index.
[g] Percentage of children born with a birthweight <2500 g.
[h] Mortality of children under 1 year of age per 1000 live births.
[i] Percentage of population with access to a safe water supply.
[j] Public expenditure on education as a percentage of the gross national product.
[k] Gross national product per capita in current US$.
[l] Number of people aged over 15 years who reportedly can read and write, divided by the number of the population in the same age group.
[m] Debt services as a percentage of goods and services.
[n] Percentage of the total population living in urban areas.

Table 3. Distribution of surveys by severity categories of wasting prevalence[a]

Severity of wasting prevalence[b]	Africa	Latin America	Asia
Acceptable (<5)	35.4	86.3	27.0
Poor (5–9)	31.8	12.7	24.3
Serious (10–14)	13.3	1.0	24.3
Critical (⩾15)	19.5	0.0	24.3

[a] The surveys analysed were classified according to the severity of wasting prevalence observed and are expressed as a percentage of all surveys analysed.
[b] The severity category was determined according to the percentage of children under five years of age who were wasted (shown in parentheses). For example, wasting prevalence is critical when more than 15% of the children fall under –2 Z-scores for weight-for-height.

increasing again in more recent years. In Latin America, wasting prevalence decreased linearly at an average of 0.16% per year over the timespan of the study (1966–95). In Africa, high rates of LBW infants and low rates of adult literacy (a measure of the distribution of resources in society as a basic-level factor) were associated with wasting prevalence in the population, although the association with LBW was marginally significant. Adult literacy did not completely eliminate the effect of LBW rates on wasting prevalence, although its effect was attenuated. The model explained a small percentage (7%) of the wasting variability for Africa, but problems with model validity may explain this result (see below). In Latin America, LBW was the only ecological variable associated with wasting prevalence. The narrow range of wasting prevalence (mean = 3.03%, range 0.30–10.00%) and of other variables in Latin America may have contributed to the paucity of associations.

Novel aspects of the conceptual framework

The present study differed from earlier studies (*18*, *19*), in that each level of the conceptual framework was modelled by morbidity, mortality, and socioeconomic variables and the validity of the model was empirically tested. In contrast, no immediate-level factors were included in the earlier studies, neither were morbidity variables included. In addition, all other variables for underlying and basic factors were different in the earlier studies compared to the present study, with the exception of the percentage of the population with access to safe water. Both of the earlier studies found that underlying and basic factors were significant predictors of anthropometric deficits in nutritional status. The use of a mixed model in the current study allowed all available anthropometric surveys for each region to be analysed, thus increasing the power of the study and the interregional variation. However, the availability of such a broad geographical area and timespan limited the choice of ecological correlates.

In the second study (*19*), an econometric model was used to predict the prevalence of underweight (low weight-for-age). The model took into account the lack of independence of the observations and added variables at each level of the model as a sequential set (as in the present study). However, weight-for-age is a composite of height-for-age (mainly the result of long-term influences) and weight-for-height (mainly the result of short-term influences) (*9*) and thus the results of the two earlier studies are not strictly comparable. Nevertheless, variables representing mother- and child-caring practices, which differed from the present study, were found to contribute strongly to the prevalence of underweight in children under five years (*19*).

Mother- and child-caring practices

In the present study, LBW was included as an underlying-level factor that reflected mother- and child-caring practices and was a consistent predictor of wasting prevalence in all three regions. Mother- and child-caring practices go beyond mother and child health care services since the practices refer to the way children are fed, nurtured, taught, and guided. Care

Table 4. Ability of models to explain the variability in wasting prevalence between countries

Region	Model level	Models[a]	Between-country variability[b] %	–2 LL χ^c
Africa	Immediate causes	Full model[d]	–9.8	1.63 (>0.10)[e]
	Underlying causes	Full model	–2.0	3.40 (>0.25)
	Basic causes	Full model	–2.3	5.20 (>0.25)
	Final model[f]	Survey year + LBW[g] + adult literacy[h]	–6.9	4.00 (<0.050)
Latin America	Immediate causes	Full model	+ 4.3	3.20 (>0.10)
	Underlying causes	Full model	–12.5	8.00 (<0.01)
	Basic causes	Full model	–29.5	6.40 (>0.05)
	Final model	Survey year + LBW	–37.5	6.60 (= 0.01)
Asia	Immediate causes	Full model	–40.8	17.30 (<0.005)
	Underlying causes	Full model	–60.5	4.40 (>0.25)
	Final model	Measles incidence + LBW + safe water[i]	–64.3	14.50 (<0.005)

[a] Model variables were: Immediate causes, full model: measles incidence, calorie supply per capita as percentage of requirements. Underlying causes, full model: food production per capita index, low birth weight, infant mortality, percentage of the population with access to safe water. Basic causes, full model: public expenditure on education as percentage of gross national product, gross national product per capita, adult literacy rate, debt services, percentage of the population living in urban areas.
[b] Percentage change in the variability explained by the new model when compared to the intercept-only model.
[c] Goodness-of-fit test: –2 log likelihood χ^2.
[d] The full model is the model including all the basic-level variables.
[e] Figures shown in parentheses are *P*-values.
[f] The final model is the most parsimonious model that best fits the data.
[g] LBW = low birth weight. See footnote g, Table 2.
[h] See footnote l, Table 2.
[i] See footnote i, Table 2.

Table 5. Final models for wasting prevalence

Africa *n*[a] = 101		Latin America *n* = 84		Asia *n* = 88	
Intercept[b]	8.17[c] (4.13)[d] *0.06*[e]	Intercept	311.1 (84.48) *<0.01*	Intercept	8.90 (2.94) *<0.01*
Survey year	–0.37 (0.23) *0.11*	Survey year	–0.16 (0.04) *<0.01*	Measles incidence (per 1000 population)	0.85 (0.46) *0.07*
Survey year squared	0.11 (0.04) *0.01*	LBW[f] (%)	0.17 (0.06) *<0.01*	LBW (%)	0.26 (0.08) *<0.01*
LBW[f] (%)	0.27 (0.15) *0.08*			Safe water[g] (%)	–0.08 (0.03) *<0.01*
Adult literacy[h] (%)	–0.10 (0.04) *0.02*				

[a] *n* is the number of surveys analysed for each region.
[b] The intercept refers to the values of the outcome variable (prevalence of wasting) when all other predictor variables are at their zero level.
[c] Unless otherwise indicated, figures in roman type are coefficients.
[d] Figures in parentheses are standard deviations.
[e] Figures in italics are *P*-values.
[f] LBW = low birth weight. See footnote g, Table 2.
[g] See footnote i, Table 2.
[h] See footnote l, Table 2.

and support for mothers are among the practices that affect child nutrition and health (*2*).

The higher the proportion of LBW in the population, the greater the likelihood that it is a result of intrauterine growth retardation (IUGR) as opposed to prematurity (*1*). IUGR is a major clinical and public health problem in poor countries and its major determinants are nutritional: short maternal stature, low pre-pregnancy body mass index, and low gestational weight gain. Short maternal stature is principally due to undernutrition and infections during childhood; low pre-pregnancy body mass index reflects chronic maternal undernutrition; and low gestational weight gain is due to inadequate dietary intake (*24–26*). The proportion of babies with LBW may reflect the condition of women, their health, nutrition, and status in society, not only during pregnancy but also during the women's own infancy, childhood, and adolescence (*27*), which potentially makes LBW a valid proxy for mother- and child-caring practices. However, LBW could also theoretically represent another level of the framework, as a proxy for a host of different factors. For example, LBW could be considered a proxy for morbidity (an immediate-level factor), given that children with LBW have higher incidence of respiratory infections and diarrhoea (*28*).

Despite the fact that this is not an individual-level study, the consistent association between LBW and wasting prevalence brings to mind the intergenerational effect of malnutrition (*2*). Girls who grow poorly are more likely to give birth to LBW babies, and if the suboptimal standard of living in which these babies are born does not radically change, the cycle will continue. Short maternal stature, low pre-pregnancy body mass index, and low gestational weight-gain are thought to be the mediating factors between socioeconomic conditions and IUGR (*26*). In the present ecological study, the association between LBW and wasting prevalence suggests that environmental determinants that produce high proportions of LBW infants will also produce a high prevalence of wasting in a population.

Building explanatory models of wasting prevalence

According to the framework in this study, adding a set of variables for any of the cause levels (Fig. 1) should have explained most of the variability in wasting prevalence. However, this was not consistently observed in this study. Although immediate-level factors captured some of the wasting variability in Asia, most of the variability was captured by underlying-level factors. As expected, the basic-level factors did not add anything to this variability. In Africa and Latin America, the decrease in between-country variability was slight at any level of the framework, which may be explained if the variables that represent each level of the framework are invalid. This could be the case, since it was not known whether the variables used in the framework were the appropriate ones to actually represent each level. For example, while the food production per capita index might represent the availability of food, it might not represent accessibility to food. Also, the burden of disease in a population might be better measured using the incidence of diarrhoeal diseases, instead of using the incidence of measles. However, because of underreporting and incomplete data, data on the incidence of diarrhoea would not have provided a reliable measure of the burden of diarrhoea in populations.

The validity of using certain variables may also differ across and within regions and this might have affected the relative contributions of the framework levels to wasting prevalence in each region. Thus, framework levels should have been represented with different variables in each region. For example, given the burden of malaria in Africa, particularly in children, the prevalence of malaria should have been included in the model for Africa, which could have increased the explanatory power of the model. However, the data on malaria prevalence were incomplete.

Finally, it might have been better to use other ecological variables in the framework, but they could not be included due to missing values. For example, the case fatality rate for measles was considered to be an immediate-level factor because of the association between states of malnutrition and the severity of infectious diseases, but again data on measles mortality (numerator of the case fatality rate) were incomplete. The mortality rates for children younger than 5 years old could have solely represented underlying-level factors (*29*), but were not included due to the lack of observations prior to 1983. Instead, infant mortality was included since time-series data were available. The Gini coefficient (a measure of income distribution) and unemployment rates (a proxy for economic restructuring programmes) could also not be included because of missing values.

Use of secondary datasets

The feasibility of integrating secondary datasets into the models for wasting prevalence was examined by including routinely collected morbidity, mortality, and socioeconomic variables used for policy-making. However, there were practical difficulties in linking the secondary datasets because data entry methods were not standardized. The nomenclature and/or format for country names differed among databases and they did not merge correctly (e.g. Republic of Korea or Korea Republic; Myanmar or Burma; Burkina Faso or Apro Volta). Similar problems were encountered with age groups. They were not broken down in the same manner and formats differed for the age group and year (e.g. 0–4.99 or 0.00–4.99; 1990–1994 or 1990–94). Such problems were solved by computer programming, but other problems could not be resolved.

For example, definitions of variables (such as breastfeeding rates) were different across time and among databases and could not be used in the analysis. In other cases, a variable was used if the definition still met the conceptual requirements of the level (e.g. the percentage of the population living in urban areas). Due to non-standardized data collection among databases, not all surveys could be matched exactly by year and were matched to within $\pm$ 5 years. This criterion for matching could have flattened the trend of some of the variables and possibly obscured associations. Since the secondary datasets were not collected specifically for the present analysis, important variables might have been missed that correlate better with the prevalence of wasting in populations. Also, it was difficult to assess the data quality, due to the broad scope of data sources, the time span, and number of countries.

Limitations of the model

A covariance structure other than compound symmetry (e.g. first-order autoregressive) could have been more appropriate, since observations within a country that are close together in time may be more highly correlated than those far apart in time. This was not possible, however, because the dataset used in the present study did not allow other types of covariance structure to be tested. It was therefore decided to represent the pattern of time correlation in the data assuming compound symmetry, since the specific type of covariance structure was not of interest per se, but was rather used to obtain valid standard error estimates.

Another problem encountered was missing data on covariates for all the country/year units. Missing data could have led to selection-biased estimates for the parameters of interest, because it was assumed that the available observations were representative of missing data (*30, 31*). However, the mixed model procedure provided an alternative method for estimating the effects of variables (β coefficients), using only the information available in the dataset (*32*). Using a random model, the effects were estimated as a function of the country data and as a function of the data from the sample as a whole. For countries with more information, country-specific effects were influenced more heavily by that country's data. Conversely, when there was little information from a given country, the country-specific effects were influenced more towards the group mean effects.

Lack of statistical power was possible because of the probable lack of reliability of the variables and the reduction in sample size after adding variables at the basic level. Analyses using national and non-national anthropometric surveys were presented here because analyses using only national surveys yielded similar results. For example, the fixed effects had the same signs (with the exception of measles incidence), albeit with larger P-values (as expected due to smaller sample sizes). In addition, as the variability in wasting prevalence was explained better by models that used only national surveys, the results of the current study reported here are probably conservative.

Future directions

Future research should focus on improving the way the conceptual framework is represented. It may be easier to represent the conceptual framework correctly by examining smaller geographical units. Given the association between LBW and prevalence of wasting, research at individual and community levels should concentrate on identifying factors that affect mother- and child-caring capacities in different settings. For example, actions to improve the rights and social position of women might also improve the nutritional status of children under five years of age.

Finally, in times characterized by the globalization of the economy, the liberalization of markets, and reductions in the budgets for health services and education worldwide, it is all the more important to improve measures of the impact of these changes on the well-being of children and communities. A concerted effort should also be made by international agencies to make new and existing databases compatible by standardizing data collection and entry methods. ■

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Conflicts of interest: none declared.

Résumé

Prévalence de l'émaciation d'origine nutritionnelle : construction de modèles explicatifs à partir de données secondaires

Objectif Comprendre de quelle façon le contexte social affecte l'état nutritionnel des populations, mesuré par la prévalence de l'émaciation chez les enfants de moins de 5 ans, en Afrique, en Amérique latine et en Asie ; présenter une procédure systématique de construction des modèles de prévalence de l'émaciation selon un cadre conceptuel pour les déterminants de la malnutrition ; examiner la faisabilité de l'utilisation de données facilement accessibles recueillies au cours du temps pour construire des modèles de prévalence de l'émaciation dans les populations concernées.

Méthodes Les associations entre la prévalence de l'émaciation et les paramètres écologiques ont été examinées dans les trois régions. Les modèles linéaires mixtes généraux ont été ajustés à l'aide des données d'enquêtes anthropométriques pour les différents pays de chaque région.

Résultats Le faible poids de naissance, l'incidence de la rougeole et l'accès à de l'eau propre expliquent 64 % de la variabilité de l'émaciation en Asie. En Amérique latine, le faible poids de naissance et l'année de l'enquête expliquent 38 % de cette variabilité ; en Afrique, le faible poids de naissance, l'année de l'enquête et l'alphabétisation des adultes en expliquent 7 %.

Conclusion Dans les trois régions, le faible poids de naissance se distingue en tant que facteur prédictif de la prévalence de l'émaciation. Les mesures axées sur les droits de la femme pourraient avoir un effet sur l'état nutritionnel des enfants car le faible poids de naissance semble refléter divers aspects de la condition des femmes dans la société. Les bases de données doivent être compatibles entre elles pour faciliter l'analyse intégrée qui servira aussi bien à la recherche nutritionnelle qu'aux choix politiques. Il faudra de plus améliorer la validité des paramètres représentant le cadre conceptuel des modèles.

Resumen

Prevalencia de la emaciación en diversas poblaciones: elaboración de modelos explicativos a partir de datos secundarios

Objetivo Entender cómo influye el contexto social en el estado nutricional de la población, determinado en función de la prevalencia de emaciación entre los menores de 5 años en África, América Latina y Asia; presentar un método sistemático para elaborar modelos de la prevalencia de la emaciación, usando un marco conceptual para los determinantes de la malnutrición; y examinar la viabilidad del uso de datos de fácil obtención reunidos a lo largo del tiempo para construir modelos de la prevalencia de emaciación en poblaciones.

Métodos Se examinó la relación existente entre la prevalencia de emaciación y diversas variables ambientales en tres regiones. Los modelos lineales mixtos generales se ajustaron usando datos de estudios antropométricos para los países de cada región.

Resultados El bajo peso al nacer (BPN), la incidencia de sarampión y el acceso a un sistema de abastecimiento de agua salubre explicaban el 64% de la variación de la emaciación en Asia. En América Latina, el BPN y el año de encuesta explicaban el 38%; y en África el BPN, el año de encuesta y el grado de alfabetización de los adultos explicaban el 7%.

Conclusión El BPN resultó ser una variable independiente determinante de la prevalencia de emaciación en las tres regiones. Las medidas relacionadas con los derechos de la mujer podrían influir en el estado nutricional de los niños, pues el BPN refleja al parecer varios aspectos de la situación de la mujer en la sociedad. Hay que asegurar la compatibilidad de las bases de datos a fin de facilitar la realización de análisis integrados con miras a las investigaciones y la adopción de decisiones normativas en materia de nutrición. Además, es necesario mejorar la validez de las variables de representación del marco conceptual.

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Annex A. Countries, areas, or territories surveyed (number of surveys)

Africa (*n* = 157)

Algeria (2), Benin (2), Burkina Faso (3), Burundi (5), Cameroon (3), Cape Verde (4), Central African Republic (2), Congo (2), Côte d'Ivoire (2), Democratic Republic of the Congo (12), Djibouti (1), Egypt (5), Equatorial Guinea (1), Eritrea (1), Ethiopia (4), the Gambia (2), Ghana (3), Guinea (3), Kenya (7), Lesotho (4), Liberia (1), Libyan Arab Jamahiriya (1), Madagascar (7), Malawi (6), Mali (2), Mauritania (2), Mauritius (2), Morocco (2), Mozambique (1), Namibia (2), Niger (5), Nigeria (2), Rwanda (4), Sao Tome and Principe (1), Senegal (5), Seychelles (1), Sierra Leone (4), Somalia (1), South Africa (11), Sudan (2), Swaziland (1), Togo (4), Tunisia (3), Uganda (5), United Republic of Tanzania (5), Zambia (3), Zimbawe (1).

Latin America (*n* = 99)

Antigua and Barbuda (1), Argentina (2), Barbados (1), Belize (2), Bolivia (5), Brazil (17), Chile (2), Colombia (5), Costa Rica (2), Dominica (2), Dominican Republic (3), Ecuador (1), El Salvador (3), French Guiana (1), Guatemala (9), Guyana (1), Haiti (4), Honduras (6), Jamaica (5), Mexico (3), Nicaragua (7), Panama (4), Paraguay (1), Peru (2), Trinidad and Tobago (2), Uruguay (2), Venezuela (7).

Asia (*n* = 110)

Afghanistan (1), Bahrain (1), Bangladesh (12), Cambodia (1), China (3), Hong Kong Special Administrative Region of China (1), India (7), Indonesia (2), Islamic Republic of Iran (3), Iraq (5), Jordan (2), Kuwait (1), Lao People's Democratic Republic (3), Lebanon (1), Malaysia (4), Maldives (3), Mongolia (2), Myanmar (4), Nepal (3), Oman (1), Pakistan (6), Palestinian Self-Rule Areas (5), Philippines (6), Qatar (1), Republic of Korea (1), Republic of Yemen (3), Saudi Arabia (2), Singapore (1), Sri Lanka (9), Syrian Arab Republic (1), Thailand (10), Turkey (1), Viet Nam (3).